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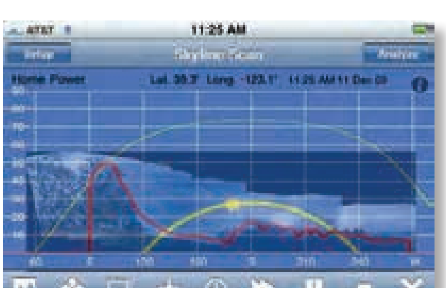


Photos (clockwise from bottom left): Jeff Oldham; Robert Riversong; www.solarenergy.org; Rebekah Younger; www. apmhydro.com; Jytte Piggott

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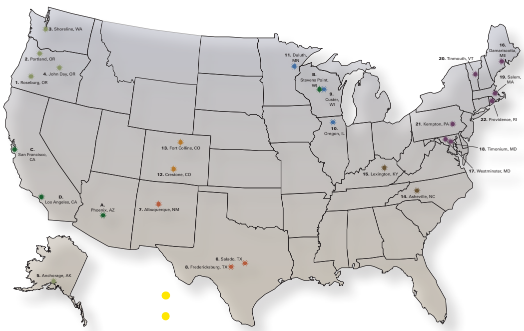
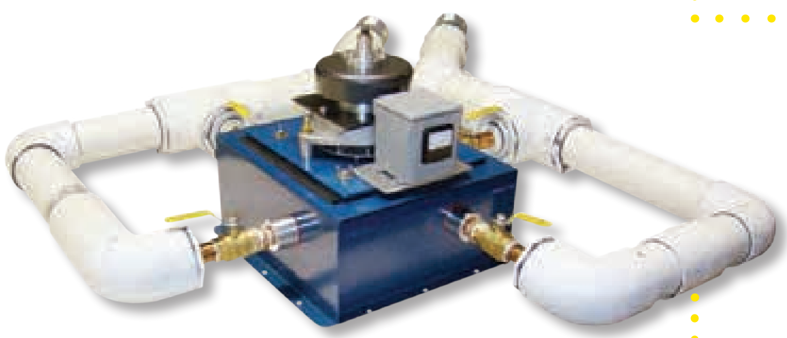
Photo by Khanti Munro



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# Changing Lives, Changing Perspectives

I've just returned from another stint in Central America, helping a group of students learn about solar electricity, and helping poor families by bringing solar-electric lighting to their homes. Spending time in the not-overly-developed world makes me reflect on our energy use here in the United States.

The most expensive system my students and I installed this winter cost a few hundred dollars, and took a modest level of design skill and time to put together. A smaller pre-built package—consisting of a small PV module, small battery, and an LED task light—costs about $100 and is simple enough for almost anyone to install. Even simpler, solar flashlights and lanterns can now be purchased for $15 to $40.

Here in North America, these systems may seem inadequate—like toys or educational kits. But in poor rural areas of the world, these simple systems can have a huge impact on a family's quality of life. A few high-efficiency lights can be life-changing, allowing them to cook, work, study, and socialize with bright, clean, low-cost lighting. Replacing candles, kerosene lanterns, or even a jar of kerosene with a rag for a wick, small solar-electric systems are a huge technological leap and financially freeing, since families no longer have to buy fuel. Switching to a fuel that produces no pollution also translates into a healthier home environment. And these small systems are reasonably affordable for a simple reason—the energy appetite of the owners is small.

Compared to homes in the not-so-developed world (and even with Europe's), the average U.S. home has a sizable energy appetite. Part of that can be attributed to climate (heating takes the biggest portion of the residential energy pie), our aversion to sweat (air-conditioning comes in second), and our tendency to build bigger homes, which require more energy to provide heating, cooling, and lighting. That's why installing a solar-electric system—without examining usage and efficiency first—can be an expensive undertaking. But what happens if we optimize our energy use, first turning to conservation and then to efficiency?

My take-away lesson from working down south was this: We can scale back—or start small—and still have a high quality of life. On a per-capita basis, residences in the United Kingdom use about a third less energy than U.S. homes—so what's their secret? Begin by addressing your energy needs—how can you conserve energy? Where can you implement energy-efficiency measures? What do you really need?

When you reduce your home's energy appetite, you reduce your financial footprint, saving money (and, consequently, reducing the size of the solar-electricity system you want). Plus, since your home will use less energy, its efficiency will contribute to cleaner air, soil, and water. And that works well the whole world 'round.

—Ian Woofenden, for the *Home Power* crew

## Think About It...

*"Humans aren't simply the burping, biological users of resources; they're the discoverers of resources, the creators of resources, the makers of communities, cities, history. A human being isn't only a mouth that must be filled, but a brain that can think and a pair of hands that can work."*

*—Brendan O'Neill*

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# Energy Star's Evolution

## A New Plan and a New Attitude Could Re-Energize the Energy Star Program

Consumers shopping for energy-efficient appliances are well-acquainted with the blue Energy Star (ES) label. But do the appliances really deliver what their labels promise?

Among other things, the 18-year-old ES program has been criticized for its lax specifications, weak oversight of manufacturers, and slow revision process. With $300 million of federal stimulus money going to support rebates for consumers buying products bearing the ES label, it's under even more scrutiny.

Lane Burt, an independent expert on energy efficiency and manager of building energy policy for the National Resources Defense Council, has followed the program's ups and downs. His take: "The program is a victim of its own success."

"The criticism is justified," says Burt, "but people should not write off the Energy Star program just yet. The program has been highly successful and has grown to cover more than 50 product categories, but resources have been an issue in recent years."

Last year, the DOE and EPA, which jointly manage the program, signed a memorandum of understanding to more clearly define the roles and responsibilities of each agency, helping to move program projects forward. Under the new partnership terms, the EPA will continue to be the brand manager for the program, setting performance levels and overseeing monitoring and verification of products, homes, and commercial buildings. The DOE agreed to increase its monitoring and verification of test procedures used to evaluate if products meet ES specifications.

The agencies followed up the memorandum with the December release of the *Enhanced Program Plan for Energy Star Products*—a strategic framework that outlines specific goals, including expanding the program to cover more products, revising specifications more frequently, and improving testing and verification procedures. The plan also calls for the creation of a top-tier Super Star program that will promote the most energy-efficient 5% of products on the market in a given category.

The ES program is intended to present the top 25% most energy-efficient products in a given category. When that number reaches 35%—that is, 35% of the appliances in a certain category bear the ES label—specifications are supposed to be reviewed. But, says Jennifer Amann, director of the building program at the American Council for an Energy-Efficient Economy (ACEEE), there has been too much time between specification revisions, and as a result, a much larger percentage of available products are earning the ES label.

"If all appliances have the label, then Energy Star is really worthless," says Burt, who advocates for firmer deadlines for revisions and a "freshness dating" approach to labeling that would indicate which version of ES specifications a product has met.

Under the current structure, Burt explains, all products bear the same Energy Star logo and can do so for perpetuity once they meet the required specifications. This, he says, means consumers cannot tell whether the product meets the most recent specifications, which would be more stringent.

The enhancement plan emphasizes the need for improved verification procedures. As a voluntary program, ES operates on a self-certifying and self-policing basis, entrusting manufacturers to evaluate and certify their products, as well as monitor the marketplace and report questionable claims of competitors.

Cases of manufacturers abusing this power in recent years underscored the need for the DOE to step up in its role of product verification—a point illustrated by the recent case involving LG Electronics where testing of LG's French-door refrigerators by independent labs found that energy usage was typically twice that claimed by the company and did not meet ES specifications.

An internal DOE audit, released last October, fueled the fire. The report confirmed that the agency does not properly track whether manufacturers of ES products have met the required specifications and also faulted the agency for not following through to ensure that the ES label is removed from unqualified products.

Setting the tone for stricter enforcement in the future, the agencies banned 20 of LG's refrigerators from using the ES label as of January 20, 2010—despite the company's assertions that they misunderstood the testing procedures, which direct manufacturers to run the energy tests while the ice maker and its components are on but "inoperative."

The enhancement plan calls for *all* products to be verified through tests in an accredited laboratory. The plan also calls for increased "off-the-shelf" product testing across the full suite of ES product categories—a much-needed measure that must be properly executed to be effective, Burt cautions.

"The element of surprise is essential. The products need to be purchased at random and directly from retailers—not sent from the manufacturers," Burt says.

"Energy Star separates A and B students from C students, but doesn't spotlight the honor roll at all," according to the letter authored by Harvey Sachs, an ACEEE senior fellow.

The ACEEE is among the various stakeholders that submitted comments about the enhancement plan. In a January letter to the program's administrators, the council expressed its reservations—most notably, the fact that the 25% selection cutoff does not select the "top-performing" appliances. They also suggested setting a higher standard that will more effectively drive energy savings.

"Energy Star separates A and B students from C students, but doesn't spotlight the honor roll at all," according to the letter authored by Harvey Sachs, an ACEEE senior fellow.

Among other points, the letter addressed the need to develop a formal process that enables Energy Star to implement voluntary specifications that stay ahead of required federal minimum efficiency standards—to drive market transformation by pushing manufacturers to reach new levels of innovation sooner rather than later.

According to the plan, nine specification revisions—including geothermal heat pumps, light commercial HVAC equipment, and gas furnaces—will be completed by the end of 2010. Even with such good intentions, some doubt whether the agencies can cut through the red tape and expedite its revision process, which has been known to take up to three years.

## New Program Rates 'Top 10'

This spring, the Energy Star program may have some friendly competition. TopTen USA will be launching a new rating program to identify the most energy-efficient products on the market.

"Our goal is to point consumers to the cream of the crop," says Dean Norman, president and executive director of TopTen USA. "As good as Energy Star is, it doesn't enable consumers to distinguish between the efficient and the *most* efficient products on the market. That's where we come in."

The program aims to identify the top 10 energy-efficient products available in various categories, including refrigerators, freezers, room air conditioners, televisions, desktop computers, laptop computers, lighting, passenger vehicles, dishwashers, and clothes washers.

The selection of TopTen products will be largely based upon publicly available data. The size and/or volume of a particular product will be factored into its energy use calculation, and when necessary, products will be tested to verify questionable data. Categories may be reviewed anywhere from every few months to a year, depending on product launch cycles.

"We aim to stay as current as possible in hopes of motivating manufacturers to go beyond the current standards and voluntary specifications, and deliver new technologies to the marketplace," Norman says.

The group also plans to coordinate with utility administrators to help set benchmarks for rebate programs, encourage retailers to sell and promote TopTen products, and work with policymakers for stricter product standards and labeling requirements.

Similar TopTen rating programs are already in place in several European countries. The U.S. program is set to launch in May. Results, as well as buying tips and advice, will be published at www.toptenusa.org.

Though problems persist in the program, the critics still tend to agree that the ES program is inherently successful in promoting energy efficiency. "There's no substitute for an educated consumer," Burt says, "but starting with Energy Star is always the best bet and a good baseline to work from."

—Kelly Davidson

The *Energy Star Partnership Workplan* for 2010 reflects stakeholder comments and lays out a more detailed schedule for advancing the goals put forth in the enhancement plan. Go to www.energystar.gov to monitor the program's evolution.

# New Gear from Solmetric

## Hardware

Solmetric (www.solmetric.com) has released the next version of its solar site assessment tool, **the Suneye 210** ($1,995). Like its predecessor, the Suneye 110 ($1,495), the 210 is a handheld electronic tool that helps identify and quantify shading and solar access for siting PV arrays, solar hot water collectors, and passive solar homes.

Both models capture skyline views, helping users compare solar access in different locations. The devices display annual, seasonal, and monthly solar access percentage factors and details about obstructions (elevation angle vs. azimuth angle of objects that will shade that location). Both Suneye models can export data to Suneye Desktop software to create solar access and shade reports. Other data file types (such as .csv, .xml, and .jpg) compatible with common software can be exported. Choosing the GPS option allows files to be exported and used with Google Earth, so that you can see exactly where the Suneye data was taken.

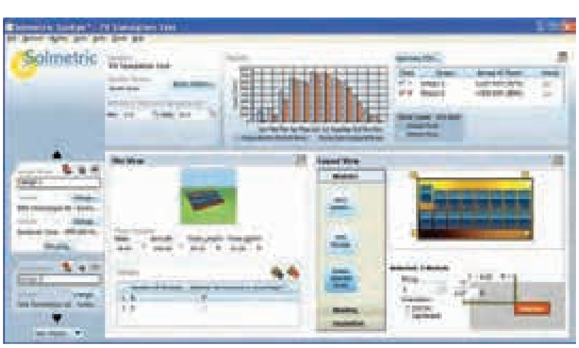

So what's new about the 210 model? Upgrades include:

- One-handed operation
- An optional integrated GPS ($200) versus an optional external GPS ($250)
- An electronic compass and electronic inclinometer (to quickly determine roof orientation and tilt)
- A "live survey" mode, to display annual sun paths live as you scan the site
- A larger battery (about twice the capacity of the 110's battery)
- Higher display resolution

## Software

Solmetric has also released its **PV Designer** software ($400) that uses Suneye data to predict PV system output, and helps to determine optimum module placement and array layout.

Users select their PV modules and define the orientation, tilt, and length and width of the mounting area, and PV Designer uses module dimension data so designers can compare layout options. For example, you can check out how many modules will fit on a roof, in portrait or landscape layout, and can consider module interspace and roofline setbacks. Users also select their inverter make and model, which the software uses (along with user inputs for the site's high and low temperatures) to display warnings when the various array options do not meet required inverter input voltage windows. Parameters can easily be reset to examine various module and inverter choices, and optimize the array's particular mounting area.




Courtesy www.solmetric.com (2)

PV Designer requires users to select their location to access insolation data, and uses this along with Suneye data to estimate the PV system's output. It predicts monthly and annual kWh for various array placement options. For example, if the lower west corner of a rooftop has more shading than the upper east portion, users can compare the predicted output that results from moving the array toward the upper corner of the roof.

## iWare

Solmetric also acquired the Sun Tracker application for iPhones from Imeasure Systems in February 2010, which will be rebranded as SolmetricIPV. This $15 app is a handy and inexpensive way to get a preliminary shade analysis for site assessment. Users who have already purchased Sun Tracker will continue to receive software updates to the Sun Tracker app. For more information, see "iPhone Apps for Solar Geeks" on page 70.

—Justine Sanchez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# Hope on the Horizon

Amid the destruction in Haiti after January's devastating earthquake, the sun is ready to lend a helping hand. Several organizations are supplying solar technologies to the ongoing relief efforts—and some will play a role in the country's long-term reconstruction. Here are a few that caught our attention:

## Nonprofits

**Solar Electric Light Fund, www.self.org.** From its Washington, DC, headquarters, this nonprofit group is accelerating its plans to provide off-grid PV systems to nine medical facilities in Haiti operated by the Boston-based nonprofit Partners in Health (PIH; www.pih.org). Most of the sites are located in the central plateau region, away from the destruction, but these clinics will help provide care for residents who have sought refuge in new communities. Solar equipment originally intended for clinics in Cerca la Source and Hinche has been diverted to an emergency field hospital in Port-au-Prince.

**Sun Energy Power International, www.sunepi.org.** SunEPI was already involved with several projects in Haiti when the earthquake struck. Their involvement in began in 2007, when alongside USAID, they began assessing Haiti's health-care energy systems. This initial assessment resulted in renewable energy installations at several health-care facilities in northern Haiti. More facilities are now in the planning stages. In September 2009, SunEPI worked with SELF to provide the first solar-powered hospital system for PIH in Boucan Carré.

**Solar Cookers International, www.solarcookers.org.** The San Francisco-based nonprofit organization raised more than $8,000 to send 200-plus solar cookers and water pasteurization indicators to Haitian families affected by the tragedy. A donation of $40 will purchase one kit for a displaced family.

## Solar Tech Companies

**Intivation, www.intivation.nl.** This Netherlands company teamed up with mobile network operator Digicel Group to provide 1,000 solar-powered mobile phones to aid workers and survivors. In addition to raising $500,000 through a text-and-voice donation line, Digicel also donated $5 million to support the relief efforts and has given each of its Haitian customers $5 in credit.

**Along with SELF, SunEPI installed this PV array at a hospital in Boucan Carré, Haiti.**

Courteys www.self.org (3)

**The SolarWorld Group, www.solarworld-usa.com.** Through its Solar2World program for off-grid solar projects in the developing world, the company donated 10 kW of PV modules to help power water-pumping stations in Port-au-Prince. Additionally, the company shipped modules at a discount to operate 25 other water stations.

**WorldWater & Solar Technologies Inc., www.worldwatersolar.com.** With no infrastructure to speak of, just getting access to clean water is an ongoing struggle for the people of Port-au-Prince. WorldWater's technology is changing this at one site. In the aftermath of the earthquake, one of its PV-powered mobile water pumping and purification systems that had been donated to a nonprofit food distribution program prior to the tragedy was pulled from the rubble of a building and quickly put to work. It is now purifying 30,000 gallons of contaminated water daily at

# for Haiti

**With PV-made energy, hospitals will be able to work 'round the clock to help patients.**

the makeshift headquarters for the International Red Cross. WorldWater is launching a nonprofit branch to raise money for other systems that will aid the relief efforts. Two additional purification units have been sent to Haiti so far.

**Sun Ovens International, www.sunoven.com.** Building from more than 45 years of outreach efforts in Haiti, the Illinois-based manufacturer partnered with Friends of Haiti Organization and Feed My Starving Children to send 270,000 meals and more than 900 solar ovens to refugee camps in Port-au-Prince. The company also donated two commercial-scale solar ovens that are being used for large-scale food preparation.

**Sol Inc., www.solarlighting.com.** The Florida-based manufacturer donated more than 100 solar lighting systems to provide security, street, and roadway lighting, as well as area lighting for medical clinics, orphanages, and aid stations. The company also teamed up with Save the Children and other nonprofit groups to establish a matching program. Through participating organizations, individuals can make donations and designate that their contribution be used to buy additional solar lights for Haiti. For every solar light system purchased through donations, Sol will donate a second.

—Kelly Davidson

## In Memory of a Solar Hero: Walt Ratterman

Walt Ratterman, of SunEPI, and his Haitian friend and colleague Herb Kanski, of PA Consulting, died at the Hotel Montana in Port-au-Prince, Haiti, when it collapsed in the 7.2 earthquake on January 12. Over the past year, Walt and Herb trained and supervised Haitian contractors to implement 10 hospital power systems, and were in the process of designing the next round of solar-electric systems for nine additional hospitals with limited utility power access.

Walt's talents and the results of his work in remote areas of the world are too long to list. Besides enjoying his tales of high adventure in areas around the world such as Burma, Afghanistan, Palestine, and Rwanda, fellow wrenches and solar enthusiasts across the world trusted and admired Walt's open-book style of sharing information.

Those of us who were privileged to have known Walt all admired his high quality of work, immaculate attention to detail, and dedication to his mission—improving people's quality of life with renewable energy technologies in remote, rural areas. He was a shining example to thousands of people in the industry and worldwide.

I believe that Walt would be the first to take the attention off himself, and turn the focus to the work of providing renewable energy systems and high-quality training for these systems in the developing world. His emphasis on not just completing a project, but instead developing a sustainable solar infrastructure of technicians and product suppliers in the areas where he worked, is a legacy that will continue into the future, and shows a successful path for others to follow.

—Carol Weis, SunEPI, cweis@sunepi.org

**Herb Kanski (left) and Walt Ratterman (right).**


# Maximizing Roof Space for a Net-Zero Energy Home

Homeowners Lisa Brenner and Tom Stibolt did their homework before deciding to employ the services of Mr. Sun Solar. Before installing PV and SHW systems, they upgraded the insulation on the third floor of their home, replaced some windows, and changed some lights to LEDs. When the time was right, they had a site evaluation done by the Energy Trust of Oregon and received bids from multiple contractors. Their goal was to maximize the use of the south-facing roof of their 1916 Craftsman home in Portland's Laurelhurst neighborhood, making an investment that would cover the majority of their utility expenses well into the future as they enter retirement.

To make full use of their roof space, they selected the highest-efficiency modules available at the time, Sanyo HIT 210-Ns, which also have the benefit of a positive-only power tolerance, and lower power loss when exposed to high temperatures. A Sol-Reliant solar water heater was also installed for their domestic water heating needs, producing the equivalent of about 2,700 kWh per year in about 60 square feet of roof space, compared to the 162 square feet that would be needed to produce the same amount of energy with a PV system.

"Getting the most out of the customers' roof meant using the most efficient PV products at our disposal, as well as taking advantage of the superior power density offered in a solar thermal system," says Heath Kearns, Mr. Sun Solar's lead designer.

Designing a system layout that would work around the home's skylights and leave space for future system checkups and cleaning, while providing aesthetic value to the home, were the greatest design challenges. Fortunately, the 34° angle of the roof was a good match for the location's latitude, so the array could be installed parallel to the roof's plane. The homeowners have found that the installation of solar energy systems has made them more energy-conscious, and they have continued to reduce their use through lighting-related upgrades and behavioral changes, as well as looking more closely at the power consumption of their appliances. The residence is currently 100% energy self-sustaining and will provide increasing value to the owners well into their golden years.

## OVERVIEW

**Project name:** Brenner/Stibolt residence

**System type:** Residential grid-direct PV & SHW

**Installer:** Mr. Sun Solar, www.mrsunsolar.com

**Date commissioned:** June 22, 2009

**Location:** Portland, Oregon

**Average daily solar resource:** 4 peak sun-hours

**Array capacity:** 7.56 kW STC

**Average annual production:** 8,164 AC kWh (estimated)

**Average annual utility bill offset**: 100%

## EQUIPMENT SPECIFICATIONS

**Modules:** 36, Sanyo HIT 210-N

**Inverter:** SMA SB7000US, 7 KW rated output

**Array installation:** Mounted on south-facing roof with Unirac SolarMount system at 32° tilt

# Testing & Verifying Module Voltage & Current ...Prior to Installation

An important step in kicking off a successful PV installation is verifying module operation. This includes checking the open-circuit voltage (Voc) and short-circuit current (Isc) of each module on the ground—*before* it gets mounted.

Exactly how to measure a module's voltage and current depends on the type of meter you are using. You can take measurements with a **digital multimeter** (DMM), which uses test leads for measuring voltage and current, or a **clamp meter**, which has a openable jaw that goes around the wire to measure current. (Some clamp meters also have test lead jacks for plugging in leads for measuring voltage, and some DMMs have clamp accessories that plug into jacks.)

Use a meter capable of reading DC measurements up to the expected module Voc and Isc. If you are testing a Schott Solar ASE 310-watt module, for example, the specification sheet shows that the Voc equals 63.8 V and Isc equals 6.5 A.

## Measuring Voltage

Before turning on the meter: Plug the red lead into the "V" jack and the black lead into the "COM" jack. Set the dial for DC volts and the appropriate value range for the given Voc.

Connect the red lead to the positive connector or terminal on the module. Connect the black lead to the module's negative connector or terminal.

For every 1°C higher than 25°C (77°F) that the PV cell experiences, the module will show a 0.5% drop in voltage. On a clear, sunny day, cell temperature will be about 25 to 30°C higher than ambient air temperature. For example, if the ambient air temp is 20°C, cell temperature may be 50°C (depending on how long the module has been sitting in the sun). This translates into a 12.5% voltage loss:

**50°C - 25°C = 25°C rise**
**25°C rise x 0.5% voltage drop per °C = 12.5% voltage drop**

Under these conditions, the Schott Solar module Voc should measure about 56 V DC (63.8 V x 0.875).

## Measuring Current

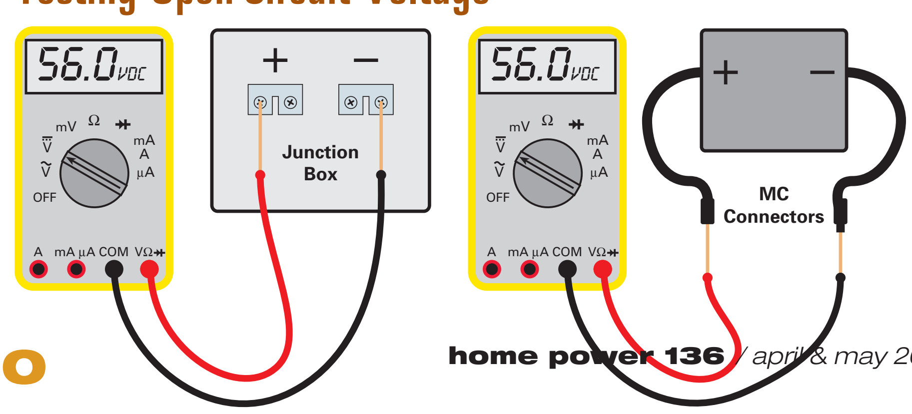
While it isn't recommended to measure the short-circuit current of multiple modules wired together, we can measure the Isc of a single module. For dependable readings, the current measurement should be done with the module receiving good solar exposure (unshaded and directly facing the sun on a sunny day). When working with modules that have pre-attached quick-connect cables, it is easiest to measure Isc with a clamp meter.

To avoid sparking, which can damage the connectors, plug the module leads together with the module in the shade or turned over. Set the meter to DC current and clamp the jaws of the meter around the connected wires—then expose the module to the sun.

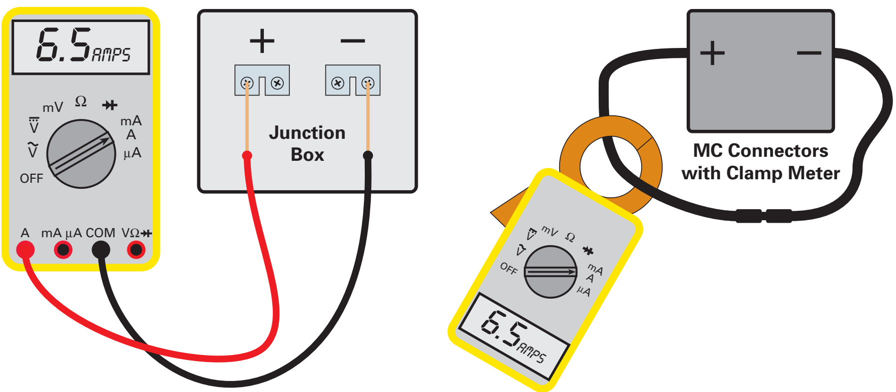
Current is directly proportional to the irradiance on the module, and even a little bit of haze can affect it. So don't be worried if the Isc value is slightly lower than stated on the spec sheet, which is based on full light of 1,000 $W/m^2$. Conversely, reflected light from snow, high altitudes, or edge-of-cloud effects may cause slightly higher readings. Having an irradiance meter handy can give you an idea of the available solar resource. With its reading, you can create a multiplier to factor into your measurements. For example, if your irradiance meter measures 800 $W/m^2$, multiply the expected amps by 0.8 to compare to your measured value.

You can measure a module's Isc with a DMM and test leads by plugging the leads into the correct jacks for measuring current, and setting the dial to the appropriate DC current range. However, sparking will likely occur when you're trying to connect the DMM leads to the module connectors or terminals, and fingers can get burnt and connectors damaged. This is why a clamp meter is preferable.

## Testing Open-Circuit Voltage



## Testing Short-Circuit Current




### Troubleshooting

Most modules carry an initial power warranty that guarantees operation within 10% of its rated output, minus the tolerance variance. If measurements are less than that, and irradiance and temperature impact have been accounted for, you might need to replace the module. Your meter's accuracy may influence the measurements, making it tough to call if you are not too far off from the expected limits. If all module measurements deviate from the expected values, then your meter's accuracy is more suspect.

To single out below-spec modules, an easier indicator is large variances between the modules you are measuring. If modules are all the same model, and field-tested under the same conditions, yet one module yields significantly lower measurements than the others, it may need to be replaced. To make sure module temperatures are consistent while you're measuring, keep all the modules in the shade. To test, pull out one module at a time. This will make it easier to spot modules that are truly reading low voltage.

—Justine Sanchez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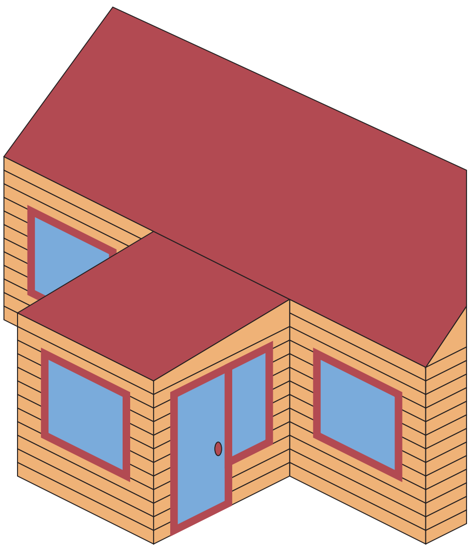

**Entry Vestibule:** Two sets of doors with useful space between reduces air exchanges and the resultant heat loss, and provides a place to deal with muddy boots and wet coats.

## A Vote for Air Locks

There were many useful ideas in Andy Kerr's article, "The Path to Greener Buildings" (*HP135*), but the floor plan shows five exterior doors—none of which has an air lock vestibule! Perhaps the garage entry qualifies as an air lock if the overhead doors are kept closed. Perhaps the screened porch is actually glazed (called a three-season porch where I live), and that would serve as an air lock for the two entries there. But the front door (facing north) and the double door to the patio have no air locks. Even if you spend a lot of money on a high-quality door, a huge gust of cold air will rush in every time it is opened.

Anyone contemplating the construction of a new building, or remodeling of an existing one, would be well advised to review traditional building designs. Combine the best of the old with the best of the new, and you will truly have a "green" building.

Christopher Born • Minneapolis, Minnesota

*Interesting suggestion, Christopher. I must admit to not having given it a thought when contemplating my habitat. The utility (efficiency) of air locks increases with (a) the temperature extremes between the building's conditioned envelope and the outside; and (b) the number of times the door is used. In certain climes and with certain soil types, a "mud room" for changing in and out of shoes and/or clothes can serve as an air lock.*

*My house is net-zero energy already. The supplemental heat in the winter comes from excess electricity generated from the roof's PV system in the summer. Given it's neither extremely cold nor extremely hot in my locale, or a commercial space with a lot of customers or clients coming and going, I'm guessing that it's less expensive to achieve net zero by putting a few more PV modules on the roof than air locks on all doors. Besides the energy sins of humans coming and going, the biggest air leaks in my house are dog doors. Then again, a dog can have the heat-generating equivalent of a 100-watt incandescent lightbulb…*

*Andy Kerr • www.andykerr.net*

## A Hybrid Life

Talk about seven degrees of separation! Your *HP134* article on the Plymouth Area Renewable Energy Initiative (PAREI) in "Greening the Neighborhood" and "Getting Amped: A Plug-In Hybrid Conversion" (*HP135*) bring our green journey full circle. Several years ago, we traveled up to Holderness, New Hampshire, to visit and train with PAREI, learning about solar domestic hot water systems by doing. We subsequently installed an Apricus AP-30 system on our home in North Wales, Pennsylvania, this past June—using PAREI's system design and your DIY heat-exchanger design from *HP97*. The system works extremely well. On a 22°F day, the differential controller showed 105°F water going into the storage tank. We just love this thing. Thanks to *Home Power* and to PAREI!

Then, like Bradley Berman ("Getting Amped: A Plug-In Hybrid Conversion," (*HP135*), we also converted our 2005 Prius to Enginer's 2 kWh system back in September, using the Enginer DIY kit. It was up and running the same day it arrived. I have an electrical engineering background, so the Enginer kit was easy to install, and works *great*. So well, in fact, that we upgraded it to the 4 kWh system last month to double the EV range. We used to get between 6 and 8 EV-only miles (or some mix of 20+ combined miles at 50% better mileage) on the smaller 2 kWh PHEV system. The upgraded 4 kWh battery more than doubled the range. Please pass on to your readers that this thing just works. We used to fill up with gasoline weekly—now it's not even once a month. It's a good value too, in comparison with the competition, especially if you travel at moderate speeds or in local traffic, with lots of stop signs and traffic lights. Support from Jack Chen of Enginer has been superb.

On another note, the "Plug-in Hybrid Conversion Systems" sidebar on page 59 of *HP135* shows a range of "approximately 1 EV-only mile" for this system. We easily achieved seven times that on the 2 kWh system (electric-only), and better than 10 times that on the 4 kWh system. Charging took about 3 hours for a full charge on the smaller system, and less than 5 hours on the larger 4 kWh system, both at 120 V.

Courtesy Kim Small

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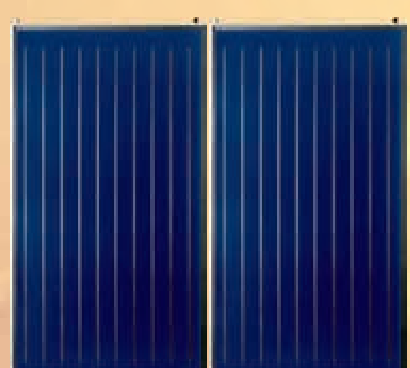

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Kim Small • North Wales, Pennsylvania

Courtesy Nejeh Yusuf

## Happy with PV in Paradise

I am fortunate to awaken every day on St. Thomas in the U.S. Virgin Islands. For years and years, I have been dreaming of harnessing the wind and taking in the lovely sun to produce my own electricity. I signed up for an online subscription to *Home Power* and started educating myself. After replacing my incandescent lightbulbs with CFLs, and placing timers on my water heaters, my utility bill was still too high. My five-year-old daughter asked me one day, "Dad, how are we going to make electricity for Mommy to wash my clothes?" I laughed, and we started searching the Internet for videos of systems being installed so that she could see what we had in mind.

I installed 36 Kyocera 210-watt modules with two grid-tied Sunny Boy inverters, roughly rated at 7.5 kW. The installation has pushed me over our budget, but in my eyes it's worth every penny when I see the sun shine down on our array and our inverters blinking, showing the watt-hours being produced. This system will only offset about half of my utility bill. I am currently in the market for a wind generator to offset the rest of our usage.

With the help of a good dealer and the staff at my local energy office, we made this solar project happen. Receiving an energy rebate, the federal tax credit, and being able to connect to my utility company (net metering) for the PV array was what really helped me make the final decision to go forward. Here on St. Thomas we have lots of sunlight and wind year-round. My family and I are sleeping better at night knowing that we are reducing our carbon footprint and doing our part to reduce global warming for our kids and their kids.

Nejeh Yusuf • St. Thomas, U.S. Virgin Islands

titop81

## $CO_2$ Correction

On page 38 ("Solar Cars," *Ask the Experts*, in *HP135*), Kelly Larson states that there are 1.37 pounds of $CO_2$ emitted for every kWh of coal-fired electricity produced. I believe she is in error.

Per a National Academy of Sciences report issued in October 2009 (as well as my own research on Kentucky power plants), the cleanest plants emit about 1.9 pounds $CO_2$ per kWh; the oldest and dirtiest about 2.5 pounds of $CO_2$. The average is 2 pounds per kWh (see *Hidden Cost of Energy: Unpriced Consequences of Energy Production and Use*, The National Academies Press, 2009).

Jeff Auxier • Louisville, Kentucky

*Thank you for your update on the amount of $CO_2$ released per kWh from coal-fired electricity plants. I interpolated between a couple of sources available at the time. The National Academy of Sciences paper you cited wasn't published when I did this research, but these values further serve to strengthen the argument for using PV to charge an electric vehicle, especially when compared to using coal-fired electricity for EV charging.*

*Kelly Larson • www.solarkelly.com*

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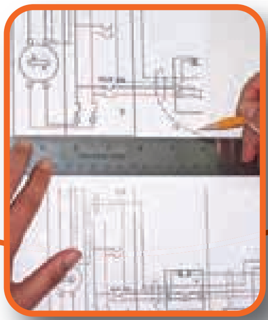

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## Getting Out of Trouble

**Here's my dilemma: My 4.5 kW PV system is only showing about 1,100 to 1,380 W on the inverter when it's running at its peak. What the heck?**

**The module open-circuit voltage is specified to be 36 V; the module I tested showed about 35 V. I haven't checked all the modules for voltage yet, but I did an amperage test with a clamp meter and it showed about 2.5 amps. Total voltage coming in with two strings is 255 to 260 V at the inverter and should be around 5 A. I guess my question is, where are the other 2,000 W I should have?**

**The arrays face close to due south and are almost perfectly perpendicular to the sun (25°) for this time of year. Yes, they are shaded in the afternoon, but not much. But even when they're not shaded at all, the output is never close to the full amount I expected.**

**Some specs: My system is on the coast of Maine. I have 20 REC 225 modules on pole mounts and an SMA SB5000 inverter. Output on a cloudy day is 4.0 to 5.5 kWh; on a sunny day, it's 6.2 to 6.7 kWh. It's less in the wintertime, but shouldn't I still see 2 to 3 kW for at least an hour on a clear winter day? What's my next step? I basically have nowhere to turn, since I bought the equipment on the Internet, and the store I bought from is just kicking merchandise out the door for the lowest cost—and least service.**

**Name withheld • via e-mail**

Unfortunately, the up-front savings that come from buying equipment and installing a system yourself can be undermined when something in your system goes awry. Purchasing equipment from a full-service company means you would have had someone to give you guidance as you installed. I *always* recommend that PV system buyers—especially newbies—buy from someone who offers after-the-sale support, even if they intend to install the system themselves.

In your situation, I suggest that you hire an experienced PV installer to troubleshoot your system—it's probably the best rescue plan. To avoid the trouble you're in, one strategy I've seen used by DIYers is to hire a pro to look over the design in advance of purchase, and then check over their work before inspection. You can likely find local pros in the yellow pages, or surf the Web (for example, see NABCEP's installer locator page or the directory at www.solarbuzz.com or www.homepower.com).

If you end up troubleshooting the system yourself, take the appropriate safety precautions, like wearing eye protection and high-voltage electrical gloves. Then start with the easy stuff. Since you have a clamp-on style meter, you can measure the Vmp and Imp of both module strings (each string should have 10 modules in series). Measure when the array is getting good solar exposure (sunny day, late morning) and while the system is running.

If your system is performing correctly, the array Vmp should measure approximately 250 to 280 V DC; the Imp should measure between 7 and 8 A on each string. If you don't see these values, then shut down the system (via the DC and AC disconnects) and check for blown fuses in the integrated series string combiner box in the SMA inverter and/or in an external combiner box (if installed).

If no fuses are blown, you can continue troubleshooting by checking the Voc and Isc on each module, which, with good solar exposure, should be between 32 and 36 V, and 8 A, respectively. You will have to unplug each module from the series string to make sure that all modules are isolated from one another. (For additional information on testing module Voc and Isc, see "Methods" in *The Circuit* in this issue.)

If you don't have a clear day to measure array and/or module output, getting good values will be tricky. Using an irradiance meter will help you check actual light available, which could help characterize the expected output. If the conditions are changing a lot (like during partially cloudy weather), however, getting reliable readings is tough.

It definitely seems like something is not right with your system. System losses are commonly estimated to be about 30% (from temperature derating, module mismatch, soiling, wire losses, inverter losses, and so on), so you should see power output of around 3,000 W under sunny conditions. I would expect the average annual daily output of a 4.5 kW system to be about 12 kWh or more per day (depending on your shade-free solar access). I'll be interested to know what you find.

While I don't know when you purchased your equipment, please know that REC Solar did recall all of its modules sold in 2008 and some of those sold in 2007. If your individual module readings are not in the range they should be, manufacturing defects could be the problem.

Ian Woofenden • *Home Power*

**"Using an irradiance meter will help you check actual light available, which could help you characterize the expected output."**

## Wind Turbine Rotor Balance

**I am running a Jacobs wind generator at my place in New Mexico. It has been operational for more than 30 years: I've owned it for 12 years and have been operating it for the last five years.**

**The turbine runs fine once it is up to speed, but it has a harmonic at low speeds, when it shakes badly. This started about a year ago and has gotten worse. How do I balance the turbine to remove this harmonic vibration?**

**Grey Chisholm • Madrid, New Mexico**

Several things may need attention. If your machine vibrates at higher operating speeds, the problem is probably an out-of-balance rotor, which you can address by balancing the rotor. Hugh Piggott's method (see the balancing sidebar in "Troubleshooting Small Wind-Electric Systems" in this issue) is one way of balancing blades by determining the center of gravity for each blade. Alternatively, you can balance the entire rotor as a unit, similar to balancing a wheel and tire on an old-fashioned bubble balancer.

A vibration at low speeds usually indicates that one of the blades is out of the plane of rotation—a tracking problem. As wind speed picks up and centrifugal forces bring the blade into the plane of rotation, the vibration usually stops.

The first thing I'd suggest for troubleshooting is to check the distance between blade tips and some point on the tower, making absolutely sure that the turbine does not shift its yaw position. If it does, the measurements are worthless. Bad tracking can be caused by a warped blade, so check this by sighting down each blade.

The shaking in your turbine could also indicate something more serious, such as:

- A bent generator shaft. Check for this by slowly rotating the shaft with a screwdriver or something at right angles to the shaft near the governor hub. You're looking for run-out, or wobble, in the shaft.
- Something amiss in the governor. In this case, my first suspicion would be the blade-pitching knuckles. This is a disaster waiting to happen, especially if a knuckle gives out in high winds. The only way to check the play in the knuckles is to remove the springs from the governor, and then look for slop while operating the governor.
- An unlikely problem, but worth checking for, would be that the governor has loosened on the shaft.

This should get you started. Wind turbine balance issues are not always easy to resolve, but I encourage you to track this to the source before you regret it.

Mick Sagrillo • Sagrillo Power & Light

## Foundation Vents

**I've been working on sealing and upgrading the insulation in my house. Could well-sealed, automatic foundation vents control airflow into and out of the sort-of-heated crawl space? My local hardware store carries thermally activated, louvered automatic foundation vents (the kind that open at 70°F and close at about 40°F). It seems like installing those would be a big improvement over what is there now. However, I'm wondering if there is**

**something that would seal better than those light metal louvers. Can you give me some guidance?**

**Luke Scharf • via e-mail**

You can ventilate a crawl space either with passive air vents (thermally controlled or not), or seal them closed and install a ventilation fan vented to the outside and controlled by a humidistat—commonly referred to as "power ventilated." In this case, size the fan to exhaust 50% or more of the total volume of crawl-space air every hour.

An added bonus of power ventilating is the assurance that airflow is always moving from the home's interior, down across the floor, and out through the crawl space. Otherwise, it's almost certain the opposite will occur via the stack effect. Have someone with a manometer or pressure-gauge test and verify that the crawl-space pressure is negative with reference to the house when the crawl space fan and all exhaust devices in the home are operating at full flow.

Power ventilation is much more effective than traditional, passive ventilation, which only works as intended when there is enough outside wind to create cross-ventilation. I am not comfortable relying on nature to supply buildings with proper ventilation, unless this was properly engineered in the original design.

More important is whether there is an unintentional or intentional heat source in the crawl space. If it's unintentional heat, try to determine the source: it's usually HVAC duct leakage or building heat loss through the floor above. Unintentional heat loss in a crawl space can also contribute to serious building and health issues. Here are some effective ways to treat crawl spaces as an outside zone:

- Mitigate any potential water intrusion into the crawl space
- Provide adequate perimeter drainage around the exterior
- Install a sump pump if excessive seasonal water is an issue
- Install a 6 mil or better polyethylene vapor barrier over all exposed earth, with a water-tight seal around all edges/seams, and hold edges away from wood components
- Air seal the crawl space as well as possible from the house above. If power-venting, air seal from the outside
- Insulate the floor to its greatest potential and/or local requirements
- If uninsulated ducting exists, consider installing additional insulation to the foundation for greater overall crawl space performance

If it's intentional heat, then you are into the realm of a conditioned crawl space, which requires meeting critical details for effective ventilation. Most likely, any system must also meet local building regulations. If you're considering this method, consult with a local, experienced pro.

For additional details on improving the efficiency and performance of crawl spaces, check out Building Science Corp. at www.buildingscience.com.

Tom Brenton • Azimuth Integral Homes

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# CHARTING YOUR SOLAR COURSE

Courtesy www.sanjuancollege.edu

by David Del Vecchio, with Kelly Davidson, Justine Sanchez, Ryan Mayfield & Erik Westerholm

Looking to break into the solar biz? Even in these challenging economic times, there are jobs to be had in this growing market, and with government funds and decreasing costs fueling new projects and green job training, the time is right to make your move. With a little know-how, the right training, and a sunny disposition, you can be on a new, green career path.

## Finding Your Path

The first step is to find the job you would like in the solar energy industry. Research the various careers and which skills are required. A good place to start is the online help-wanted ads. The job descriptions posted on job search and company Web sites will help you determine what skills and credentials are needed for specific jobs. Social networking Web sites, like Facebook and LinkedIn, are excellent resources as well. You can connect with professionals in the field who might be willing to share their experiences and answer your questions.

While much of this article discusses installation and system design training, there are many specialties within the solar industry to consider. What path you choose depends on what skills you have—and what skills you're willing to learn. Opportunities are plentiful in associated fields as well—most notably energy efficiency, energy management, and building sciences. But even if you're not tech-savvy or interested in field work, you can still find a job in solar energy. The industry depends upon an ever-growing nontechnical workforce, with jobs ranging from truck drivers and warehouse managers to accountants and staffers in human resources and public relations.

## The Installer Path

Decades ago, besides know-how, all you needed to do PV installation work was a working knowledge of electricity and a truck. There was little oversight or regulation. The *National Electrical Code* didn't even include PV systems until 1983—the birth year of solar's Section 690.

Long gone are the days of learning by trial and error on the job. The majority of solar industry jobs now require specialized training and, in some cases, a trade license, apprenticeship time, and certification. Fortunately, there is no shortage of training options. With more than $500 million in funds from the Economic Stimulus Act and other governmental grants earmarked for green job training, more options are coming. However, some new training companies are making misleading claims about the quality of their training and trainers, making it more important than ever for you to do your homework before signing up.

The level of training you require depends on your ultimate objective, your current skills, and any local requirements. Before you select your training program, be sure to consider the education and credentials required by your local jurisdiction to work legally and to qualify your customers' systems for incentives.

If you are an electrician wanting to incorporate PV installation into your business or a roofer interested in learning the hardware for mounting on roofs, then hands-on training, such as assembling a working system, is essential. If you are an engineer, advanced-level classes—for example, those covering in-depth, PV-specific *NEC* issues—will aid your move into design work or manufacturing. If you are fresh out of high school or making a dramatic career change, an engineering degree may be the foundation you need to get a job as a PV system designer.

Even if you wish to get an office job at a solar energy company—say as an administrative assistant, accountant, or office manager—having some technical background will be helpful. Adding a few online courses to your résumé may differentiate you from other job candidates, and a basic understanding of the technology will help you do your job more effectively.

## Weighing Your Options

With the increased national interest in the solar industry, more schools and organizations are developing solar training programs and curricula. To find the program that best suits your needs, the "Schools/Organizations Offering PV Education" table starting on page 40 provides information for more than 150 solar education providers, from RE-specific training centers to university programs. But first it's helpful to examine the pros and cons of various training options.

**On-Site Workshops & Programs.** An increasing number of organizations and companies offer renewable energy classroom workshops and programs—ranging from a few days to several weeks. While most include hands-on training, some use lectures and textbooks exclusively. Programs can be short, intensive weeklong courses or months-long courses through a college or trade school. The important thing to remember is that full training takes time and dedication—learning to install a safe, reliable, code-compliant system takes much more than a five-day course.

The most popular courses—and the ones with the longest waiting lists—are those that offer a balance of hands-on and book learning, and let you work individually or in groups to assemble (and sometimes install) a working system.

Compared to online courses, one advantage of on-site learning is the face-to-face interaction with instructors and other students—and the networking that naturally occurs and may lead to future jobs. Programs that offer hands-on learning allow students to work with and install system components in a supervised setting, adding to and solidifying concepts learned during lectures.

Most of these programs are open to anyone who has the desire to learn. If you can pay the workshop fee and you're willing to travel to the site, then you're in. Fees—which can vary from a couple hundred to several thousand dollars—and related travel expenses may be too costly for some, as most programs do not offer financial aid and require time off from work.

Many programs are not generally accredited through an organization recognized by the U.S. Department of Education, and therefore cannot be taken for college credit. However, they may have accreditation from ISPQ (see "Quality Control & RE

## Assessing Your Solar Self

Whether you're selecting your first career or making a career change, do a thorough self-assessment to determine what RE job is most suitable for you and what skills you'll need to learn. The clearer you can be about your current skill set and the direction you want to go, the easier it will be to choose the most appropriate training route.

**Determine your transferable skills.** Dissect each job you've held and any life experiences you've had (volunteer work, hobbies, sports, etc.) to determine what skills you've accrued. Chances are, even if you're entering the work force for the first time, you have some skills that will transfer to a job in solar energy. An information technology specialization or knowing how to do Web site coding, for example, might be useful in the design of data-monitoring systems.

**Gauge your interests.** Be realistic about your likes and dislikes regarding various activities. If you do not like heights, then becoming a PV system installer is probably not the best vocation for you. Roofers, already familiar with waterproofing and fall protection, typically make excellent candidates for installation of PV modules and mounts. If you're detail-oriented by nature, then you might find your calling as a project manager or an energy efficiency auditor.

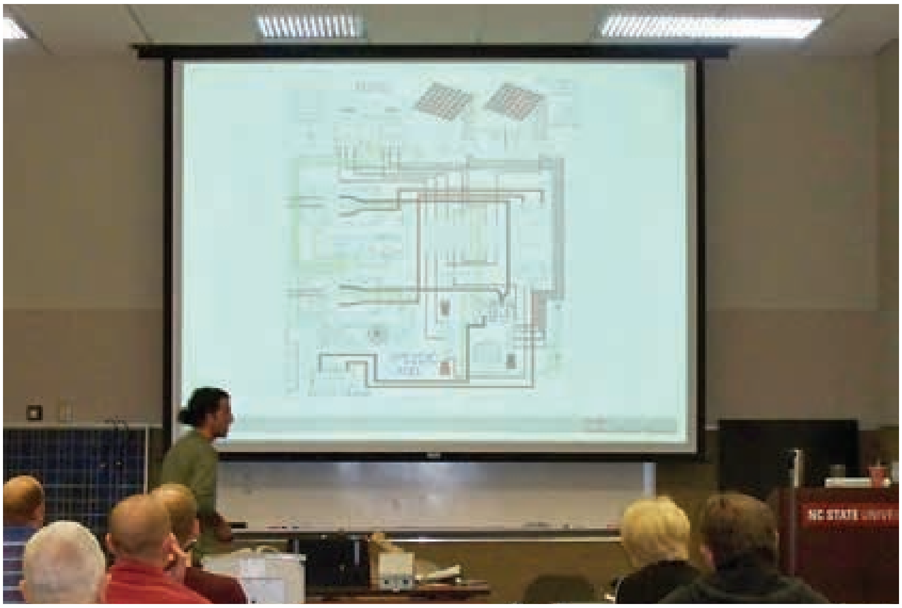
**Consider your priorities.** Take an inventory of the job characteristics that are most important to you—autonomy, security, interpersonal relations, helping others, work schedule, salary, and work environment. Your personal preferences will help you narrow job options and focus on your most appropriate opportunities.

Courtesy Maria O'Farrell

**If installing renewable energy systems is your career path, hands-on experience is critical to your future success in the field. This type of training is also helpful for those looking to apply concepts learned in the classroom.**

Education" sidebar on page 47). Most offer a certificate of completion. These certificates should not be confused with industry-recognized certifications, such as that offered by the North American Board of Certified Energy Practitioners (NABCEP). Some of these programs meet criteria set by NABCEP and may fulfill educational requirements needed to qualify for taking the NABCEP exam, and/or qualify as continuing education credits required to maintain NABCEP certification.

Depending on your background and existing skill set, attending a workshop or two may get your foot in the door with a solar company, but you'll likely need to pursue some level of certification or additional credentials if you're serious about making a career in the industry.


Courtesy Maria O'Farrell

**On-site workshops and courses typically devote significant time to classroom learning, studying RE system concepts before students head into the lab yard for hands-on training.**

**Online Courses.** Many well-established training centers now offer online courses, which generally run from four weeks to several months. The curricula is usually the same as the classroom courses offered by the same provider, but without the on-site group dynamic or hands-on opportunities. Instructors are available for questions, and communication is usually via e-mail and message boards. However, responses can take anywhere from minutes to days, depending on the number of students in the course and message timing.

Students can interact and pose online questions, but they complete lessons and perform classroom exercises, quizzes, and homework on their own, which can be an advantage compared to group settings, since instructors can gauge each student's level of understanding independently. A key benefit of online education is the lack of geographical constraints: All you need is an Internet connection. If there are no solar workshops offered in your area, you can still participate in RE training courses via distance learning. Online courses also offer greater flexibility and convenience for people who work or have families. The slower, self-paced schedule can be both a blessing and a curse, allowing students to retain and synthesize the information but requiring a fair amount of self-discipline to stay focused.

Online courses are a good way to prepare for a basic, hands-on course, but they also can be a good way to recap, or expand upon, material learned in a hands-on course or workshop.

**Community colleges** offer a variety of certificate, degree, and continuing education programs to train technicians for careers in manufacturing, maintenance, and installation of RE systems. Many programs have good reputations, and unlike RE training centers, tend to have more support for students, like financial aid and career counseling. Classes can accommodate part-time and working students, and most credits are transferable to four-year colleges offering bachelor's degrees and higher. Plus, tuition costs are considerably less compared to four-year schools. Like other RE training programs, those at community colleges are in high demand and often have long wait lists.

A two-year associate's degree could be a good fit for newcomers to the solar work force who might benefit from having a degree or for individuals wanting to shift their career in an entirely new direction. Two-year programs can include hands-on shop time—and internships spent working side-by-side with trained technicians in the field. Having a degree tends to carry a bit more weight when it comes time to apply for certain jobs and garner higher starting salaries.

## Solar Training at Energy Fairs & Conferences

National solar event organizers know their venues are the perfect time to offer training opportunities, and attendees can take maximum advantage of their time away from work. Training can be as short as hour-long seminars on specific solar topics during an energy fair to full pre-event workshops ranging from several days to a week. These trainings can help get folks up to speed on different solar topics before they attend the solar event—or they can offer learning opportunities for those wanting to start solar businesses. For individuals already in the biz, NABCEP continuing education credits are offered through new product training and technical updates. One example is the upcoming "Solar Success" training to be held before the 2010 ASES National Conference (see www.solar-success.org for more information).

## Certificate vs. Certification?

Earning NABCEP's entry-level certificate should not be confused with NABCEP professional certification. An entry-level certificate demonstrates that the certificate holder has gained a fundamental knowledge of PV systems suitable for a supervised, entry-level position with a dealer/installer or other PV company. While this is a benchmark to strive for in your own training, it is *not* a sufficient qualification for an installation training provider or self-employed installer.

You may spend some of your time completing general education requirements for a more rounded education, and find that required classes are offered infrequently (i.e., every other semester). Smaller class sizes can mean more personal attention from your instructor and more time with the equipment, but it also means there are fewer spots available, which may make it harder to get classes you need.

Some people appreciate a general educational foundation and feel that taking a variety of course topics keeps the educational experience diverse. Others favor a more focused route. In that case, pursuing a one-year certificate or enrolling in noncredit continuing education courses may be the best option. Such programs may be a good fit for career changers looking to test the waters or those already in the work force who want to enhance their existing skills. For an even quicker fix, consider shorter, job-specific training offered through vocational or trade schools.

Informational interviews with a program's directors or instructors can be helpful in assessing whether a program will meet your needs—and whether the classes you want will be offered when you need them. As with any other training option, you'll want to verify the experience and qualifications of the instructors, and talk to recent graduates to find out whether the program proved valuable in the job market and opened the right doors.

**Four-Year Schools.** Numerous colleges and universities offer undergraduate and graduate degree programs that lay the groundwork for careers in RE. Typically, RE-related coursework falls under engineering, building science, or various environmental programs.

Until recently, there were few programs that focused specifically on RE, but more and more schools recognize the growing need for RE-specific training and have specialized four-year degrees to prepare students for a range of careers in the renewable energy industry. The Oregon Institute of Technology in Portland, the State University of New York in Canton, Illinois State University in Normal, and Appalachian State University in Boone, North Carolina, are among the schools leading the way. Such programs often have a strong focus on engineering principles and offer coursework in PV, wind, biomass, hydropower, and geothermal energy, as well as energy management and energy efficiency. (Note: The table starting on page 40 lists several university programs, but isn't all-inclusive.)

While a college degree is not necessary for success in the solar industry, it certainly doesn't hurt to have one. However, if you would like to work in product development or in energy management, then a degree is essential. Depending on the program, you may find yourself spending more time in the lecture hall than in the field. Look for programs with a strong hands-on component and internship placement, and be sure to take advantage of every opportunity to do field work. Four-year degrees are more expensive and time consuming, but starting salaries tend to be higher, depending on the market and the position. Financial aid and scholarships can lessen the financial burden for those who qualify.

**Apprenticeships.** In some jurisdictions, an apprenticeship is a requirement to earn your license to install PV or solar thermal systems. Most programs combine paid on-the-job training with related classroom instruction. An apprentice works under the supervision of a license holder, generally a master electrician, plumber, or HVAC technician. Typically, an apprentice will work during the day and attend night or weekend classes at a technical school or community college. Depending on the jurisdiction and the license, an apprenticeship program may last from one to four years. Upon completion of the program, an apprentice must pass a written exam to qualify to work for a licensed contractor and supervise other apprentices. In some states, this allows an installer to pull permits and start an installation business.

*(continued on page 46)*

**Some RE training centers offer students hands-on opportunities to work on many different system types and mounting structures.**

Courtesy www.solarenergy.org

# Schools/Organizations Offering PV Education*

**web extra**

For more details on programs, see the expanded table at www.homepower.com/webextras

| State | School or Program Name | City | Phone | Web Site |
|---|---|---|---|---|
| AR | John Brown Univ. | Siloam Springs | 479-238-8743 | www.jbu.edu/science/renewable_energy |
| AZ | Coconino Comm. College | Flagstaff | 928-526-7696 | www.coconino.edu/ academics/curriculum/collegecatalog |
| | Arizona State Univ. | Tempe | 480-727-6963 | www.schoolofsustainability.asu.edu |
| | Rio Salado College | Tempe | 480-446-0400 | www.erenewableresource.com |
| | Pima Comm. College | Tucson | 520-206-7134 | www.pima.edu/program/construction/solarinstaller-cert.shtml |
| CA | Cabrillo College | Aptos | 831-479-6235 | www.cabrillo.edu/academics/cem |
| | Humboldt State Univ. | Arcata | 707-826-4345 | www.humboldt.edu/~ere |
| | UC Berkeley Extension | Berkeley | 510-642-4151 | www.extension.berkeley.edu/profseq/solar.html |
| | CCAC Int. Polytechnic Inst. | Calexico | 760-357-2995 | — |
| | Applied Professional Training | Carlsbad | 800-431-8488 | www.aptc.edu |
| | Orange Coast College | Costa Mesa | 714-432-5072 | www.orangecoastcollege.edu/academics/divisions/technology |
| | Sun Pirate | Cotati | 415-332-7246 | www.sunpiratesolar.com |
| | College of the Redwoods | Eureka | 707-476-4347 | www.redwoods.edu/Departments/construction |
| | Boots on the Roof | Fremont | 888-893-0367 | www.bootsontheroof.com |
| | The Solar Living Inst. | Hopland | 707-472-2458 | www.solarliving.org |
| | Golden West College | Huntington Beach | 714-892-7711 x52180 | www.goldenwestcollege.edu/environment |
| | College of Marin | Kentfield | 415-457-8811 x8200 | www.marin.cc.ca.us |
| | Allied Business Schools | Laguna Hills | 800-732-7410 | www.training4green.com |
| | Solar Universe/Solar Univ. | Livermore | 925-455-4700 | www.sunprotraining.com |
| | LA Trade Tech. College | Los Angeles | 213-763-3701 | www.lattc.edu |
| | East LA Skills Ctr. | Los Angeles | 323-224-5970 | www.elasc.adultinstruction.org |
| | New Tech. Training Inst. | Los Angeles | 818-247-0989 | www.newtechtrain.com |
| | Ohlone College | Newark | 510-742-2360 | www.ohlone.edu |
| | Meritt College | Oakland | 510-434-3840 | www.ecomerritt.org |
| | The English Ctr. | Oakland | 510-836-6700 x104 | www.englishcenter.edu |
| | MiraCosta College | Oceanside | 888-895-8186 | www.mccae.org |
| | Pasadena City College | Pasadena | 626-585-7274 | www.pasadena.edu |
| | Diablo Valley College | Pleasant Hill | 925-685-1230 | www.dvc.edu |
| | Sierra College | Rocklin | 916-660-7900 | www.sierracollege.edu/programs/solarenergy.html |
| | Sonoma State Univ. | Rohnert Park | 707-664-2430 | www.sonoma.edu/ensp |
| | American River College | Sacramento | 916-484-8675 | http://web.arc.losrios.edu/~electron |
| | Skyline College | San Bruno | 650-738-4354 | www.skylinecollege.edu |
| | SDSU College of Ext. Studies | San Diego | 619-594-5821 | www.ces.sdsu.edu |
| | Green Career Inst. | San Francisco | 866-545-5441 | www.greencollarschool.com |
| | City College of San Francisco | San Francisco | 415-239-3285 | www.ccsf.edu |
| | CACTUS | San Jose | 818-687-1323 | www.greencactus.org |
| | Metropolitan Ed. District | San Jose | 408-723-4222 | www.metroed.net |
| | San Jose City College | San Jose | 408-206-9704 | www.sjcc.edu/Acad/Divisions/applied/solar.html |
| | Solar Training Inst. | San Jose | 408-625-7400 | www.trainingforsolar.com |
| | College of San Mateo | San Mateo | 650-574-6133 | www.collegeofsanmateo.edu/solar |
| | Step Up Education | Santa Cruz | 800-800-1638 x687 | www.solarclassesonline.com |
| | Santa Monica College | Santa Monica | 310-434-8652 | www.smc.edu |
| | EnerCal Inst. | Santa Rosa | 800-627-9642 | www.enercai.com |
| | Santa Rosa Junior College | Santa Rosa | 707-527-4246 | www.santarosa.edu/instruction/cte/go-green.php |
| | Stanford Univ. | Stanford | 650-723-2300 | www.stanford.edu |
| | California South Bay Univ. | Sunnyvale | 408-400-9008 | www.csbu.us/green-energy-certificate-program.php |
| | Brooks Engineering | Vacaville | 707-332-0761 | www.brooksolar.com |
| CO | Univ. of CO Continuing Ed. | Boulder | 303-735-1005 | http://conted.colorado.edu |
| | Solar Energy Int. (SEI) | Carbondale | 970-963-8855 | www.solarenergy.org |
| | Quinntas RE | Denver | 303-733-4055 | www.quinntas.org |
| | Colorado School of Mines | Golden | 303-273-3844 | www.energyminor.mines.edu |
| | Red Rocks Comm. College | Lakewood | 303-914-6306 | www.rrcc.edu |
| | Arapahoe Comm. College | Littleton | 303-734-3701 | www.coloradotraining.com |

Note: New programs continue to be implemented across the United States. Information in the table is current as of February 2010. "—" means did not reply.

| Type | Years in Place | SHW | ISPQ Accred. | ISPQ Cert. Trainers | NABCEP Certified Installers | NABCEP Entry-Level Exam | Online Courses | Hands-On Courses | College Credit | Cred./ Degrees Offered |
|---|---|---|---|---|---|---|---|---|---|---|
| Univ. or college | < 1 | ✓ | | | 1 (pend.) | | | ✓ | ✓ | BS |
| Comm. college | 10 | | | | | | | ✓ | ✓ | AAS |
| Univ. or college | 2 | ✓ | | | | | ✓ | ✓ | ✓ | BS+ |
| Comm. college | < 1 | | | | | ✓ | | ✓ | | |
| Comm. college | 2 | Pend. | | | | ✓ | | ✓ | ✓ | Cert. |
| Comm. college | 3 | Pend. | | | | ✓ | | ✓ | Pend. | |
| Univ. or college | 35 | ✓ | | | | | | ✓ | ✓ | BS, MS |
| Univ. or college | — | — | | — | — | — | | ✓ | ✓ | — |
| Vocational | — | — | | — | — | ✓ | — | — | — | — |
| Vocational | 17 | | | | 1 | ✓ | | ✓ | ✓ | AA pend. |
| Comm. college | — | ✓ | | — | — | — | — | ✓ | ✓ | — |
| RE training ctr. | 3 | ✓ | ✓ | 1 | 1 | ✓ | ✓ | ✓ | | |
| Comm. college | 3 | ✓ | | | 1 | Pend. | | ✓ | ✓ | |
| RE training ctr. | 2 | ✓ | ✓ | | 1 | ✓ | ✓ | ✓ | | |
| RE training ctr. | 11 | ✓ | ✓ | | 5 | ✓ | ✓ | ✓ | | |
| Comm. college | 8 | ✓ | | | | ✓ | ✓ | ✓ | ✓ | Cert. |
| Comm. college | 3 | | | | | ✓ | | ✓ | ✓ | |
| Vocational | < 1 | Pend. | | | | ✓ | ✓ | | | |
| RE training ctr. | < 1 | Pend. | Pend. | | 1 | | | ✓ | | |
| Comm. college | 2 | | | | | ✓ | | ✓ | ✓ | Cert. |
| Vocational | 3 | | | | | ✓ | | ✓ | | |
| Vocational | < 1 | | | | 1 | ✓ | | ✓ | | |
| Comm. college | 2 | Pend. | | | | ✓ | | ✓ | ✓ | Cert. pend. |
| Comm. college | 33 | ✓ | | | | ✓ | | ✓ | ✓ | AA |
| Non-profit org. | — | — | | — | — | ✓ | — | ✓ | — | — |
| Comm. college | < 1 | Pend. | | | | ✓ | | ✓ | | |
| Comm. college | — | — | | — | — | ✓ | — | — | — | — |
| Comm. college | 10 | ✓ | | | | ✓ | ✓ | ✓ | ✓ | Cert., AA |
| Comm. college | < 1 | | | | | Pend. | | ✓ | ✓ | Cert. pend. |
| Univ. or college | 30 | ✓ | | | | | | | ✓ | BA, BS |
| Comm. college | 1 | | | | 2 | ✓ | | ✓ | ✓ | Cert. |
| Comm. college | 2 | | | | 1 | ✓ | | ✓ | ✓ | Cert. |
| Univ. or college | 2 | ✓ | | | | | ✓ | | | Cert. |
| RE training ctr. | 2 | ✓ | | | 1 | | ✓ | ✓ | | |
| Comm. college | 1 | | | | | ✓ | | ✓ | ✓ | |
| RE training ctr. | — | ✓ | | | — | ✓ | | ✓ | ✓ | — |
| Vocational | 1 | | | | | ✓ | | ✓ | | |
| Comm. college | 3 | | | | 1 | ✓ | | ✓ | ✓ | Cert. pend. |
| RE training ctr. | 1 | | | | | Pend. | | ✓ | | |
| Comm. college | 5 | | | | | ✓ | | ✓ | ✓ | Cert. pend. |
| RE training ctr. | 2 | | | | | Pend. | ✓ | | | |
| Comm. college | < 1 | | | | | | | ✓ | ✓ | AA, Cert. |
| RE training ctr. | 1 | ✓ | | | | Pend. | ✓ | | ✓ | |
| Comm. college | — | — | | — | — | ✓ | — | ✓ | — | — |
| Univ. or college | 30 | ✓ | | | | | ✓ | ✓ | ✓ | BS, PhD |
| Univ. or college | 1 | | ✓ | | | ✓ | | ✓ | ✓ | Cert., MS |
| Individual Trainer | 22 | | N/A | Pend. | N/A | | | ✓ | | |
| Univ. or college | 3 | ✓ | | | | | ✓ | ✓ | ✓ | Cert. |
| RE training ctr. | 19 | ✓ | ✓ | 9 (6 pend.) | 22 | ✓ | ✓ | ✓ | | |
| RE training ctr. | 1 | | ✓ | 6 (pend.) | 2 | Pend. | | ✓ | | |
| Univ. or college | 30 | ✓ | | | | | | ✓ | ✓ | BS |
| Comm. college | 30 | ✓ | | | 2 | ✓ | | ✓ | ✓ | Cert., AA |
| Comm. college | 1 | ✓ | | | | ✓ | ✓ | ✓ | ✓ | Cert. |

## Schools/Organizations Offering PV Education, cont.'d

| State | School or Program Name | City | Phone | Web Site |
|---|---|---|---|---|
| CT | Gateway Comm. College | North Haven | 203-285-2426 | www.gwcc.commnet.edu |
| FL | UCF Florida Solar Energy Ctr. | Cocoa | 321-638-1473 | www.fsec.ucf.edu |
| | USSolar Inst. | Key West | 305-744-3445 | www.ussolarinstitute.com |
| | Solar Source Inst. | Largo | 800-329-1301 | www.solarsource.net |
| | Westside Tech. Ctr. | Winter Garden | 407-905-2009 | www.westside.ocps.net/technical_programs/alternative_energy |
| GA | Solairgen | Dahlonega | 706-867-0678 | www.solairgen.com |
| HI | Hawaii Pacific Univ. | Kaneohe | 808-236-7908 | www.hpu.edu |
| IL | John A Logan College | Carterville | 618-985-2828 | www.jalc.edu |
| | Kankakee Comm. College | Kankakee | 815-802-8864 | www.kcc.edu |
| | Illinois State Univ. | Norma | 309-438-3557 | www.tec.ilstu.edu/renewable_energy |
| LA | Baton Rouge Comm. College | Baton Rouge | 225-216-8436 | www.mybrcc.edu |
| | Louisiana CleanTech Network | Kenner | 504-343-4638 | www.lacleantech.net |
| MA | Cape Cod Comm. College | Barnstable | 508-362-2131 | www.capecod.mass.edu |
| | Benjamin Franklin Inst. of Tech. | Boston | 617-423-4630 | www.bfit.edu |
| | Massasoit Comm. College | Brockton | 508-588-9100 | www.massasoit.mass.edu |
| | HeatSpring Learning Inst. | Cambridge | 800-393-2044 | www.heatspring.com |
| | Bristol Comm. College | Fall River | 508-678-2811 x2264 | www.bristolcc.edu/noncredit |
| | Greenfield Comm. College | Greenfield | 413-775-1472 | www.gcc.mass.edu |
| | AltE Univ. | Hudson | 877-878-4060 | www.altestore.com |
| | Springfield Tech. Comm. College | Springfield | 413-755-4501 | http://cbt.stcc.edu/specialinterest |
| | Quinsigamond Comm. College | Worcester | 508-751-7904 | www.qcc.mass.edu |
| MD | Frostburg St. Univ., WISE Ed. Program | Frostburg | 301-687-4298 | www.frostburg.edu/renewable |
| | Nat. Joint Apprent. & Training Comm. | Upper Marlboro | 301-715-2320 | www.njatc.org |
| ME | Kennebec Valley Comm. College | Fairfield | 207-453-5000 | www.kvcc.me.edu |
| MI | Fond du Lac Tribal & Comm. College | Cloquet | 218-879-0891 | www.fdltcc.edu |
| | Wayne State Univ. | Detroit | 313-577-3716 | www.eng.wayne.edu/page.php?id=1505 |
| | Oakland Comm. College | Royal Oak | 248-246-2553 | www.oaklandcc.edu/est |
| | Northwestern Michigan College | Traverse City | 231-995-1701 | www.nmc.edu/ees |
| | Macomb Comm. College | Warren | 586-445-7191 | www.macomb.edu |
| MN | Lake Superior College | Duluth | 218-260-9920 | www.lsc.cc.mn.us |
| | Hibbing Comm. College | Hibbing | 218-312-9807 | www.hibbing.edu |
| | KidWind Project | St. Paul | 651-917-0079 | www.kidwind.org |
| | St. Paul College | St. Paul | 651-846-1583 | www.saintpaul.edu/ContinuingEducation/Pages/SolarTech.aspx |
| MO | Evergreen Inst. | Gerald | 303-883-8290 | www.evergreeninstitute.org |
| | Metropolitan Comm. College | Kansas City | 816-604-1000 | www.mcckc.edu |
| | Crowder College | Neosho | 417-451-3223 | www.crowder.edu/SCIENCE-TECHNOLOGY |
| MT | Univ. of Mont., Applied Comp. & Elect. | Missoula | 406-243-7916 | http://ace.cte.umt.edu/energy |
| NC | Appalachian State Univ., Dept. of Tech. | Boone | 828-262-6361 | www.appstate.edu |
| | Central Piedmont Comm. College | Charlotte | 704-330-6531 | www.cpcc.edu/gs |
| | Sandhills Comm. College | Pinehurst | 910-692-6185 | www.sandhills.edu |
| | Central Carolina Comm. College | Pittsboro | 919-542-6495 x236 | www.cccc.edu |
| | North Carolina State Univ. | Raleigh | 919-513-0775 | www.ncsc.ncsu.edu |
| NH | Lakes Region Comm. College | Laconia | 603-524-3207 x763 | www.lrcc.edu |
| NJ | Middlesex Comm. College | Edison | 732-906-4681 | www.middlesexcc.edu/institute |
| NM | Central New Mexico Comm. College | Albuquerque | 505-224-5217 | www.cnm.edu |
| | Northern New Mexico Comm. College | Espanola | 505-747-2264 | www.nnmc.edu/academics/departments/engr |
| | San Juan College | Farmington | 505-327-5705 | www.sanjuancollege.edu/reng |
| | NM State Univ., Inst. for Energy & Envt. | Las Cruces | 575-646-2038 | www.nmsu.edu |
| | Luna Comm. College | Las Vegas | 505-454-5370 | www.luna.edu |
| | Santa Fe Comm. College | Santa Fe | 505-428-1641 | www.sfccnm.edu |
| NY | Ctr. for Sustain. Ener. Bronx Comm. Coll. | Bronx | 718-289-5332 | www.csebcc.org |
| | SUNY Canino School of Engr. Tech. | Canton | 315-386-7411 | www.canton.edu/csoet/alt_energy |
| | SUNY Delhi | Delhi | 607-746-4545 | www.delhi.edu |

| Type | Years in Place | SHW | ISPQ Accred. | ISPQ Cert. Trainers | NABCEP Certified Installers | NABCEP Entry-Level Exam | Online Courses | Hands-On Courses | College Credit | Cred./ Degrees Offered |
|---|---|---|---|---|---|---|---|---|---|---|
| Comm. college | — | — | | — | — | ✓ | — | ✓ | — | — |
| RE training ctr. | 30 | ✓ | ✓ | | 1 | ✓ | Pend. | ✓ | | |
| RE training ctr. | 1 | ✓ | | | 1 | ✓ | ✓ | ✓ | ✓ | |
| Post-secondary | 3 | ✓ | | | 2 | ✓ | ✓ | ✓ | ✓ | Cert. |
| Vocational | 2 | ✓ | | | | ✓ | Pend. | ✓ | | |
| RE training ctr. | 6 | ✓ | ✓ | | 1 | Pend. | | ✓ | | |
| Univ. or college | 3 | | | | | ✓ | ✓ | | ✓ | |
| Comm. college | — | — | | — | — | ✓ | — | ✓ | — | — |
| Comm. college | 2 | ✓ | | | 1 | ✓ | | ✓ | ✓ | Cert., AA |
| Univ. or college | — | — | | — | — | | — | — | ✓ | BS |
| Comm. college | — | — | | — | — | ✓ | — | ✓ | — | — |
| RE training ctr. | 2 | ✓ | | 1 (pend.) | | ✓ | ✓ | ✓ | | |
| Comm. college | 3 | ✓ | | | | ✓ | | ✓ | ✓ | Cert. |
| Univ. or college | — | — | | — | — | ✓ | — | ✓ | — | |
| Comm. college | < 1 | | | | | ✓ | Pend. | ✓ | Pend. | |
| RE training ctr. | 1 | | ✓ | | 1 | ✓ | ✓ | ✓ | | |
| Comm. college | — | — | | — | — | ✓ | — | — | — | |
| Comm. college | 3 | ✓ | | 1 (pend.) | 1 | ✓ | | ✓ | ✓ | Cert., AA |
| RE training ctr. | 3 | ✓ | ✓ | 1 | 1 | ✓ | | ✓ | | |
| Comm. college | 3 | | ✓ | | 2 | ✓ | ✓ | ✓ | | |
| Comm. college | — | — | | — | — | ✓ | — | ✓ | — | |
| Univ. or college | 2 | | | | | ✓ | | ✓ | | |
| Trade org. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| Comm. college | — | — | | — | — | ✓ | — | — | — | |
| Comm. college | 3 | | | | | ✓ | ✓ | ✓ | ✓ | Cert. |
| Univ. or college | 5 | ✓ | | | | | | | ✓ | Cert., MS |
| Comm. college | 30 | ✓ | | | | | ✓ | ✓ | ✓ | AAS, Cert. |
| Comm. college | < 1 | | | | | ✓ | | ✓ | ✓ | AAS, Cert. |
| Comm. college | < 1 | | | | | | ✓ | ✓ | ✓ | Cert. |
| Comm. college | — | — | | — | — | ✓ | — | — | — | |
| Comm. college | < 1 | | | | 1 | ✓ | | ✓ | | AA pend. |
| RE training ctr. | < 1 | ✓ | | | | | | ✓ | | |
| Comm. college | 1 | ✓ | | | 2 | ✓ | | ✓ | | |
| RE training ctr. | 8 | ✓ | Pend. | | | | ✓ | ✓ | | |
| Comm. college | 1 | | | | | | ✓ | | ✓ | Cert. |
| Comm. college | 31 | ✓ | | | | Pend. | ✓ | ✓ | ✓ | AA, AAS, Cert. |
| Univ. or college | 2 | | | | 1 | ✓ | ✓ | | | AAS |
| Univ. or college | 30 | | | | | ✓ | | ✓ | ✓ | BS, MS |
| Comm. college | 1 | | | | 1 | ✓ | | ✓ | ✓ | AA |
| Comm. college | — | — | | — | — | — | — | — | — | |
| Comm. college | 1 | ✓ | | | 1 | ✓ | | ✓ | Pend. | Cert., AA |
| Univ. or college | 6 | ✓ | ✓ | | 2 | ✓ | Pend. | ✓ | | |
| Comm. college | 3 | ✓ | | | 1 | ✓ | | | | Cert., AS |
| Comm. college | < 1 | | | | | ✓ | | ✓ | | |
| Comm. college | 1 | ✓ | | | | ✓ | | ✓ | ✓ | |
| Comm. college | < 1 | ✓ | | | | | ✓ | ✓ | ✓ | BS |
| Comm. college | 10 | ✓ | | | | | | ✓ | ✓ | AAS |
| Univ. or college | — | — | | — | — | — | — | — | — | |
| Comm. college | 3 | ✓ | | | | | | ✓ | ✓ | AAS |
| Comm. college | 5 | ✓ | | | 1 | ✓ | | ✓ | ✓ | AAS |
| Comm. college | 6 | ✓ | ✓ | | | ✓ | | ✓ | | |
| Univ. or college | 3 | | | | | ✓ | ✓ | ✓ | ✓ | BS |
| Univ. or college | 6 | | ✓ | | 1 | | | ✓ | ✓ | |

## Schools/Organizations Offering PV Education, cont.'d

| State | School or Program Name | City | Phone | Web Site |
|---|---|---|---|---|
| NY | ETM Solar Works | Endicott | 607-785-6499 | www.etmsolar.com |
| | Farmingdale State Univ. of New York | Farmingdale | 631-420-2450 | www.farmingdale.edu |
| | SUNY Ulster County Comm. College | Kingston | 845-802-7171 | www.sunyulster.edu |
| | SUNY Orange County Comm. College | Middletown | 845-344-6222 | www.sunyorange.edu |
| | Consortium for Worker Ed. | New York | 212-414-2380 | www.cwe.org |
| | Ulster County Board of Coop. Ed. | Port Ewen | 835-331-5050 | www.ulsterboces.org |
| | Dutchess Comm. College | Poughkeepsie | 845-431-8907 | www.sunydutchess.edu/cfweb |
| | SUNY Rockland Comm. College | Suffern | 845-574-4465 | www.sunyrockland.edu/go/cppd |
| | SUNY Coll. of Env. Science & Forestry | Syracuse | 315-470-6817 | www.esf.edu/outreach |
| | Hudson Valley Comm. College | Troy | 518-629-4835 | www.hvcc.edu |
| | Alfred State College, Ctr. for Comm. Ed. | Wellsville | 607-587-4017 | www.alfredstate.edu |
| OH | Cuyahoga Comm. Coll., Ctr. for Sustain. | Cleveland | 216-987-3027 | www.tri-c.edu |
| | Wright State Univ. | Dayton | 937-775-5145 | www.cs.wright.edu/mme/future-grad-rce.shtml |
| | Sinclair Comm. Coll., Ctr. for Energy Ed. | Dayton | 937-512-2183 | www.sinclair.edu |
| | Cincinnati State Tech. & Comm. College | Evendale | 513-569-1497 | www.cincinnatistate.edu |
| | Owens Comm. College | Maumee | 567-661-7163 | www.owens.edu |
| | Hocking College, Energy Inst. | Nelsonville | 877-462-5464 x7035 | www.hocking.edu |
| | Tri-County Career Ctr. | Nelsonville | 740-753-3511 | www.tricountyhightech.com |
| | Oregon Career & Tech. Ctr. | Toledo | 419-697-3450 | www.oregoncityschools.org |
| | Univ. of Toledo | Toledo | 419-530-2241 | www.utoledo.edu |
| OR | Central Oregon Comm. College | Bend | 541-383-7270 | http://noncredit.cocc.edu |
| | Lane Comm. Coll., NW Energy Ed. Inst. | Eugene | 541-463-3977 | www.nweei.org |
| | The Oregon Inst. of Tech. | Portland | 503-821-1250 | www.oit.edu/portland/programs/renewable-energy-engineering |
| | Portland Comm. College | Portland | 503-244-6111 | www.pcc.edu/programs/electronic-engineering |
| PA | Northampton Comm. College | Bethlehem | 610-332-6260 | www.northampton.edu |
| | Harrisburg Area Comm. College | Harrisburg | 717-221-1338 | www.hacc.edu/GreenTechnology |
| | SEDA-COG's Energy Resource Ctr. | Lewisburg | 570-524-4491 | http://erc.sedacog.org |
| | Infinite Solar Training Facility | Philadelphia | 215-464-6460 | www.solarschoolpa.com |
| | Comm. College of Allegheny County | Pittsburgh | 412-237-2525 | 3www.ccac.edu |
| PR | Univ. of Puerto Rico Aguadilla | Aguadilla | 787-890-7118 x264 | www.uprag.edu |
| RI | New England Inst. of Tech. | Warwick | 800-736-7744 x3420 | www.neit.edu |
| TN | Cleveland State Comm. College | Cleveland | 423-473-2447 | www.clevelandstatecc.edu |
| | Pellissippi State Comm. College | Knoxville | 865-694-6666 | www.pstcc.edu/bcs |
| | Tennessee Tech. Ctr. at Pulaski | Pulaski | 931-424-4014 | www.ttcpulaski.edu |
| TX | Austin Comm. College | Austin | 512-223-7525 | www.austincc.edu |
| | ImagineSolar | Austin | 512-443-5725 | www.imaginesolar.com |
| | Houston Comm. College | Houston | 713-718-5253 | www.hccs.edu |
| | Ontility Energy Solutions | Houston | 877-558-7479 | www.ontility.com |
| | Alamo Colleges, St. Philips College | San Antonio | 210-486-2499 | www.alamo.edu/spc/acad/dest |
| | Texas State Tech. College Waco | Waco | 254-867-3206 | www.waco.tstc.edu/epc |
| UT | Salt Lake Comm. College | Sandy | 801-957-5252 | www.slcc.edu/continuinged/solar.asp |
| VT | NorthWoods Stewardship Ctr. | E. Charleston | 802-723-6551 | www.northwoodscenter.org |
| | Green Mountain College | Poultney | 802-287-8030 | www.greenmtn.edu |
| | Vermont Tech. College | Randolph Center | 800-728-1783 | www.vtc.edu |
| WA | Edmonds Comm. College | Lynwood | 425-640-1509 | www.edcc.edu |
| | Shoreline Comm. College | Shoreline | 206-396-8446 | www.northwestsolarcenter.org |
| WI | Lakeshore Tech. College | Cleveland | 920-693-1238 | www.gotoltc.edu |
| | Midwest RE Association | Custer | 715-592-6595 | www.the-mrea.org |
| | Northeast Wisconsin Tech. College | Green Bay | 920-498-6908 | www.nwtc.edu |
| | Madison Area Tech. College | Madison | 608-246-6800 | www.ceret.us |
| | Milwaukee Comm. Service Corps | Milwaukee | 414-372-9020 | www.milwaukeecommunityservicecorps.org |
| | Mid-State Tech. College | Wisconsin Rapids | 715-422-5428 | www.mstc.edu |

| Type | Years in Place | SHW | ISPQ Accred. | ISPQ Cert. Trainers | NABCEP Certified Installers | NABCEP Entry-Level Exam | Online Courses | Hands-On Courses | College Credit | Cred./ Degrees Offered |
|---|---|---|---|---|---|---|---|---|---|---|
| Other | 10 | ✓ | | 2 | 3 | | ✓ | ✓ | | |
| Univ. or college | 9 | | ✓ | 2 | 2 | ✓ | | ✓ | | |
| Comm. college | — | — | | — | — | ✓ | — | ✓ | — | |
| Comm. college | — | — | | — | — | — | — | — | — | |
| Other | — | — | | | — | — | — | — | — | |
| Other | 5 | ✓ | | 2 (pend.) | 2 | ✓ | | ✓ | | |
| Comm. college | 2 | ✓ | | | | ✓ | | ✓ | ✓ | |
| Comm. college | < 1 | ✓ | | | | ✓ | | ✓ | | |
| Univ. or college | 6 | | | 1 | 1 | ✓ | | ✓ | | BS |
| Comm. college | 6 | | ✓ | 3 | 1 | ✓ | | ✓ | ✓ | Cert. |
| Univ. or college | 3 | | | | 1 | ✓ | | ✓ | | |
| Comm. college | < 1 | ✓ | | | | ✓ | | ✓ | | Cert., AAS |
| Univ. or college | 2 | ✓ | | | | | | limited | ✓ | MSE |
| Comm. college | < 1 | | | | | ✓ | | ✓ | ✓ | Cert., AAS |
| Comm. college | 2 | | | | 1 | ✓ | Pend. | ✓ | ✓ | Cert., AAS |
| Comm. college | 5 | ✓ | | | 1 | ✓ | | ✓ | | AA pend. |
| Univ. or college | — | — | | — | — | ✓ | — | ✓ | — | AAS |
| Other | — | — | | — | — | ✓ | — | ✓ | — | |
| Other | 1 | | | | | ✓ | | | | |
| Univ. or college | 23 | | | | | | | ✓ | ✓ | BS+ |
| Comm. college | 1 | ✓ | | 1 | 1 | ✓ | | | | Cert. pend. |
| Comm. college | 6 | ✓ | ✓ | 1 | 1 | ✓ | | ✓ | | AAS |
| Univ. or college | 5 | ✓ | | | | | ✓ | ✓ | ✓ | BS |
| Comm. college | 1 | | | | | | | | ✓ | Cert., AAS |
| Comm. college | < 1 | | | | | ✓ | | ✓ | ✓ | AAS |
| Comm. college | < 1 | | | | 1 | ✓ | | ✓ | ✓ | AA pend. |
| RE training ctr. | — | — | | — | — | — | — | — | — | |
| RE training ctr. | 2 | ✓ | ✓ | | 1 | ✓ | | ✓ | | |
| Comm. college | — | — | | — | — | — | — | — | — | |
| Univ. or college | — | — | | — | — | ✓ | — | ✓ | — | |
| Univ. or college | < 1 | ✓ | | | | ✓ | | ✓ | ✓ | AAS |
| Comm. college | 5 | ✓ | | | 1 | ✓ | | ✓ | ✓ | Cert., AAS |
| Comm. college | < 1 | ✓ | | | | ✓ | ✓ | ✓ | | |
| Other | < 1 | ✓ | | | | ✓ | | ✓ | ✓ | |
| Comm. college | — | — | ✓ | — | — | ✓ | — | — | — | |
| RE training ctr. | 7 | ✓ | | 1 | 3 | | ✓ | ✓ | | |
| Comm. college | — | — | | — | — | — | — | — | — | |
| Other | 1 | ✓ | ✓ | | | ✓ | ✓ | ✓ | | |
| Comm. college | 1 | ✓ | | | | ✓ | | ✓ | ✓ | AAS |
| Comm. college | < 1 | ✓ | | | | ✓ | | ✓ | ✓ | Cert., AAS |
| Comm. college | 2 | | | | 2 | ✓ | | ✓ | ✓ | AAS |
| RE training ctr. | 2 | | | | 2 | | | ✓ | | |
| Univ. or college | 2 | ✓ | | | | | | ✓ | ✓ | Cert., BS |
| Univ. or college | 2 | ✓ | | | | Pend. | | ✓ | ✓ | BS |
| Comm. college | < 1 | ✓ | | | | | ✓ | | ✓ | AA |
| Comm. college | 3 | ✓ | | | | ✓ | | ✓ | ✓ | Cert. |
| Vocational | < 1 | | | | 1 | Pend. | | ✓ | ✓ | AAS |
| RE training ctr. | 1 | ✓ | ✓ | 3 (8 pend.) | 13 | ✓ | | ✓ | ✓ | |
| Comm. college | 2 | Pend. | | | 2 | ✓ | ✓ | ✓ | ✓ | Cert., AA |
| Comm. college | 3 | ✓ | | 9 via SEI | 22 via SEI | | Via SEI | ✓ | ✓ | Cert. |
| Other | < 1 | | | | | ✓ | | ✓ | | |
| Comm. college | 2 | ✓ | | | 1 | ✓ | ✓ | ✓ | ✓ | AA |

Required or not, an apprenticeship program can be a great way to get the hands-on training and education you need. From day one, you earn a paycheck, and depending on the employer or program, you can earn college credit toward an associate's or bachelor's degree—in some cases, your employer may even reimburse you for all or part of your tuition fees.

Many states operate an apprenticeship and training division to assist with the process, and the U.S. Department of Labor recently launched its Office of Apprenticeship to help connect individuals with government-approved apprenticeships. Since state regulations and training opportunities vary, it is best to contact your state's licensing board to find approved apprenticeship programs in your area. If you plan to pursue NABCEP certification down the line, you will also want to confirm that the apprenticeship program meets the program's experience and education eligibility requirements.

Both union and non-union training centers sponsor apprenticeship opportunities. The National Joint Apprenticeship and Training Committee (NJATC), a collaboration between the International Brotherhood of Electrical Workers and the National Electrical Contractors Association, has become very active in PV education and training. (Note: Many individual JATC training centers, which were too numerous to list in the table, offer solar training for electricians.) Local chapters of the Associated Builders and Contractors association and the Independent Electrical Contractors Association might have leads. Individual plumbing, HVAC, and electrical contracting companies may also operate apprenticeship programs.

## Choosing an Installer Training Program

Before selecting a program, ask plenty of questions to ensure that the program you choose is reputable and the right one for you.

**Get Student References.** Don't just read "canned" testimonials. Ask the program for a few local contacts who went through the program, and ask around for others to get all sides of the story.

**Investigate the Training Center.** What organization or individual administers the program and what are their qualifications? Is the institution respected and known by the leading industry groups, such as the American Solar Energy Society or Solar Energy Industries Association? Is the program accredited by the IREC's ISPQ? How many of the instructors on staff are NABCEP-certified installers or ISPQ-certified trainers? (See the "Quality Control & RE Education" sidebar.)

**Scope Out the Facility.** When possible, visit the training facility to see if the latest equipment is being used and that the site is well-maintained. Disorder can indicate safety issues and disregard for regulations. Are there procedures that ensure safety and safe practices? For installation and design courses, does the facility have a roof or building to work with? The more realistic the setting, the more valuable the training.

**Look Into the Course Content.** What does the training program promise to prepare you for? Do the leading industry groups recognize the legitimacy of the specific training or certification? What skills will you have upon completing the program or course? How long has the institution offered the specific training? Is the course preparing you to pass a test, or is it training you to do a job properly? How many students are in each course? How much hands-on time do you get with projects and equipment?

**Ask for Credentials.** Who is the course instructor, and what are their qualifications? Find out exactly who teaches the specific course, and don't hesitate to ask for résumés and/or biographies. How many years has the instructor worked in the field and in what capacity? How many systems have they installed? What types of systems have they installed? Is the instructor NABCEP- or ISPQ-certified? The best instructors are those with extensive field experience—they've designed

## The Higher Education Exception

The trade-off for college credit is that you may not find a program with IREC ISPQ accreditation. Many postsecondary institutions (i.e. community colleges, universities, trade/vocational schools, institutes of technology) have not sought IREC ISPQ accreditation. Instead, most higher education institutions and programs seek accreditation by an accrediting agency or state approval agency recognized by the U.S. Secretary of Education as a "reliable authority as to the quality of postsecondary education." In the absence of IREC ISPQ accreditation, the next best way to evaluate a postsecondary program is to look at the instructors' credentials, internship opportunities, and hands-on component of the curriculum. Some postsecondary professors or instructors may be NABCEP-certified installers or IREC-independent master trainers, but that's generally the exception rather than the rule.

**On-site, hands-on training can be the most valuable kind, putting your book learning to the test.**

Courtesy www.sanjuancollege.edu

## Quality Control & RE Education

The Interstate Renewable Energy Council (IREC) became the North American licensee for the Institute for Sustainable Power Quality (ISPQ), which serves as one venue for RE education quality control. ISPQ develops guidelines and standards for comparing the "content, quality, and resources" of RE training programs. Their International Standard 01022 establishes standards and metrics to accredit and certify training programs and instructors. As of January 2010, 25 programs are accredited, and there are 10 certified master trainers and 17 certified instructors.

The IREC awards formal recognition for five ISPQ designations: Accreditation for Training Programs, Accreditation for Continuing Education Providers, Certification for Independent Master Trainers, Certification for Affiliated Master Trainers, and Certification for Instructors. Each candidate must undergo a comprehensive audit, which may take up to one year to complete, and supplemental documentation or an on-site visit is required. After initially achieving ISPQ status, certificate holders are reviewed annually during the five-year award cycle and must pay annual fees.

Another quality-control organization is the North American Board of Certified Energy Practitioners (NABCEP). This volunteer board is comprised of RE stakeholder representatives who have developed and implemented nationally recognized credential and certification programs, including voluntary certifications for professional PV and solar thermal installers, and will soon include wind installers. These certifications are in accordance with standards set forth by the National Organization for Competency Assurance and the International Organization for Standardization, as well as in compliance with the *National Electrical Code.* NABCEP's credential is widely recognized as a good measure of professionalism and is required by some jurisdictions to work as an installer. There are more than 1,000 NABCEP-certified PV and solar thermal installers. More than 3,000 individuals have passed the NABCEP entry-level PV exam (see "Certificate vs. Certification" sidebar on page 39).

When you're shopping for installer training programs, first consider those that have both ISPQ accreditation with ISPQ-certified trainers, and/or NABCEP-certified installers. These instructors should be well-versed in industry safety and quality practices, and pursuing the continuing education necessary to maintain certification.

and installed systems for many years, made mistakes along the way (and learned from them), and can explain these concepts in a classroom.

**Consider Local & State Requirements.** Talk to your local inspections office, Secretary of State's office, solar energy association, and utility about the local, regional, and state regulations for PV and solar hot water systems. Are there any license or certification requirements in your local jurisdiction?

## Job Hunting Resources

Once you have the training you need, the next step is to find a job. Here are a few places to start your search:

**Green Job Expos.** These popular events are being hosted all around the country. A quick Web search will yield nearby events.

**RE Employment Web Sites.** Post your résumé and search job boards at the following sites:

- American Solar Energy Society: www.ases.org
- Green Jobs: www.greenjobs.com
- *Home Power's* job listings: www.homepower.com/resources/jobs/
- Renewable Energy World: www.renewableenergyworld.com
- Solar Energy Industry Association: www.seia.org
- *Solar Pro*: www.solarprofessional.com

What education or credentials do you need to work legally and qualify for grant programs and incentives? Do you need an electrical or plumbing license, apprenticeship time, NABCEP certification, or any other specific education?

**Be Patient.** Solar professionals are responsible for people's investments and safety—an improperly wired PV system or shoddy workmanship can be a hazard to utility workers, homeowners, and others. Don't just take the first-available seat in any course—be prepared to wait for an opening in a top-notch program. Use the time wisely to update your résumé, work on your business plan, get some advance education, or read up on industry advancements.

## Access

**David Del Vecchio** (david@solarvillage.com) is a mechanical engineer who has been installing PV systems since 1998. A graduate of the Georgia Institute of Technology and a NABCEP-certified PV installer, he owns Solar Seed, a North Carolina consulting and design company. Del Vecchio teaches PV courses for the NC Solar Center, Solar Energy International, and a local community college.

Resources:

American Solar Energy Society • www.ases.org

Institute for Sustainable Power Quality • www.ispq-central.com.

Interstate Renewable Energy Council • www.irecusa.org

North American Board of Certified Energy Practitioners • www.nabcep.org

Solar Energy Industry Associations • www.seia.org

# MICROINVERTERS
## Make a Simple DIY Installation

**by Guy Marsden**

My wife Rebekah and I have always wanted to live a PV-powered life, but the high price of the technology—an estimated $30,000 to cover all our electricity needs—had always been outside of our budget. Then came microinverter technology, which would allow us to start small and easily expand our system in the future. That, low mortgage rates, a drop in PV module prices, and the 30% federal solar tax credit sealed the deal.

Guy Marsden

I'm an active member of the Midcoast Green Collaborative, a local volunteer organization committed to creating a sustainable economy in coastal Maine. In 2009, one of our goals was to get feed-in tariff legislation passed. The proposed law was modeled on the successful German feed-in tariff law, which levies a small fee—usually $1 or so—on every electric ratepayer's bill. The utility uses these funds to pay a premium per kWh to small-scale renewable energy generators. This helps make it cost-effective for homeowners to finance installing a PV or wind-electric system, since the income typically covers the loan payments. Once the loan is paid off—typically in 20 years—you're set up to become a profitable electric micro-utility!

I testified at a hearing before the Maine Utilities and Energy Committee, where I presented a spreadsheet showing how the financing would work with a 20-year, low interest loan and a 20-year generation contract with Central Maine Power (CMP)—our local utility. I showed that a payment from CMP of 50 cents per kWh would significantly incentivize small-scale residential solar generators.

Testifying led me to do more research on the cost and feasibility of installing my own grid-tied PV system. My first call was to my friend Naoto Inoue, the owner of Solar Market, a solar dealer and installer in Maine. He helped me design the solar heating system for my workshop back in 2001 (see "Solar Heat for My Maine Workshop" in *HP89* and "Solar Heat Upgrade: Expanding & Improving an Owner-Installed System" in *HP119*) and sold me much of the equipment. He mentioned an emerging technology—microinverters—that was changing the paradigm of PV installations. Instead of the modules being wired together to create high-voltage DC that is sent to a large, single inverter, each module is equipped with its own small inverter. The power is converted to 240 VAC right at the module, which can make the system more efficient and the design more flexible. It eliminates the shading issues

Courtesy Terrill Waldman

Guy Marsden

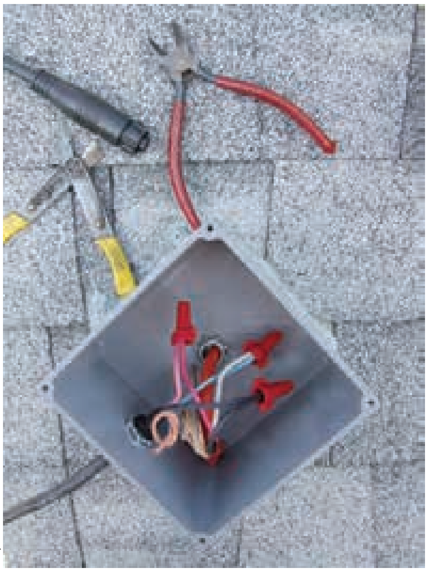
**Above: The rails, installed and ready to receive the microinverters.**

**Inset: A detail of a rail, showing the module clip and grounding system.**

**Wiring a PV module to one of the 21 Enphase microinverters.**

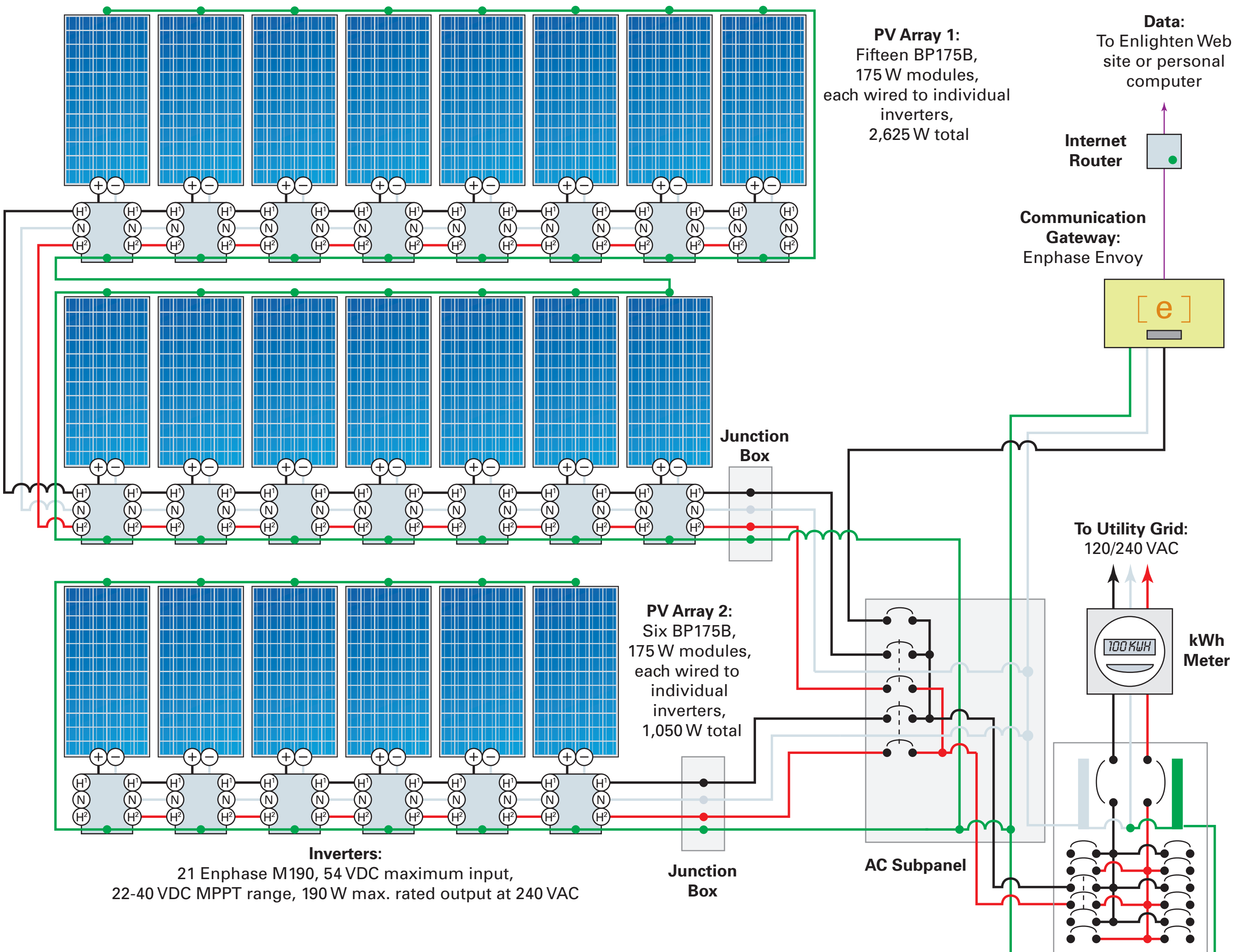
Courtesy Rebekah Younger

**One of two strings of AC connections, connected in a junction box to wiring that goes to a subpanel with the two arrays' breakers.**



Guy Marsden

## MARSDEN BATTERYLESS GRID-TIED PV SYSTEM




**Note:** All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified. WEEB grounding clips were used between modules and rails; the only ground wire is between the rails and from the rails to ground rod.

that can compromise the performance of DC systems when modules are wired in series, since shading part of one module in the series can compromise the whole string. Also, modules of different capacities can be mixed, allowing system growth over time without worrying about module mismatch.

### Designing the System

Typically, the first step in designing a PV system is to know how much power you use—or will use. But before that, to reduce your system costs, most people need to work at reducing their usage. Rebekah and I had reduced our energy footprint, both with conservation practices and efficient lighting and appliances. Our past 12 months of electric bills showed an average use of 550 kWh per month. To compare, in 2006, the average U.S. household used 880 kWh per month. Take a look at your recent electric bills and see how your home stacks up—there may be room for improvement! We use propane for cooking; propane, solar, and woodstoves for space heating; and propane and solar for water heating, so our electricity use was mostly for appliances and electronics.

Producing 550 kWh as a design ideal was the starting point. PV systems are usually rated by the total kW capacity of the modules—not the AC power produced. Energy losses come from inverting the DC to AC, wire heating, module soiling and mismatch, and other losses like module production tolerances; so a derate factor—typically 0.77—is applied by sizing tools like PVWatts (see Access). This derate and module temperature losses are used to estimate the AC kWh of a given solar array. However, the Enphase microinverters I planned to use have an efficiency of 0.95 (vs. 0.92 assumed by PVWatts) and will circumvent module mismatch issues. When incorporated into the calculation, the derate factor was 0.81—a significant improvement over 0.77!

## Installing Microinverters

The M190 Enphase microinverters were in high demand and short supply, and my vision of a "barn-raising" installation—with half a dozen friends, taking a day or so to finish—turned into a piecemeal approach while I waited for the inverters to arrive.

I began at the bottom right of the lowest rack, wired the female cable end into the roof-mounted junction box, and then mounted the first inverter. I had planned to daisy-chain the AC cables up three rows, left one module, and then down three rows until I had placed all 15 microinverters. But when I installed the second inverter in the row above the first, I found that the AC cable built into the inverter was not long enough. Oops.

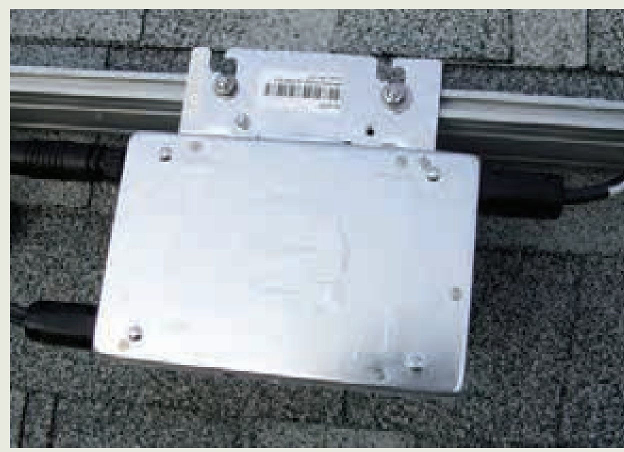
I called Enphase tech support and asked the technician to look at my blog posting photos so he could see the racking layout and understand my problem. He immediately offered to send me some 6-foot-long extension cables—free. I asked for four cables, anticipating changing the wiring sequence to start at bottom right, go left for five modules, then up one module, right five modules, then up one, then left five. Using this approach, I would only need to go up twice per block of inverters. Enphase later lengthened the cables an additional 8 inches to address this issue.

Enphase's earlier model M175 had AC cables with male and female ends; my M190 microinverters have a male cable and a female connector built into the unit. I think the two-cable design was better as it allowed more flexibility in installation.

I mounted the inverters with an extra-large washer, regular washer, lock washer, and nut over the right mounting slot. The large washer covers the WEEB grounding washer between the inverter flange and the mounting rail to ensure it gets even pressure. I used a torque wrench to tighten the nuts to 10 foot-pounds, per the Wiley Electronics' documentation for Iron Ridge mounting rails.

Enphase provides a chart that you use to indicate which inverter goes where so that their Enlighten Web interface can locate them. I removed one of the two bar-coded serial numbers that are stuck to each unit and stuck it onto the chart in the correct placement. This chart gets faxed to Enphase so that they can build the Web data page and validate the installation.

**Enphase microinverters bolt easily to the PV mounting rails. They must be mounted under the modules to prevent interference with the module frame and mounting clips.**



PVWatts further calculates the array performance based on system location, power rating, tilt, and orientation. I decided to use 21, 175 W BP 175B modules for a 3,675 W array. Our derate factor and our array's westerly orientation showed an annual production of about 3,600 kWh. PVWatts also showed the array's estimated average monthly production at 300 kWh, 250 kWh less than our average consumption, and 150 kWh less than our consumption that is billed at a higher rate. The way we are billed, the first 100 kWh is provided at a lower rate (about 12 vs. 18 cents), so there is less incentive to offset that first 100 kWh.

Guy Marsden (2)

**PV system AC subpanel, housing two double-pole 15 A breakers, which act as the PV system's disconnects. A single 15 A breaker is wired to the required AC outlet to power the Envoy communications gateway.**


**Guy uses a torque wrench to tighten the bolts on the module hold-down clips. Also note the spacing block that ensures a quarter-inch gap.**

Part of the original impetus to install our own PV system came from my experience of watching proposed feed-in-tariff legislation get strangled to death by well-intentioned members of the Maine Utilities and Energy committee. I testified and then spent many long afternoons in the committee room observing the deliberations. The bill passed, but it had no teeth—the payout was based on historic high wholesale prices and no tariff, thus zero incentives.

In the process of preparing my testimony for the committee, I began to realize that Maine's net metering law could provide at least some benefits to make the PV system more affordable. I estimated that if we were to install a system that generated all the electricity that we typically use, our annual bill would be reduced to the minimum connection fee—about $8.00 per month. It was actually financially prudent to slightly undersize the system, so that we would not be giving away any surplus. Annual system energy production values are often conservatively estimated and the system may exceed initial estimates. Under Maine's annualized net-metering agreement, the utility does not pay for a surplus at the end of the year, but only credits the excess power generated in any given month.

## Budgeting for the System

The federal tax credit allowed us to deduct 30% of the cost of the system from our federal taxes. We would have normally set funds aside on a weekly basis to pay quarterly estimates, and by avoiding having to pay them in 2009, we saw an immediate reduction in expenses. This year, we will avoid paying nearly $6,000 in taxes. We also took advantage of the Maine Public Utilities Commission's Efficiency Maine program, which offers a solar rebate that pays $2 per watt for the first 1,000 W (capped at $2,000).

To pay for the system, we refinanced our house. We had an adjustable rate mortgage that could adjust up this year, and we figured that it was a good time to lock in a 20-year fixed mortgage. To keep the money in the local economy, we found a mortgage with a local bank. I watched the economic indicators and changing mortgage rates carefully and then locked in a low loan rate in late April 2009.

We originally budgeted $26,000 for a slightly larger system that would fill the workshop roof, but decided to scale back to 21 modules, saving about $5,000. We tacked on the system cost (about $21,000) to the new mortgage for an attractive rate that was better than an equity loan or line of credit. We also explored the option of MaineHousing's Home Energy Loan Program. They limit their loans to 15 years and $30,000, but despite a better interest rate, the monthly payment would have been about the same as the new mortgage. Also, our loan officer advised us that the paperwork for these loans is significant and there are a lot of restrictions that could have precluded installing the array myself.

Over the 20-year loan term, the added expense of the PV system would translate to about $180 per month. When we account for the fact that our electric bill will drop about $60—from an average of $100 per month to about $40 per month—I estimated that our monthly mortgage would only increase by an average of $120. This was not an undue burden.

I am still hopeful that Maine will adopt a substantial feed-in tariff law, which would help pay for our PV system. In fact, if the law did offer a substantial incentive, we would probably fill both the workshop roof and the house's east-facing roof with PV modules since we would likely make a small profit from selling the energy. This is the central premise of the feed-in tariff plan—to encourage renewable energy generators by making systems affordable and even profitable.

## Solving Site Issues

While we have lots of roof space on the house and workshop, no roof faces south. To mount the solar thermal collectors used to heat my workshop, I constructed a small addition. For our PV system, I originally envisioned mounting the modules on a two-axis tracking array. But its size—about 10 by 20 feet—would have made it a giant eyesore in our garden.

A tracking array keeps the modules faced directly at the sun, increasing performance by 25% to 40%. But Naoto advised me against that decision, because he was worried that a large array's motors might not hold up well under heavy wind and snow loads.

After weighing all our options, we decided to cover the entire west-facing roof with modules. This setup would avoid shading from trees and other obstructions. According to PVWatts, the system would produce about 1,300 fewer kWh per year than a true south orientation, but would be more straightforward to install and be less obtrusive visually.

But then there was the condition of the roof—shingles were curling up at the corners, indicating that they were due for replacement. To ensure a long-lasting roof, I opted for thicker, more durable architectural shingles, which could be installed over the existing shingles, and selected a light gray color to decrease inside heat buildup in the summer.

## Getting Wired

As a DIY kind of guy, I chose to install the system myself, but relied on Naoto's considerable professional experience to specify the system components.

**Modules.** My PV module preference was based in part on their embodied energy, which includes the fuel consumed in shipping. My first choice was Evergreen, because they are made in Massachusetts—about a three-hour drive for me—but their modules weren't on the Enphase compatibility list. The BP Solar modules I purchased are made in Frederick, Maryland. So I voted with my dollars to support "locally" made modules. I did end up driving 60 miles to Solar Market to pick up the modules in my Ford Escape Hybrid, and it took two trips (at 30+ mpg) to get them all.

**Microinverters.** Until very recently, solar-electric modules in batteryless grid-tied systems were required to be wired in series strings to produce 150 to 600 VDC, then these strings were combined and fed into a central inverter. In 2008, Enphase microinverters hit the residential PV market. Each module/inverter pairing operates independently, eliminating most shading performance issues.

So instead of a single central inverter, I used 21 small ones. Each inverter reports its performance to an Envoy communications gateway via the AC wiring, then the gateway sends data to a Web site to track performance for each module/inverter pair.

The AC wiring from the particular model of microinverter I selected can parallel up to 15 units. They plug into each other like extension cords. Since we have 21 units installed, we ended up with two AC circuits that are fed into a subpanel (through two 15 A breakers) and then to the building's main load center, where it backfeeds a 30 A breaker.

## Real-World Performance

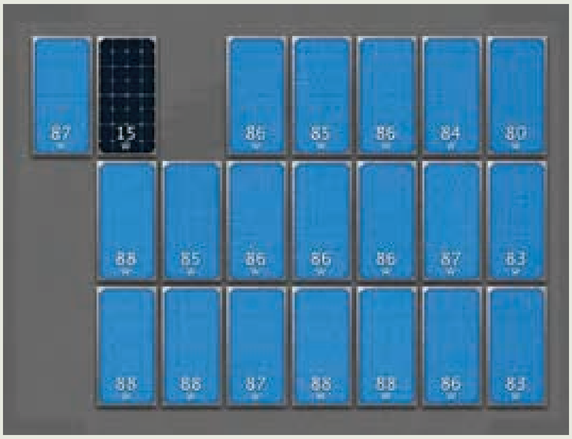
A Central Maine Power (CMP) utility crew came out to replace our single kWh meter with a double unit that allows for two readings: energy delivered by them and energy exported by our PV array. Only one meter spins at a time, indicating which way the current is flowing. As we watched, one meter would stop and the other would start as loads changed in the house. This was in the morning before the modules reached full power on a sunny August day; later, the export meter spun rapidly.

The double meter serves two main functions. First, it tells CMP how much energy I am putting into the grid, which they report to state agencies as part of the state's mandated 30% renewable energy portfolio. Second, it ensures I'm credited for every kWh that my system exports—at the full retail premium rate of 18 cents per kWh that I pay for green-sourced energy. CMP's computers do not have the capacity for crediting back to small residential producers like me, so the billing has to be hand-processed each month and both meters read by a CMP employee.

### Automated Troubleshooting

Thanks to the Enlighten feature that allows the user to review the PV module energy statistics graphically, I was alerted that my solar attic fan was causing a shading issue on one of the modules for more than an hour in the late morning.

The solution was obvious: I just had to climb up and lower the module on the attic fan to reduce the shading. Now the vent module is oriented toward the sun in the late afternoon rather than midday, but that is when the heat is highest in the attic, anyway.

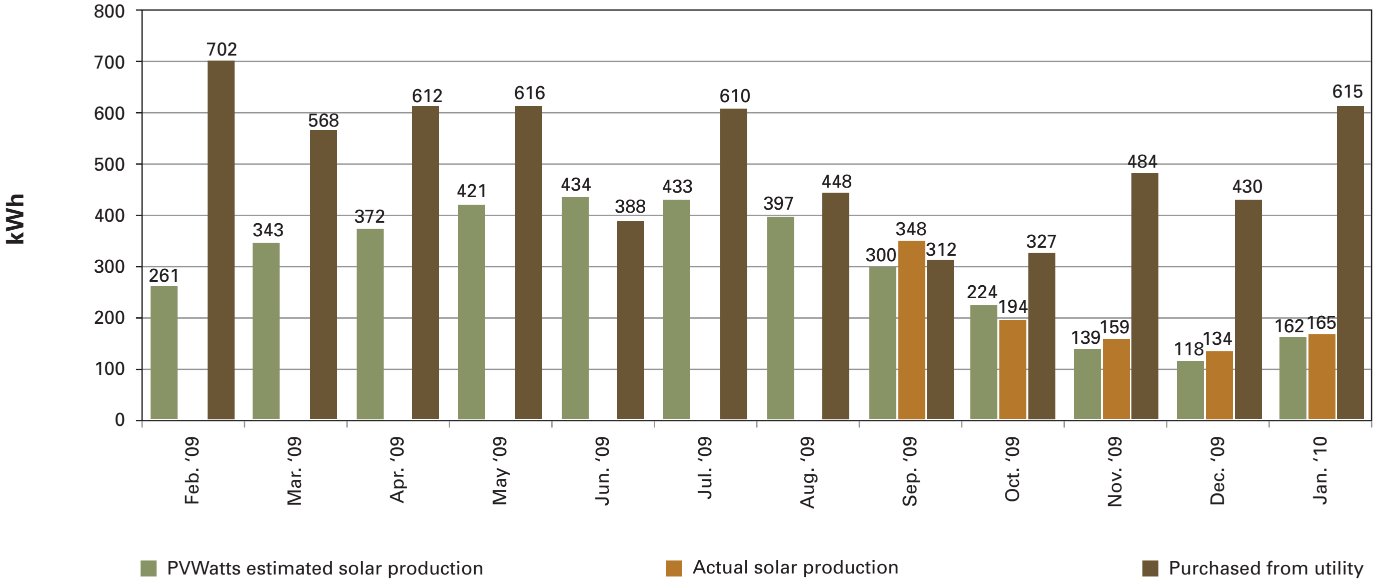



**The Enlighten software shows the shaded module producing only 15 watts.**

Courtesy Rebekah Younger

**Adjusting the small PV module on the attic fan helped reduce shading on an adjacent module.**

## Estimated PV, Actual PV & Utility-Supplied Energy




The graph above compares the energy that our PV system should generate based on PVWatts calculations with the actual energy produced, obtained from monthly reports provided by the Enphase Enlighten Web interface. The system design goal was to generate a slight surplus in June and July and generate about 25% of our needs in the middle of winter. With the various inefficiencies accounted for, our 3,675 W rated system actually has a peak power closer to 3,130 W.

Due to our business use of energy-intensive power tools and lighting, our usage varies, but on average, we use between 15 and 21 kWh a day. If we were to eliminate our business loads, our daily average would likely drop to below 13 kWh per day. Note that, in June, when Rebekah was out of town for three weeks, our consumption dropped significantly, since her business use of a 1,500 W clothing steamer, sump pump, and well pump draws were reduced. Since the system's commission in September 2009, it has usually outproduced the original PVWatts estimates and met about 55% of our annual average electricity needs.

**An Enphase Enlighten graph showing the system's total power output on January 9, 2010.**

Overall, the Enphase inverter-based system is quite simple to install—it's pretty much "plug and play." The Enphase staff is very helpful, friendly, and supportive. And I am delighted with the Enlighten Web reporting system, which costs me $2 per inverter per year. I check the performance daily and have posted the near real-time data to my Web site. While my array site did not have shading issues that would have made the Enphase inverters particularly valuable, the Enlighten stats do help identify snow-clearing issues.

## Access

**Guy Marsden** (guy@arttec.net) is a self-employed engineer who designs electronic products for a living. He owns ART•TEC LLC, manufacturing solar-powered differential temperature controllers for solar thermal applications in his solar-powered and solar-heated workshop. He also gives public talks on sustainability, and makes wood furniture and electronic art.

**Resources:**

Enphase Energy • www.enphaseenergy.com

PVWatts • www.nrel.gov/rredc/pvwatts

Solar Market • www.solarmarket.com

Wiley Electronics • www.we-llc.com/WEEB.html

Guy's installation blog (with real-time stats) • www.arttec.net/SolarPower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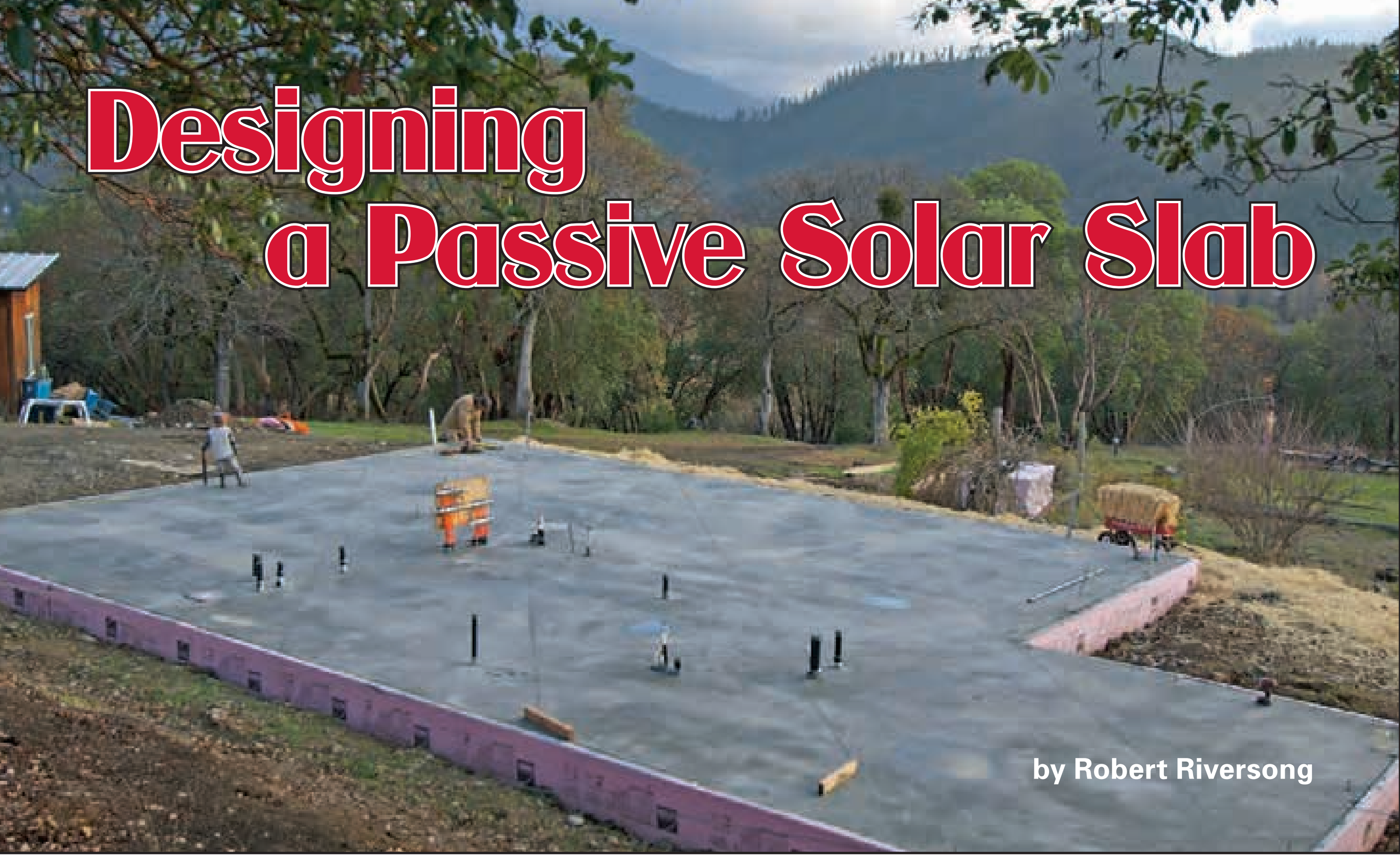


# Designing a Passive Solar Slab

by Robert Riversong

All photos courtesy Robert Riversong, except above: Claire Anderson.

A passive solar home requires five elements to take full advantage of the sun's free heat: apertures to let in the sun's warming rays; a means of preventing too much solar gain in the summer; an absorber surface that minimizes reflection; thermal mass to store the heat until it's needed; and a distribution system to move the heat to where it's required.

For a truly passive house, each of these elements should operate without mechanical power or occupant intervention. As examples, summer solar gain is handled by properly designed overhangs. The distribution system would be natural convection within an open floor plan, with storage and release handled by concrete—a massive and dense material with high specific heat (heat storage capacity per unit volume) and moderate thermal diffusivity (the propensity of heat to dissipate to all areas of the mass).

## Focus on the Slab

Perhaps the least-understood elements of passive solar design, and the ones that plagued the early passive solar pioneers in the 1970s, are the ratios of south glass area to floor area and of south glass area to thermal mass. Without proper balance—and an appropriate absorber and mass storage—an otherwise well-designed house can be unlivable.

Too much glass can mean:

- overheating even in the dead of winter
- overchilling at night
- too little privacy
- too little usable wall space
- too much glare and shadow
- too little sense of enclosure and security

**This house has an 8.25% glazing-to-floor-area ratio on the first floor (with thermal mass).**

But without sufficient thermal mass, even the proper glass-to-floor ratio can lead to daily or even hourly temperature swings and heat stratification that can make a home uncomfortable. The south-facing glazing design standard for today's passive solar homes is a window area between 7% and 12% of floor area. (For example, a 1,000-square-foot space would have between 70 and 120 square feet of south glazing.) That ratio can apply to the entire house if all stories are to be passive solar designed, or just to the primary living floor. It's often more appropriate to design a bedroom floor to be sun-tempered, with south glazing of 5% to 7% of the floor area, which doesn't require any additional thermal mass beyond normal building materials and has the benefit of providing more privacy. Beyond 12%, we enter the active solar range in which direct-gain thermal mass is not sufficient to maintain a uniform and comfortable indoor temperature without fans or pumps to move the heat to remote storage and retrieve it on demand.

## Thermal Mass & Foundation Fundamentals

The goal in designing a passive solar home's thermal mass is to be able to store midday solar heat until the early evening, when it will passively return to the living space. Thermal mass operates like a flywheel that dampens any sudden changes in acceleration or, in this case, changes in insolation—the amount of solar energy entering through the apertures—which would otherwise raise indoor air temperature.

Thermal mass is best as direct-gain, meaning in the direct path of the sun, and uniformly distributed throughout the living space. A thermal mass floor fits this need quite well, and the simplest and most cost-effective thermal mass floor is concrete slab-on-grade (meaning formed by pouring concrete within forms, either directly on the ground or with insulation between).

It's possible to pour a lightweight concrete slab on top of a wood-framed floor—if the structure has been designed to handle the extra weight—or use a tile or masonry floor finish. But to achieve the height of design elegance—using one element to serve multiple essential functions—combine the structural floor with the thermal mass, design it to be earth-coupled (taking advantage of geothermal heat) by placing the floor on a thermally protected mass of dry earth, and perhaps integrate a radiant floor heating system.

Doing this well requires designing the home literally from the ground up, integrating multiple systems, and understanding the engineering requirements of each step in the process. Every material choice and methodology decision must build toward an integrated system.

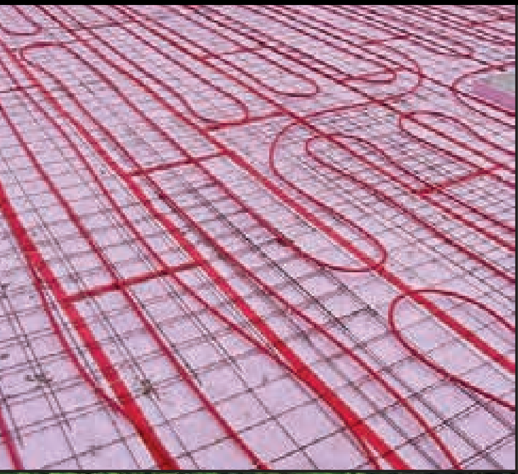
If the slab is also part of the foundation, then gravity loads and soil-bearing capacity, as well as foundation insulation, must be considered. While a monolithic slab—a floor slab with deeper-poured edges that act as footings—is popular in some areas, thermally decoupling the floor slab from the foundation is preferable because most heat loss from a slab is at the edges.

**Step 1: Frost-protected shallow (FPS) foundation with exterior and slab-edge insulation pre-installed.**

**Step 2: Adding the below-slab mechanicals.**

**Step 3: Leveling and compacting the subslab fill.**

**Step 4: With the vapor barrier installed, a layer of rigid foam insulation over it provides a thermal break from the earth.**



Step 5: Remesh or rebar placed over the rigid foam provides attachment points for PEX tubing.

Step 6: Pouring and distributing the concrete.

Step 7: The medium-brown integral color used to tint the concrete will help absorb solar radiation efficiently.

Step 8: Smoothing the slab's surface to its final texture.

## Other Important Elements

Solar builders have a wide array of "aperture" (window) options, and with sufficient demand, perhaps manufacturers will begin to offer the kind of highly insulating windows that also have high solar heat gain coefficients (SHGC, as listed on the National Fenestration Rating Council label on new units). Only some Canadian manufacturers and a few high-end custom window makers in the United States are selling windows that are appropriate for passive solar applications. (Unfortunately, the current federal tax credit program, in which consumers can subtract up to $1,500 from their federal tax liability for installing high-efficiency windows, excludes high solar heat gain windows from eligibility, since it calls for an SHGC of ≤ 0.30.)

Good building designers are beginning to understand the importance of overhangs, both for rain protection and for preventing summertime overheating in passive solar homes.

Many also appreciate the value of a south-side open floor plan, with private rooms, entries, and utility/storage spaces clustered along the north. An elongated east-west axis enhances a southern exposure that's oriented within 15° of true south to optimize solar availability.

A frost-protected shallow foundation (FPSF) often works well, at least in well-drained soils, and the reinforced concrete grade-beam becomes the building's foundation. In wetter areas, a rubble-trench foundation can be used. With this system, drainage is provided via a perimeter trench, dug below the frost line and drained to daylight at a lower elevation. The trench is then filled with clean mixed stone to grade. Then, a grade beam is poured at the surface, on top of the stone. A more conventional alternative would be a frost wall, though that requires three pours: footings, walls, and slab.

### Slab Details

The building foundation, whether grade-beam or frost wall on footings, needs to be sized to carry the design or code-specified live and dead loads, including snow loads, into the ground, and the ground has to be of sufficient load-bearing quality to receive them. Typical soils, with the exception of loose sand, soft clay, and sandy loam, will carry at least 2 tons per square foot. Though codes may mandate wide footings as a general practice, most two-story homes don't need more than an 8- to 10-inch-wide perimeter footing reinforced with 1/2-inch-diameter steel rebar. Don't forget to place additional steel-reinforced interior linear footings or pads under center bearing walls and point loads, like chimneys and posts.

Clean, granular gravel or sand fill is often required to bring the interior up to the level of the subslab insulation (as shown in the Step 3 photo on page 61), and that fill must be mechanically compacted in 6- to 8-inch lifts. But first, all subslab mechanicals must be carefully placed, since there is no way to move things once they are cast in concrete. This would include any first-floor fixture and floor drains, water lines, and underground electrical and other utilities. It's also wise practice to install a subslab radon vent in any new construction, since radon soil gas is found in all geographic areas of the United States and is carcinogenic. Then, a radon/vapor barrier must be placed on the compacted fill (I use tear-resistant 4-mil cross-laminated Tu-Tuf), and subslab insulation, leaving 4 inches for steel reinforcement (either 6-inch welded wire mesh or steel rebar) and concrete.

The amount of subslab insulation to use depends on the climate zone, the amount of exterior foundation insulation, and whether the slab will be part of a radiant heating system. 2009 International Energy Conservation Code (IECC) insulation standards for foundations are R-10 for zones 4 and 5, and R-15 for zones 6 and 7 (see map).

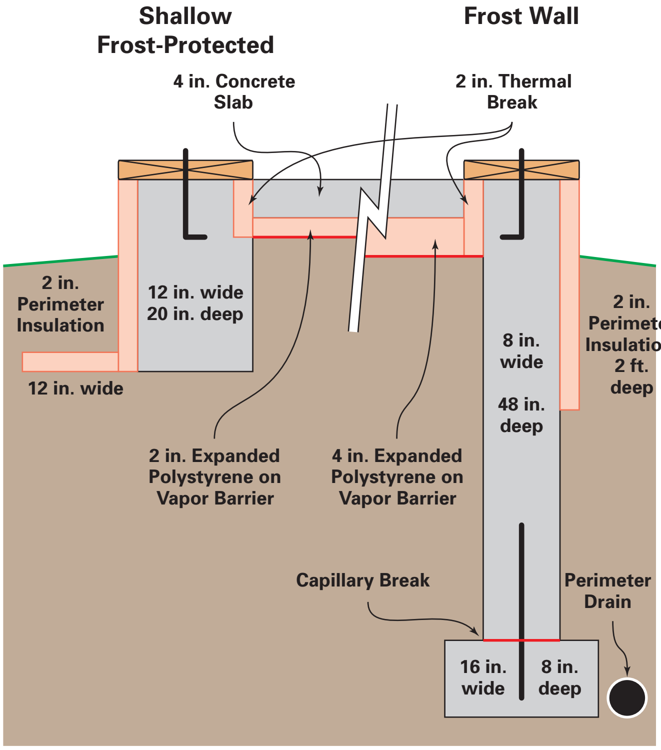
Extruded polystyrene (XPS, Styrofoam) is the industry standard for subgrade insulation because of its durability, compressive strength, low moisture absorption, dimensional stability, and high R-value (R-5 per inch). It is also highly resistant to acids and alkalis. For a heated slab, I recommend an additional R-5 beyond code minimums, except with a frost-protected shallow foundation, which relies on heat loss downward to maintain the earth temperature above freezing and which has an additional R-5 to R-10 exterior foundation and wing insulation. As important as subslab insulation is for a radiant or solar-heated slab, the greatest heat loss from a slab-on-grade occurs at the vertical edges—this is why I prefer to pour a slab separate from the foundation and isolate it with R-10 edge insulation.

Any foundation type, particularly a slab-on-grade, must also be hydraulically isolated from the ground with capillary breaks—a material that prevents the migration of moisture between the earth and the foundation, between the foundation and slab, and between the foundation and wood framing. The subslab vapor barrier and edge insulation serve this purpose, as does the sill seal and metal termite flashing installed on the grade beam before wooden sills. But few builders bother to include a capillary break between footings and foundation wall to prevent the wicking of water up the concrete, which has a theoretical capillary height of 6 miles! I prefer a brush-on latex masonry waterproofing such as UGL DryLock.

## Slabs with the Larsen Truss System

In climates with high heating loads, exterior wood-framed walls can be built 12 inches thick with a modified Larsen truss system to achieve highly insulated walls (R-40 or better). This system readily accommodates a 12-inch-wide grade beam, which includes 2 inches of exterior XPS foam and 2 inches of slab-edge insulation, which all gets covered by the wall.

## Foundation Options




Codes require that concrete used in residential construction have a minimum rated strength of 2,500 psi, which is the compressive strength it achieves after 28 days of curing. But since the mix tends to get extra water during pouring and because stronger concrete is also more waterproof, I order 3,500 psi mix for foundations and 4,000 psi mix for slabs. In addition to 6-inch welded wire-mesh reinforcement (which has a grid pattern that simplifies laying out and securing radiant tubing), I also specify short polyester fiber reinforcement in the slab mix. Steel reinforcement, whether a grid of rebar or welded wire mesh, offers tensile strength to resist cracking from settling or ground movement. The short fibers, invisible once the slab is power-troweled, help prevent the small shrinkage cracks that can occur if mix water is allowed to evaporate too quickly (or excess water is added on site). All concrete work should be covered by plastic or kept wet for three days to allow initial curing to occur, unless the concrete is colored. Covering or wetting can mottle the color, so it's better to apply a curing sealer which should meet the ASTM C1315 standard and be type 1 (clear), class A (non-yellowing), all-acrylic.

Dense materials, like concrete, which have a specific heat of 28 Btu per cubic foot per degree Fahrenheit (about half that of water), tend to allow heat diffusion at a rate of about 1 inch per hour. So the heat of the noontime sun will penetrate to the bottom of a 4-inch-thick slab by about 4 p.m. and all that heat will have returned to the interior by about 8 p.m.—making a

Step 9: Power-troweling the slab provides a smooth finish.

Step 10: Applying a curing sealer over the finished concrete will help protect the surface from stains.

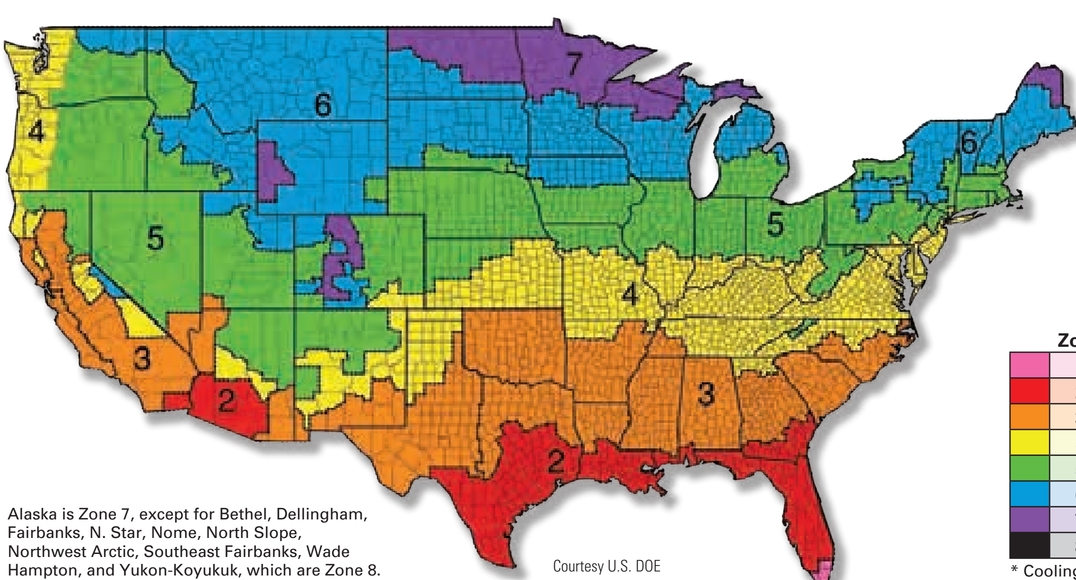
4-inch-thick slab ideal for solar thermal mass. This is called the "diurnal heat constant" and it shows a diminishing return with a slab thicker than 4 or 5 inches. (If the heat is moving in one direction only, such as in a Trombe wall, then 8 inches is ideal.)

## After the Pour

If the slab surface is to be the finished floor, then any of several dozen standard colors can be premixed at the batch plant for a small extra fee, and this saves the cost of additional finish materials and labor. Any solar absorber surface should have low specularity (somewhat matte-textured, not glossy) and a medium hue such as brick red or terra-cotta brown, which have solar absorptivity factors of 70% to 80%. Even untinted concrete has an absorptivity of 65%, which is within the acceptable range. A finished concrete floor also needs to be sealed to prevent water absorption and staining. The choices are surface coatings, which tend to create a sheen until worn in, and penetrating sealers made of siloxanes, silanes, or silicates. Siloxanes are the least volatile, penetrate well, can last for 10 years, and can be applied on a slightly damp substrate. Silicates, unlike the other two, have poor water repellency, poor water vapor permeability, and a shorter working life. A surface film or paint can be applied, but that has to wait until complete cure, which can take up to three months.

If a solar slab is to be fully or partially covered by other floor finishes, those coverings must have good solar absorptivity and a total R-value no greater than R-0.5. Tile or masonry works well, and a 3/8-inch, laminated, prefinished hardwood strip flooring can be installed without too much loss of the floor's thermal mass function. The wood alternative makes a concrete floor "softer" on the feet and offers a warmer feel to the house, but use material with a matte finish for low specular reflection and enough color for good solar absorption. The thin, laminated hardwood will be more stable than solid sawn lumber, which is important on a

## IECC Climate Zones




Alaska is Zone 7, except for Bethel, Dellingham, Fairbanks, N. Star, Nome, North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk, which are Zone 8.
Hawaii, Guam, Puerto Rico, and the Virgin Islands are Zone 1.

Courtesy U.S. DOE

| Zone | Thermal Criteria: CDD 50* | Thermal Criteria: HDD 65** |
|---|---|---|
| 1 | > 9000 | – |
| 2 | 6,300–9,000 | – |
| 3 | 4,500–6,300 | – |
| 4 | < 4,500 | < 5,400 |
| 5 | – | 5,400–7,200 |
| 6 | – | 7,200–9,000 |
| 7 | – | 9,000–12,600 |
| 8 | – | > 12,600 |

* Cooling Degree Days over 50°F
** Heating Degree Days under 65°F

floor that will be changing temperature. Throw rugs are OK if the total area is limited to 20% of the floor's area.

Because a house does not require additional thermal mass until the south glazing area exceeds 7% of floor area, a rule is to allow for 6 square feet of direct-gain, 4-inch-thick mass for each square foot of south glass beyond 7%. For example, a 1,000-square-foot house with 120 square feet of south glazing (12%—the maximum for passive solar) would require 300 square feet of slab floor available to the sun. That would be 60% of the south half of the house, or no more than 40% of the floor blocked by furniture and coverings.

If that small house was super-insulated as well, even in the cloudy Northeast it could get close to 50% of its annual heat requirement from the sun. For the small incremental cost of additional south windows and careful design, coupled with a highly efficient thermal envelope, the heating costs can be decreased by at least half, compared to a conventionally constructed home. Upgrading from energy-code standards to a super-insulated, passive solar home might add 5% to the construction costs of the home. But the energy savings more than offset the additional mortgage payment, so the payback occurs in the first month.

## Mixing Heating Strategies

If the passive solar design is complemented by a radiant heating system, then—sunshine or clouds—the floor will be warmer than room temperature. Human thermal comfort requires warm feet and cool heads. Most heating systems—particularly forced hot air—cause air-temperature stratification, with the ceiling warmer than the floor. This detracts from occupant comfort. A radiant floor increases the mean radiant temperature of the living space. What makes radiant floor heat more efficient is that the thermostat can be lowered a few degrees without any sacrifice in comfort. The average temperature-dependent infrared radiance of room surfaces has

## Solar Slab Fundamentals

Elements of a high-performance passive solar thermal mass slab:

**Must support structural loads and be supported by the ground**

- Perimeter frost wall, grade beam, or thickened edge for footings
- Interior linear or pad footings for load-bearing partitions or concentrated loads
- Well-compacted, mixed aggregate fill under slab

**Must contain all first-floor fixture and floor drains**

- Carefully planned and placed drain-waste-vent pipes
- Inside perimeter radon vent
- Other underground utilities, including wood heater combustion air supply

**Proper concrete mix, reinforcement, admixtures, colorants & sealants**

- Higher-strength concrete reduces the likelihood of surface or settling cracks
- Steel reinforcement (either rebar grid or welded wire mesh), placed 1 inch from bottom of pour
- Short-fiber polyester added to boost tensile strength and improve surface integrity
- Premixed colors for an easy finished floor
- Curing sealer applied after power-troweling to prevent dry-out and preserve color

**Good solar access**

- Sun sweeps across slab in fall, winter, and spring
- Windows are shaded with overhangs in summer
- Maximum slab area in direct sun during peak heating season
- Minimal insulating floor coverings or obstructions in areas of direct gain

**Proper balance of glass to mass**

- No additional mass required with 7% floor area in south glazing
- 6 feet$^2$ of direct-gain slab or 9 feet$^2$ of direct gain, thermal mass wall for every foot$^2$ of glass beyond 7%

**Good surface solar absorptivity**

- Medium-to-dark earth tones
- Matte or textured surface—not glossy, unless thermal mass is in wall

**Ample thermal storage material**

- Dense: concrete, tamped earth, or masonry
- High specific heat (heat capacity per unit volume)
- Moderate diffusivity (distributes heat internally, but not too quickly)
- Good infrared emissivity (ability to radiate heat)
- About 4 inches thick for floor, or 8 inches thick for free-standing wall
- Good diurnal heat capacity (ability to store and release heat in 24-hour cycle)

**Good environmental isolation**

- Insulated from ground below (but not too much for good earth-coupling)
- Well-insulated at slab edges (where most heat loss occurs)
- Protected from water & water vapor with air/vapor barrier
- Subslab radon venting to evacuate carcinogenic soil gas

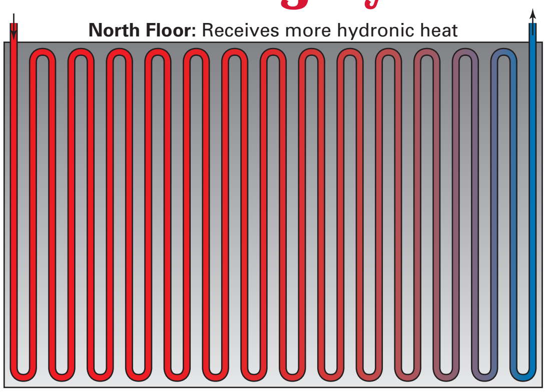
**Natural convection distribution**

- House designed with open floor plan
- If house has more than one story, central open stairway to move heat upstairs
- Perimeter floor grills for return flow (balanced with noise & privacy concerns)

**Appropriate maintenance**

- Re-seal (with siloxane) when floor begins to absorb water or stains

## Self-Regulating Hydronic Radiant Heating System




**The heat exchange rate between the tubing and slab is dependent on temperature difference ($\Delta$T). In the shaded north section of the slab, more $\Delta$T equals more heat exchange. In the sun-warmed section of the slab, less $\Delta$T equals less heat exchange. The result: When the sun shines, more of the hydronic heat is delivered to where it's needed.**

at least as much effect on comfort as air temperature. In other words, warm floors and walls are more important to occupant comfort than warm air. One thing to avoid with a high mass radiant floor, though, is a setback thermostat. There is too much thermal inertia, or lag time, to make changing the floor temperature a strategy for saving energy.

Some building experts discourage mixing passive solar with radiant floor technology since the lag time can make it more challenging to maintain uniform indoor temperatures—especially when the floor is warming from below and then the sun comes out. Even if the thermostat shuts off the radiant circulation, the heat already in the floor will continue to emerge, while the sun is also heating the space. However, this can be an asset. Since the sun is raising the slab temperature, there will be less heat exchange from the radiant tubing in the south half of the slab and more heat available to the north half, which doesn't have the benefit of receiving solar gain. This selective heat redistribution function would be most efficient if the radiant tubing was looped in a north-south orientation.

Throw in a wood heater with outside air for combustion, and the balancing act becomes more delicate. But the learning curve for occupants who have chosen this mix of heat inputs would be short, and the benefits should outweigh the liabilities. With or without supplemental radiant floor heat, a passive solar slab can be a cost-effective multiple-function element of a well-designed and energy-efficient home.

### Access

**Robert Riversong** (housewright@ponds-edge.net) is a master housewright with 30 years' experience designing and building passive solar, super-insulated homes. He teaches and consults on building technology, building science, and engineering.

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Magnum Energy 120VAC

Magnum MS4024 4000W/24VDC
ME-RC50 remote display
Surge arrestor on AC input & output
Surge arrestor on +/- PV input
MidNite Solar MNE250STM-L E-Pnl
Two 63 amp charge control breakers
FM60 or Classic 150 installed
(Classic 150 available 2nd quarter 2010)
2 bat temp sensors installed
Tested & crated

**Price $4925.00**

Options: FM80 or Classic200 or 250
DC-GFP for FM series (NR on Classic)

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Magnum MS4024-AE 120/240VAC or
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Surge arrestor on +/- PV input
MidNite Solar MNEXXXSTM-240-L E-PNL
Two 63 amp charge control breakers
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Options: FM80 or Classic200 or 250
DC-GFP for FM series (NR on Classic)

OutBack 120VAC

OutBack VFX3524 or VFX3648
Grid-tie or Off-grid
Mate remote display
Surge arrestor on AC input & output
Surge arrestor on +/- PV input
MidNite Solar MNEXXXSTS-L E-Pnl
Two 63 amp charge control breakers
FM60 or Classic 150 installed
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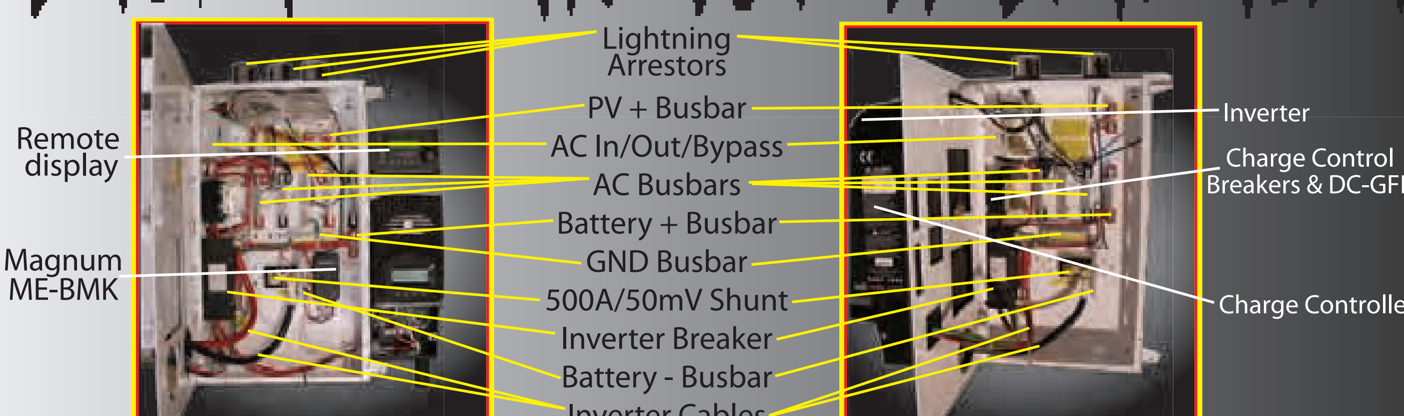
FM60 or Classic 150 installed
2 bat temp sensors installed
Tested & crated
Price: **$4999.00**

Options: FM80 or Classic200 or 250
DC-GFP for FM series (NR on Classic)




Magnum 240 AE E-Panel

OutBack Plus E-Panel

Note: The following Solar distributors have been manufacturing pre-wired MidNite systems for many years. They will continue to provide systems manufactured by themselves or MidNite. These distributors may be able to provide customization beyond the standard systems offered by MidNite solar.

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**17722 67th Ave NE Unit C, Arlington WA 98223**
**425-374-9060 www.midnitesolar.com**

# iPhone Apps for Solar Geeks

by Jeff Oldham


Ben Root

By bridging the division between communications and computing, Apple's iPhone has taken the mobile technology world by storm. It's a cell phone, but much more, offering PC-like functionality in a handheld package. So what does it have to offer solar enthusiasts and RE installers? A lot.

## Already On Board

The iPhone has taken smart phones to a level never before seen. For installers and solar geeks, this single device can replace a day-pack full of instruments and reference books. While it may look identical to the older 3G, the latest-generation 3GS features:

- Voice prompts, allowing hands-free access to calling and most features of the music player.
- A sensitive digital compass that retains accuracy at various viewing angles (the only digital compass I'm aware of that can do this). When held up to look at or to trace the sky or object, the compass continues to function accurately, unlike other compasses that need to be held level.
- A video camera, which is great for recording site visits. I like to narrate as I shoot video and assess a potential RE site, pointing out issues.
- A 3-megapixel camera, with an autofocus that allows good close-ups (about 2 inches), including quality document photographing. Good for taking photos of modules, labels, project sites, installations, etc.

Then, there are the apps, third-party-developed software based on the iPhone's software development kits—tools, templates, and examples for building software for the iPhone operating system.

## The Apps

Most apps that can be used for solar assessment use the iPhone's built-in sensors to perform their feats. These sensors include a sensitive accelerometer that detects position and movement, global positioning sensor (GPS), light sensor, proximity sensor, and a camera.

Sounds sophisticated—and potentially expensive. But downloaded from Apple's iTunes store, more than 90% of the apps are less than $10 and thousands are free. As an added bonus, the iPhone—offered in 8-, 16-, and 32-gigabyte memory options—has terrific storage capacity for apps (and other files and media). It also will synchronize to your Macintosh or Windows contacts, notes, and calendar, in addition to your iTunes library, and allows you to check e-mail and browse the Web using your cell phone signal (or 3G or wireless Internet access), making working on the fly a snap.

## Apps for the Field

# Sun Tracker

**($14.99)** For solar installers and DIYers, this is the "must-have" app that incorporates every sensor and nearly every feature of the phone to provide accurate site assessments and reporting. Start by naming your site and then the GPS plugs in the latitude, longitude, elevation, and heading. Next, set the array azimuth and tilt (or, if you are working with a tracking array, select from single or dual-axis tracking). Pick the closest weather station from the drop-down menu. You may optionally enter a per-kWh cost of energy, and the model of PV module and inverter you're using, from a built-in database with a wide variety of module and inverter manufacturers and models. Everything you need is loaded into the iPhone—no network connection is necessary to complete a site assessment, so you're good to go even in remote locations. Sun Tracker will also run on the iPod Touch.

Here's how it works. After setup, you scan the skyline. Press the scan icon to launch the heads-up display. Wait for the start tone and then simply trace the skyline using the cross hairs. (With a 3G, you must first set the "start" and "stop" points and then perform a smooth scan at a constant rate—with a bit of practice, it yields very good results.) As you trace the skyline, Sun Tracker records the elevation and heading of any obstructions.

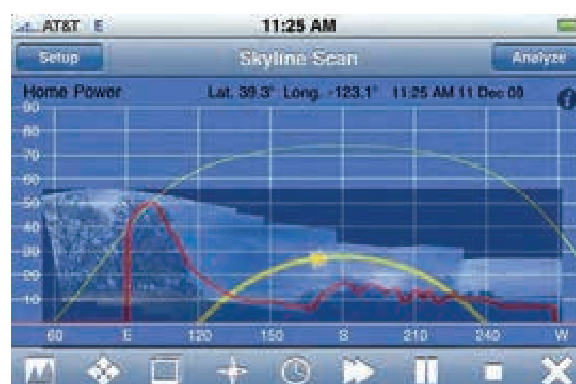
When complete, you end up with a sun plot for your location, showing that day's sun path compared to winter and summer solstice sun paths. A scan can be completed in about 10 seconds, so you can quickly evaluate a number of potential locations and easily choose the best one. You can also animate the sun's arc over your scan for different months to see variations in the site's solar exposure over the seasons.

Sun Tracker software also allows you to superimpose a panoramic photo of the site (see AutoStich and AutoPan below) on your scan with the ability to edit the photo size to get a good fit. This is generally only needed for presentations; the trace should be your guide, rather than the photo.

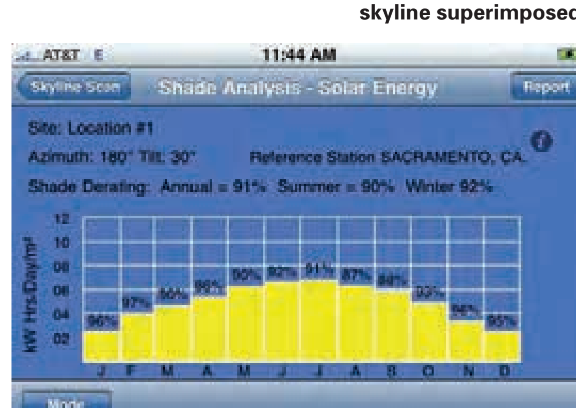

Step 1: Trace the skyline using the cross hairs to generate your skyline scan (red line in the screen shots, at right).


Getting started with the setup screen on Sun Tracker.


A Sun Tracker skyline scan (red), showing summer and winter sun plots for this location (yellow).




The same skyline scan, with a panoramic photo of the skyline superimposed.




The Sun Tracker shade analysis shows the percentage of sunlight that will be received each month.

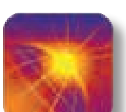
Once you settle on the array location, running the Analysis feature—which takes about 30 seconds—produces a graph showing the percentage of solar energy captured per square meter per month, the percentage of shade derating per month, and percentage of available sun hours for each month.

You now have the option to produce a two-page presentation report with your company name, logo, presenter, and customer names. These documents can be e-mailed right from the phone back to the office and/or customer.

Another nice feature of this app is the heads-up display. Just launch the camera and hold the phone up to the skyline or roofline: the display shows exactly what is behind it, allowing you to read azimuth and altitude angles as you move the cross hairs around your field of view. This also works on the 3G for scans and elevation. But only the 3GS will also display heading to site along a building's eave and instantly get a calculation of the roof pitch and orientation azimuth at a glance—with your boots on the ground!

Sun Tracker is a remarkable tool that rivals all the competition—and at a much lower cost. It has the capabilities required by professionals, but its ease of use and price puts it in reach of the solar enthusiast. One minor limitation is that it can be awkward to position yourself at array level to perform the scan on a rooftop, but by lying on your side, you can get within 12 to 18 inches.

Solmetric, the company that brought us the SunEye digital site analysis tool, recently acquired Sun Tracker and will begin marketing the app under its own brand, SolmetricIPV. Users who purchased Sun Tracker will be able to continue accessing updates.



## Sun Seeker

**($2.99, 3GS only)** An assessment tool that spans several applications, Sun Seeker allows you to quickly check building overhangs and sunlight penetration into a structure, as well as site a solar window. The opening screen displays a grid of the sky, with latitude and longitude readings; the sun's current position and daily path; winter and summer solstice curves; sunrise and sunset times; real-time solar azimuth and elevation; shadow ratio (sweet!); and sun-path length. A summary screen reports that day's Sun Details.

The third screen is a three-dimensional heads-up display that superimposes the sun's path and solstices on the real-time image, along with the elevation and azimuth of what the cross hairs are pointing at. This allows you to instantly see the relationship between the target object and the sun's paths. You can also trace the sun's path on its curve line and see what objects will cast a shadow—and where you need to move to avoid it. You can capture the screen to your iPhone album or e-mail it directly from within the program. You can also easily display the sun path for any day you select. A real bargain for what it does.

### Helper Apps

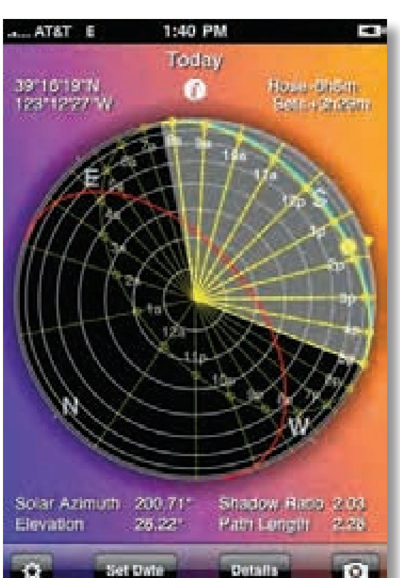
## AutoStitch Panorama

**($2.99)** While this isn't dedicated solar software, AutoStitch is a useful partner. It allows you to take a series of photos and stitch them together, enabling 360-degree panoramic images. The accuracy of this software is remarkable—it's less distorting then anything I've seen at any price for a computer! A panoramic image can be imported into Sun Tracker and overlaid on the skyline scan.

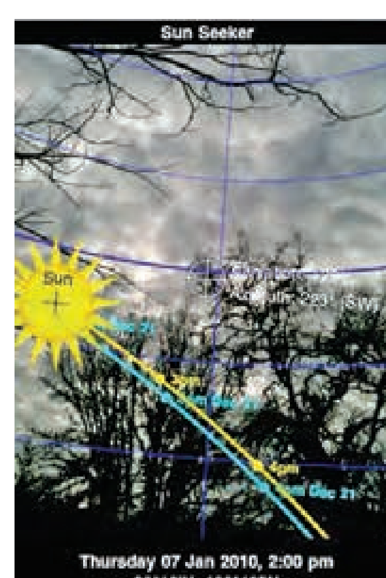
## AutoPan

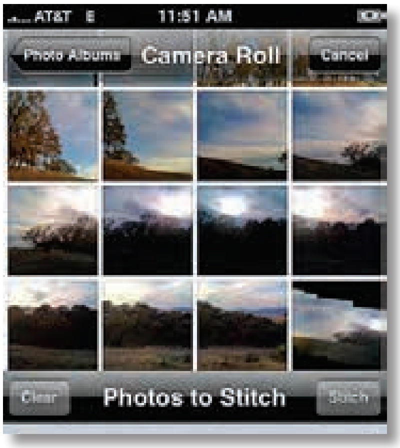
**($1.99)** Created by Sun Tracker's developer, this tool automatically snaps photos at optimal intervals, using the phone's compass as you scan across the landscape to set up the perfect panorama in AutoStitch. Tip: Keep the Elevation at 30° as you pan—this minimizes stitching distortion and puts the bottom of the screen at 0°. Well worth the two bucks.

**The Sun Seeker assessment tool gives detailed information on solar access at the site (left), detailed sun information (center), and superimposes the sun's path and solstices on a real-time image (right).**










AutoStitch Panorama allows you to stitch a series of photos together to generate 360° panoramic images.

## MotionX GPS

**($2.99)** Far ahead of most handheld GPS units, MotionX GPS integrates with Google Maps. With the 3GS, the maps even rotate as you do, so the map is always facing your view. Perfect for figuring out your coordinates when you're trying to track down that property in the boonies or find your way around congested city streets. It taps into satellite data and can lock onto a satellite just about anywhere on Earth. If the satellite signal is blocked, it switches to cellular tower triangulation to help you find out just where you are.

### Virtual Toolbox

## iConvertIt

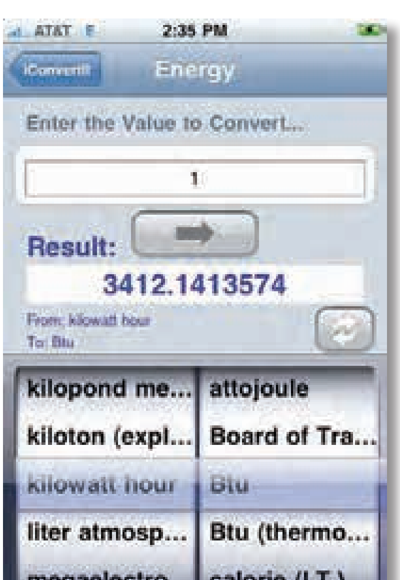
**($1.99)** An affordable unit converter, this program contains 19 categories, each with the units you are most likely to need. For example, use this to convert from square meters to square feet, or Btu to kWh, etc. Simple and fast, using the classic iPhone "roller bar." It does a reverse convert with one keystroke.

## Equivalence

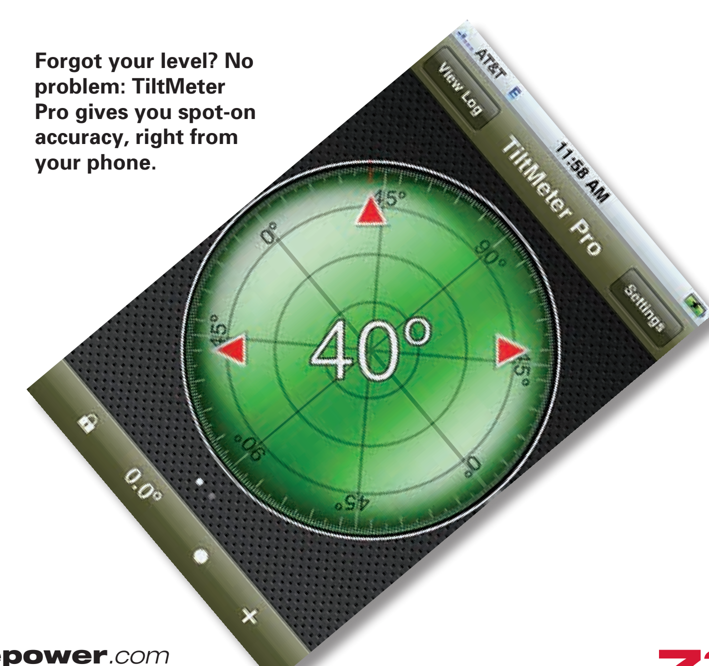
**($2.99)** A step beyond iConvertIt into the more esoteric and scientific conversions and units. Aimed at electrical and mechanical engineers, it can cope with mass, magnetic fields, and flux and insulation, just for starters.

## TiltMeter Pro

**($0.99)** Perhaps my most-used app, TiltMeter Pro contains several levels in one program: a bulls-eye level, digital angle level, and a virtual bubble level. Each one can be set to display in degrees, pitch (x:12, x:14), percent, and radians. After careful calibration, accuracy is spot-on. Plus, it can log and e-mail readings. Handy features include a reading lock at a key press and an auto-lock, which waits for a stable reading (for you to quit moving) and then locks the display. Terrific for measuring in out-of-sight places, like under an eave where you cannot see the display (it is accurate only on the side of the iPhone that does not have the volume key). You can also set a reference point to see how far off the mark you are. Perfect for level, plumb, roof and array pitch—even for hanging a picture frame straight!




Stumped by a conversion? iConvertIt comes to the rescue.




Forgot your level? No problem: TiltMeter Pro gives you spot-on accuracy, right from your phone.

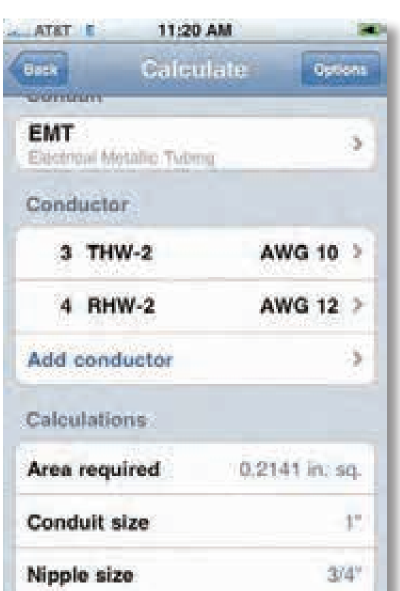

**Ecalcs offers voltage, current, voltage drop, and many more calculations at the push of a button.**

## Ecalcs

**($3.99)** An often-used tool on my iPhone, Ecalcs does the calculations for Ohm's law, horsepower, voltage, current, kVA, kW, transformers, voltage drop, and wire size. Each of these categories contains a good depth of detail and many factors to consider—far too many to list here. If you do any level of electrical work, this app will be helpful.

## Conduit Fill Calculator

**($2.99)** Based on the *2008 NEC*, Conduit Fill Calculator helps you figure proper conduit size and fill factors. The database contains 50 conductors and 12 types of conduit. You can mix conductor types and sizes and get quick field sizing.




**Proper conduit size and fill factors—at your fingertips, with Conduit Fill Calculator.**

## Wire Size

**($2.99)** Also taking a page from *2008 NEC* (specifically, table 310.16), Wire Size calculates current and wire size from AWG 18 to 2,000 kcmil, taking into consideration voltage drop, ambient temperature correction, and number of wires in a raceway. It's easy to use and fast.

## Decibel Meter

**($1.99)** Accurate and fast, with optional displays and peak capture, Decibel Meter is useful for figuring out sound mitigation effects on gensets and general decibel measurement needs. My trusted ±2 db meter and the Decibel Meter were within 1 to 2 db of each other when I measured the constant sound from my bench grinder, and the app is much faster in capture. It's hard enough to find a db meter with this many features, not to mention at this price!

## Flashlight & myLite

**(Free)** Shed a little light on the situation with a flashlight app. These programs fill your iPhone's screen with bright white light (or, if you're in a festive mood, pick from a selection of colored screens). Plus, the price is hard to beat. About as bright as a single LED flashlight.

## Brushes

**($4.99)** Although there are numerous drawing apps that are much cheaper, if not free, Brushes is a powerful drawing tool. I use it in the field to make sketches or notes with a sweep of my finger. Plus, your Van Goghs can be e-mailed.

### Apps for the Office:

## Graphing Calculator

**($0.99)** Does about anything you need in a graphing calculator. It's worth the buck even for simple math, if for nothing but keeping running totals on-screen.

## Spell Check

**($0.99)** A spell-checker and dictionary, with pronunciation. Its vast database does not require an Internet connection.

## Air Sharing

**($4.99)** A major shortcoming of the iPhone is its poor ability to import documents from your computer and then read various file types. That leaves you e-mailing the doc to yourself and then crossing your fingers that the phone can open it. Air Sharing makes this a hassle of the past. Connect via Wi-Fi to your computer (Mac or PC) and simply drag and drop files. Air Sharing allows you to organize them and offers a reader for most formats.

## Get a Grip

Good luck keeping a hand on your sleek iPhone. It's like trying to hold onto a wet bar of soap! To protect your investment, try the Speck ToughSkin ($22 to $35; www.speckproducts.com), which has a thick rubber case, with a clear screen protector and a removable belt clip that doubles as a movie-viewing stand. Its straight sides and flat back actually improve the accuracy of the leveling tools (see the TiltMeter Pro app).

### Phone Perfection?

A user-friendly interface that's packed with apps is sure to be a crowd-pleaser, but the iPhone isn't without its downsides. Currently, AT&T is the only available cell service provider for iPhones, leaving no other options or competition. Outside urban locations, where cell towers are fewer and farther between, getting a good connection may be an issue.

The iPhone's big screen is a beauty, but combined with its powerful processor and typical heavy use of apps, the battery is typically drained in less than three days. You may find that an external backup battery is useful. (However, many external batteries also integrate the battery into a case, although this can interfere with using the level and angle tools.) Prices range widely, but the best values I've found are the Griffin TuneJuice ($30) and LuckyPacks's I-UP 5400 ($60). The TuneJuice, which uses four AAA batteries, will add about 60% to 70% to the phone's typical run time, more if you carry extra batteries with you. With its 5,400 mAh, sealed lithium-ion battery, the I-UP will increase the phone's run time or completely recharge it six to seven times. However, beware: Many external battery packs for the 3G will not work on the 3GS. Be sure to choose the right backup battery for your model.

When it comes to software, there's only one real hitch: The app costs listed are volatile. There are frequent sales, intro prices, and inflation. However, most app developers aren't yet charging for upgrades. So if you get introductory pricing, you can end up saving money on future expanded and improved releases. Plus, most developers listen carefully to user feedback and massage their products accordingly. The applications and memory are what make the iPhone so powerful. The least-used feature on mine? Making phone calls.

### Access

**Jeff Oldham** (joldham@hughes.net) is the owner of Regenerative SOLutions and a solar contractor, with more than 30 years experience in RE and sustainable development. He lives off-grid with solar and micro-hydro. His work is 60% off-grid and 40% grid-connected, with about half of it international, primarily in Latin America.

# U.S.Battery's Brand New RE-L16XC

## Not just another golf car battery with a fancy new "RE" label. U.S.Battery has made real improvements from the inside out.

### *Outside Positive Plates (OSP™) = More Amp Hours.*

The primary causes of positive plate deterioration are positive grid corrosion and positive active material wear-out or softening and shedding. These failure modes are the result of the normal overcharge required to fully charge batteries and to mix the electrolyte to prevent electrolyte stratification. In addition, batteries that are used in applications that require continuous float charging may be more susceptible to grid corrosion as a result of prolonged overcharging. Also, batteries that are subjected to frequent deep discharges (greater than 50% DOD) often exhibit increased effects from positive active material wear-out. This is usually the case in Renewable Energy applications. Testing at U.S.Battery has shown that an effective method for mitigating the effects of positive plate deterioration is to increase the ratio of positive to negative active material by ***adding a positive plate*** and removing a negative plate from a conventional cell design resulting in an Outside Positive (OSP™) cell design vs a conventional Outside Negative (OSN) cell design. This design approach results in a cell with increased positive to negative active material ratio, increased positive to negative grid ratio, and increased protection of the positive plate from positive plate deterioration. This results in longer life, increased capacity, and more stable performance over the life of the battery.

### *The only battery in its class with DEFENDER™ Moss Shields for longer reliable battery life.*

Electrical shorting can be caused by 'mossing' shorts at the top of the cell element. These mossing shorts are the result of positive active material particles that have softened and shed from the positive plates, become suspended in the electrolyte, and eventually collect at the top of the cell element. Once enough of this material has collected to bridge the tops of the separators, it can contact both a positive and a negative plate where it converts to conductive lead and forms a short circuit resulting in cell and battery failure. This failure mode is more prevalent in stationary applications than in vehicular applications because of the absence of vibration and shock that normally dislodges the mossing material and causes it to fall to the bottom of the container where it collects innocuously in the mud cells. Testing at US Battery has shown that the use of insulating 'moss shields' in batteries used in these stationary applications can effectively prevent the formation of these mossing shorts. This results in longer life, increased capacity, and more stable performance over the life of the battery.


**SPECIFICATIONS**
**RE L16 / 6-VOLT**

| | |
|---|---|
| AMP HOURS (100hr.rate) | 470 |
| AMP HOURS (20hr.rate) | 428 |
| AMP HOURS (5hr.rate) | 334 |
| MINUTES (@ 75 AMPS) | 254 |
| MINUTES (@ 25 AMPS) | 914 |
| LENGTH | 11-7/8" (302mm) |
| WIDTH | 7-1/8" (181mm) |
| HEIGHT | 16-3/4" (425mm) |

U.S.Battery Manufacturing Company

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# Designing

## A STAND-ALONE PV SYSTEM

by Khanti Munro

Khanti Munro

The Ackerman-Leist pole-mounted array stands at the garden's edge, an integrated part of the family's homestead.

Living off the grid is a romantic ambition for some, a practical necessity for others. But whatever your motivation for off-grid living, cutting the electrical umbilical cord from the utility shouldn't be taken lightly. Before you pull out the calculator, size up the realities and challenges of living off the grid. Then, once you're convinced it's the way for you, use this guide to design a successful stand-alone system.

### Design Considerations

Designing a stand-alone PV system differs substantially from designing a batteryless grid-direct system. Instead of meeting the home's annual demand, a stand-alone system must be able to meet energy requirements every day of the year. The PV system must be able to keep the battery bank charged—or include a generator for backup—because once the last amp-hour is drawn, the lights go out (see "Backup Generators" sidebar).

**Efficiency first!** This long-standing mantra for PV system design still holds true and is especially important for off-grid systems. Using energy efficiently should always be a prerequisite to energy design and production. Every $1 spent on energy efficiency is estimated to save between $3 and $5 on PV system costs. As a system designer, it's virtually impossible to mandate *wise* energy use by the end user, but we can specify efficient appliances, such as Energy Star refrigerators and clothes washers, and strategies, such as shifting loads to non-electric sources during times of low solar insolation. For more on efficiency and load-shifting, see "Toast, Pancakes & Waffles: Planning Wisely for Off-Grid Living" in *HP133*.

**Energy Consumption and the Solar Resource.** Carefully comparing the home's daily and seasonal energy usage with the daily and seasonal availability of the sun will help prevent energy production shortages. This important step involves a careful analysis of the home's changing seasonal load profile and the corresponding solar resource throughout the year. Paramount to this analysis is the presence or absence of a backup charging source, such as a generator. If a backup charging source is not incorporated, the designer should choose as the design target the time of year when energy consumption is expected to be highest and the solar resource at its lowest—usually during the depths of winter.

Without a backup generator, a PV system must produce every watt-hour required, at all times of the year. This is often a tall task during the winter months and typically results in a costly system that is oversized for the rest of the year. For this reason, stand-alone systems without a backup charging source are often limited to smaller, nonresidence applications, such as seasonal cabins.

For systems with a backup charging source, more design flexibility means designers can use average consumption numbers and peak sun-hour values. For example, they can choose to size the system at a time of year when energy consumption is not at its highest or lowest, but in the middle—say, a typical day in the fall or spring. In addition, they might use the specific location's average solar resource. Using the average for both consumption and sun-hours will strike a good balance between an affordable array size and generator run time. If minimal generator run time is desired, the array and battery bank may need to be upsized based on more conservative consumption and sun-hour values.

## Size it Up: A Case Study

Let's explore an example sizing scenario, component by component, with a method Solar Energy International (SEI, see Access) uses in its classes to size stand-alone systems using an maximum power point tracking (MPPT) controller:

**Who:** The Ackerman-Leist family
**Where:** Pawlet, Vermont, approximately 3/4 mile from utility service
**Solar window:** 8 a.m. to 4 p.m.
**Average daily solar resource:** 4.6 peak sun-hours*
**System backup:** 4 kW backup engine generator
**System voltage:** 24 VDC
**Projected energy use (AC and DC):** 2.2 kWh per day
**Expected avg. ambient temperature for batteries:** 60°F
**Record low temperature:** -35°F
**Desired days of autonomy:** 3
**Desired battery depth of discharge:** 50%
**Battery:** 6 V nominal, 225 Ah, deep-cycle flooded lead-acid
**PV modules:** 12 V nominal, 80 W STC , array tilt equal to the latitude (43°)
**Charge controller:** MPPT, 60 A
**Array mounting:** Pole-mount
*Peak sun-hours are based on Concord, New Hampshire, values, which more accurately reflect the site's latitude and weather patterns.

## Step 1: Estimate Electric Load

Determine the amount of energy (kWh or Wh) that will be consumed on a daily basis. If it is for a home not yet built, this can be a very involved and time-consuming step. A designer will need to work closely with the homeowner/builder to realistically estimate the daily and seasonal energy requirements.

Shawn Schreiner

**A watt-hour meter gives precise figures on consumption for appliances already owned. Without that information, the values in the "Loads" table must be estimated.**

The power (W) of individual loads and their estimated energy consumption (Wh) can be tallied to calculate the household's average daily load. This step will help identify opportunities for efficiency improvements and pave the way for sizing the system components. The table below lists the electrical loads found in the Ackerman-Leist household. The family heats their home with wood, cooks with wood and propane, uses a propane refrigerator, and heats their water with a solar thermal system and a backup propane boiler, so those are not factors in the load analysis.

According to the table, daily household loads average 1.8 AC kWh and 0.36 DC kWh (from the chest freezer), totaling almost 2.2 kWh a day.

## Ackerman-Leist Load Analysis

| AC Loads | V | x | A | = | W | x | Qty. | = | Total W | x | Hours Each Day | x | Days Each Week | ÷ | Days In a Week | = | Avg. Wh/ Day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CF lights | 120 | | 0.17 | | 20.4 | | 10 | | 204.0 | | 4.00 | | 7 | | 7 | | 816.0 |
| Laptop computer | 120 | | 0.50 | | 60.0 | | 1 | | 60.0 | | 2.00 | | 5 | | 7 | | 85.7 |
| Staber clothes washer | 120 | | 4.00 | | 480.0 | | 1 | | 480.0 | | 0.42 | | 3 | | 7 | | 86.4 |
| Satellite internet modem | 120 | | 0.30 | | 36.0 | | 1 | | 36.0 | | 2.00 | | 5 | | 7 | | 51.4 |
| Well pump | 120 | | 13.00 | | 1,560.0 | | 1 | | 1,560.0 | | 0.25 | | 7 | | 7 | | 390.0 |
| Composting toilet fan | 120 | | 0.13 | | 15.6 | | 1 | | 15.6 | | 24.00 | | 7 | | 7 | | 374.4 |
| | | | | | | | | Total AC W for Inverter Sizing | 2,355.6 | | | | | | Total Avg. Daily AC Wh | | 1,803.9 |

| DC Loads | V | x | A | = | W | x | Qty. | = | Total W | x | Hours Each Day | x | Days Each Week | ÷ | Days In a Week | = | Avg. Wh/ Day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SunDanzer freezer | 24 | | 2.5 | | 60 | | 1 | | 60 | | 6.00 | | 7 | | 7 | | 360 |
| | | | | | | | | | | | | | | | Total Avg. Daily DC Wh | | 360.0 |


**Contained in this simple battery box, three parallel strings of four 225 Ah Trojan T-105 batteries make a 24 V, 675 Ah battery bank.**

## Backup Generators

Employing a backup generator in a stand-alone PV system is a prudent addition. Trying to produce every last watt-hour needed can cost a pretty penny in added PV array and battery bank capacity—much more than the cost of a generator. That's why using a backup generator in a stand-alone PV system can make financial sense. A reliable backup source allows greater design flexibility and, most often, a smaller and more cost-effective system. The size of the PV array can be reduced to a more affordable size, while a backup generator can make up the difference when the solar resource is inadequate. In addition, equalization, an important aspect of battery maintenance, can be difficult to achieve with a PV array alone. As long as there is fuel in the generator, you aren't dependent on the weather to keep the lights on and the beer cold. (For more information on backup generators, see "Engine Generator Basics" in *HP131*.)

### Step 2: Battery Bank Sizing

The average daily load is then used to calculate the battery requirements. The batteries must be able to store the total daily load, in addition to the extra energy lost by inverting from direct current (DC) to alternating current (AC). Dividing the AC average daily load by the inverter efficiency (90% standard), inflates the average daily load that the batteries must store to account for efficiency losses from the inverter. While inverter manufacturers will commonly list "peak efficiency" (generally ranging from about 92% to 95%), we use a more conservative 90% to account for the fact that the actual operating efficiency depends on the AC load, which is constantly fluctuating. Hence, an inverter will rarely operate at the load level which results in peak efficiency.

The battery bank's ambient operating temperature is also taken into consideration, since temperature affects a flooded lead-acid battery's internal resistance and ability to hold a charge. As temperatures fall below 80°F, battery capacity is reduced. A battery temperature multiplier table can be used—check with the battery manufacturer for their specific correction factors.

Days of autonomy is also an important design criterion, as it dictates how many days the battery bank will need to sustain the average daily load when there is little or no sunshine to recharge it. It's a compromise between having energy during overcast spells, how much time the generator will run, and the added cost of a larger battery bank. The more days of autonomy desired, the larger the battery bank. Generally three to five days of autonomy provides a good balance. Keep in mind that the larger the battery bank, the larger the PV array will need to be to recharge the bank sufficiently on a regular basis—or the more the generator will be needed to pick up the slack.

The last major design criterion for sizing batteries is the depth of discharge (DOD). While deep-cycle lead-acid batteries are designed to discharge 80% of their capacity, the deeper they are discharged on a regular basis, the fewer charge/discharge cycles they can provide over their lifetime. When choosing a DOD, strike a balance between longevity, cost, and the significant hassle of replacement. Many system designers will specify a 50% DOD to be used in the worksheet. Because several days of autonomy are accounted for, which increases the battery bank size, the actual depth of discharge during sunny weather will often be less than 20%. The DOD design value can greatly affect the cost of the battery bank. (For simplicity, the numbers from the load table have been rounded in the following equations.)

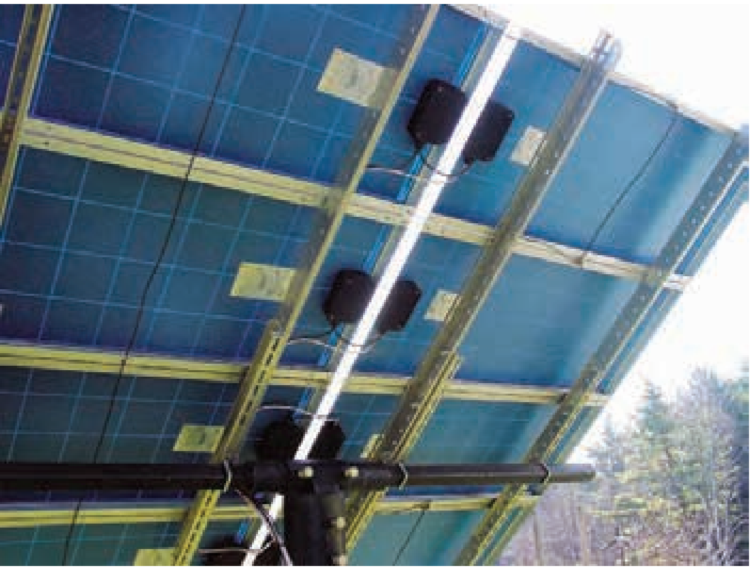
**(1,800 AC Wh Avg. Daily Load ÷ 0.9 Inv. Eff.) + 360 DC Wh Avg. Daily Load = 2,360 Wh/day**

**2,360 Wh/day ÷ 24 DC System Volts = 98.3 Avg. Ah per day**

**98.3 x 1.11 battery temperature multiplier x 3 days autonomy ÷ 0.5 DOD = 654.7 total system Ah**

## Battery Temperature Multiplier

| Ambient Temperature (°F) | Multiplier |
|---|---|
| 80 | 1.00 |
| 70 | 1.04 |
| 60 | 1.11 |
| 50 | 1.19 |
| 40 | 1.30 |
| 30 | 1.40 |
| 20 | 1.59 |



Khanti Munro

**This pole-mounted array offers unimpeded solar access at the site from 8 a.m. until 4 p.m.**

**654.7 ÷ 225 Ah individual battery capacity = 3 parallel battery strings (rounded up from 2.9)**

**24 V system voltage ÷ 6 V battery voltage = 4 batteries in series**

**3 parallel strings x 4 batteries in series = 12 total batteries**

The battery calculations indicate that a battery bank made up of 12 of the chosen 6 V, 225 Ah, flooded lead-acid batteries will provide adequate storage to meet daily energy requirements, inverter efficiency losses, operating temperature effects, days of autonomy, and the desired average depth of discharge. The number of batteries or series-strings of batteries connected in parallel should be kept to a minimum, preferably three or less. This minimizes the chance of unequal charging from one battery or string to the next. While using higher-capacity batteries would have resulted in fewer parallel strings, the Ackerman-Leists chose lower-capacity batteries for budgetary reasons.

Batteries are rated by their capacity in amp-hours and at the rate that they are charged/discharged. In most PV systems, the appropriate Ah rating to use is based on a discharge over 20 hours. Unlike shallow-cycle vehicle batteries, deep-cycle batteries in PV systems are charged and discharged over 24 hours, and the weather, level of solar irradiance, and energy usage patterns all influence the charge/discharge scheme. In this system example, the battery could provide 225 Ah of stored energy—if discharged 100% over 20 hours. If it were discharged faster, the capacity would be less, and vice versa. Be sure to check with the battery manufacturer, as they provide battery-specific Ah capacity values based on different charge/discharge rates. Choose the 20-hour rate when sizing and selecting batteries, unless a specific load profile dictates otherwise.

## Step 3: Array Sizing

Now that we have calculated loads and storage, next calculate the array size in watts, and the number of PV modules needed. The array calculations must include Wh per day (calculated from the average daily load), the location's solar resource, expressed in daily peak sun-hours, battery efficiency losses (about 20%), module temperature losses (about 12%), possible array shading, and a conservative derate multiplier to account for things like wire losses, module soiling, and production tolerance.

**Peak sun-hours** are the equivalent number of hours per day when solar irradiance (intensity) averages 1,000 watts per square meter, as derived from the National Solar Radiation Database (http://rredc.nrel.gov/solar/pubs/redbook/). Dividing the Wh required by the location's peak sun-hours leaves us with the initial PV array watts needed. For this sizing example, the solar data for Concord, New Hampshire (at 43.2°N) provides the closest estimate of the solar resource for Pawlet, Vermont (at 43.3°N) at an array tilt angle equal to latitude. Since this system is using a backup generator, the average daily peak

### web extra

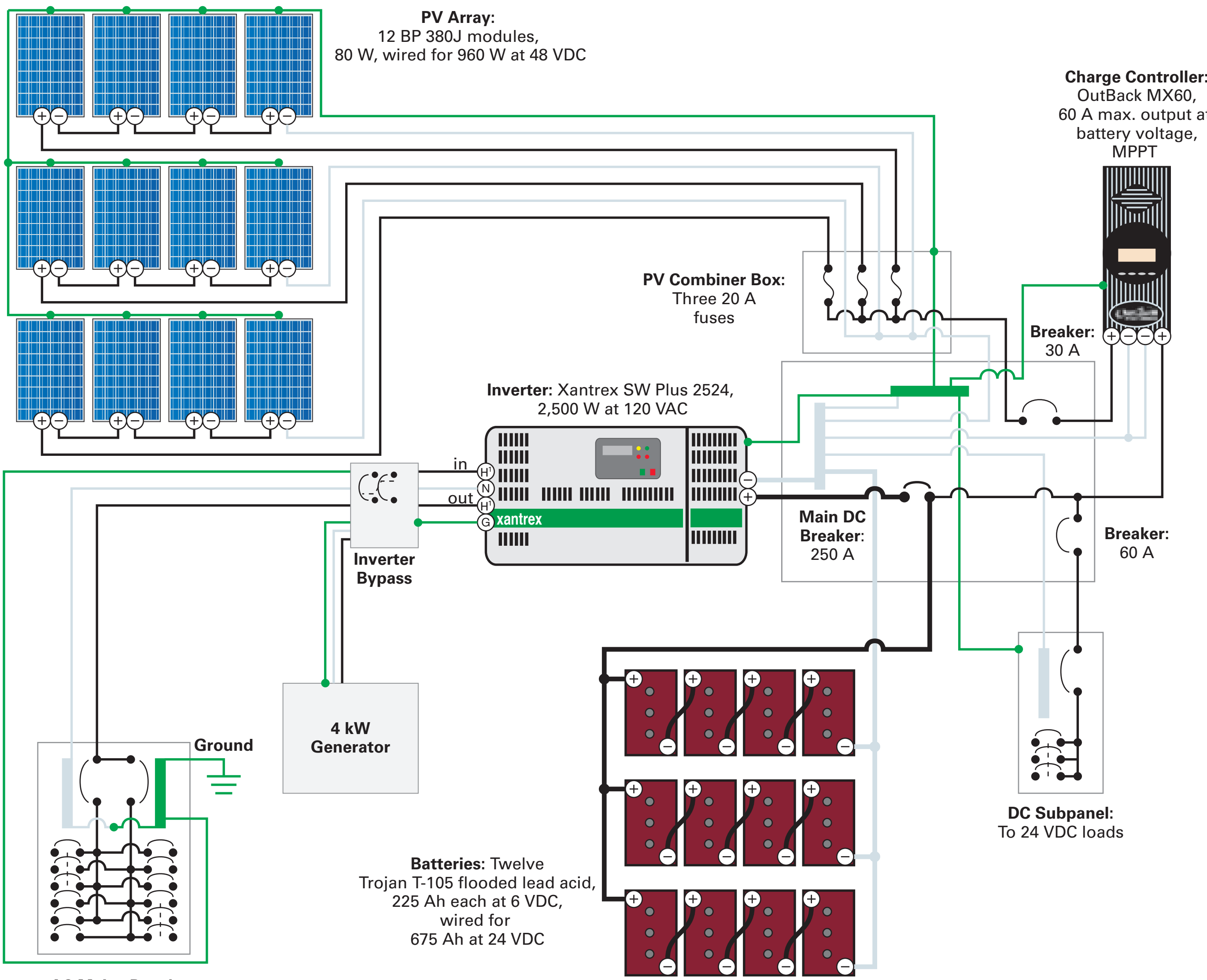
## Off-Grid or On: Getting Real

Living without the utility (off-grid) means managing your own power plant, and the costs and responsibilities should be examined carefully. For a detailed analysis of the advantages and disadvantages, see "Off or On Grid? Getting Real" on the Web Extras page at www.homepower.com.

## Estimating Generator Run Time

So how much will you need to rely on your generator? You can start by estimating the system's expected energy production at the location's average daily sun-hours, and then look at the times of year when you'll be short, due to higher consumption and less sun. Once you have an idea of how much energy you'll need to make up, you can estimate the generator run time. Changing weather and consumption patterns make estimating this a moving target, but this process will give the designer an idea of when during the year the generator will run and for how long—and may prompt the designer to suggest additional load-shifting and efficiency measures for these times.

## Ackerman-Leist Off-Grid PV System




**Note:** All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.

sun-hours can be used (4.6), as the generator can cover energy shortages during periods of low insolation or high energy consumption—or both. If less generator run time is desired, the array size must be increased or daily energy consumption must be reduced appropriately (or both).

**Battery efficiency:** Since batteries are not 100% efficient in converting electrical energy into chemical energy and back again, the array size must be increased to account for energy lost in the storage process. A common battery efficiency is 80%.

**PV temperature losses:** Module standard test conditions (STC) ratings, which are based upon a cell temperature of 77°F (25°C), don't reflect real-world operating conditions. To account for losses due to higher cell temperatures, a derating value of 0.88 can be used. This assumes an average daytime ambient temperature of 68°F and an estimated cell

## PVWatts System Derate Computation

| Component Derate Factor | Derate Value | Acceptable Value Range |
|---|---|---|
| PV module nameplate DC rating | 0.950 | 0.800 – 1.050 |
| Mismatch modules | 0.980 | 0.970 – 0.995 |
| Diodes & connections | 0.995 | 0.990 – 0.997 |
| DC wiring | 0.980 | 0.970 – 0.990 |
| AC wiring | 0.990 | 0.980 – 0.993 |
| Soiling | 0.950 | 0.300 – 0.995 |
| Age | 1.000 | 0.700 – 1.000 |
| Derate Factor* | 0.85 | |

*Computed by multiplying all derate values together


**Step-down MPPT controllers can help decrease wiring costs by allowing PV array voltage to be higher than the battery bank voltage.**

temperature of 122°F. (Another way to calculate temperature losses would be to use the specific module's maximum power temperature coefficient, in conjunction with a cell temperature based on the record high daytime local temperature.)

**Shading coefficient:** Although 9 a.m. to 3 p.m. is often considered the ideal solar window, site-specific shading should always be evaluated for the whole day. Even moderate shading can have a substantial impact on array output. In the case of this sizing example, with a shade-free solar window of 8 a.m. to 4 p.m., an average shading coefficient of 0.90 was determined with a Solar Pathfinder array siting tool.

**Derate factor:** A 0.85 derate factor (from NREL's PVWatts online performance calculator) accounts for other system losses, including module production tolerances, module mismatch, wiring losses, dust/soiling losses, etc. An experienced designer can adjust this value to reflect conditions for your specific site. See the table for a summary of these values.

**2,360 Wh daily load ÷ 4.6 peak sun hours ÷ 0.8 battery efficiency ÷ 0.88 temp. losses ÷ 0.9 shading coefficient ÷ 0.85 system derate = 953 W peak array**

**953 ÷ 80 W STC individual module = 12 modules needed**

**48 V nominal array voltage ÷ 12 V nominal module voltage = 4 modules per string, 3 strings total**

The resulting 12-module array will have a capacity of 960 W STC, rounded up slightly from the 953 W specified in the calculations. Although the DC system voltage and the battery bank are 24 VDC, this array can be wired at a higher voltage of 48 VDC, because of the "step-down" feature of the charge controller being used. Since the modules are nominally rated at 12 V, they will have to be wired into three series-strings of four modules each.

If these calculations seem conservative, it is because they are. It is imperative to design a system that will operate reliably and efficiently—and that will produce, on average, the expected amount of energy required. In other words, it is the designer's job to give the system manager/homeowner a *realistic* idea of what to expect.

## Step 4: Controller Sizing

With an array size specified, a charge controller is next—sized to safely handle and regulate the array's incoming power to prevent overcharging the batteries. A charge controller needs to be selected based on the maximum array watts, nominal battery voltage, and desired features. A MPPT controller allows the array to maximize the energy put into the batteries, particularly under cold conditions (high array voltage) and low battery voltage. These controllers also have the ability to step down a higher array voltage to a lower battery bank voltage which, in turn, helps keep wire size and costs down for long wire runs. It can also reduce the number of series fuses and the size of the combiner box. To prevent damaging the controller and potentially voiding its warranty, the maximum open-circuit voltage (Voc) of the array must never exceed the charge controller's maximum voltage rating at the lowest expected ambient temperature.

**12 modules x 80 W each = 960 W (max. W controller must handle)**

**960 W ÷ 1,500 W max. controller W rating at nominal battery voltage (24 V) = 1 charge controller required (rounded up from 0.64)**

**22.1 V module Voc x 4 modules in series x 1.25 temp. multiplier (per *NEC Table 690.7* for record low temp. of -35°F) = 110.5 VDC maximum PV array Voc**

**110.5 max. Voc < 150 VDC, the controller's maximum Voc rating**

***Max. system voltage was calculated using the module's Voc temp. coefficient**

Although charge controllers are most commonly rated by the amount of current (amps) they can deliver to the battery bank, it is often simpler to compare the calculated array watts with the controller manufacturer's recommendation for

**Select an inverter to handle the maximum loads that will be on at once in the home. Choosing the next larger size will help ensure your system can meet the demands of future loads.**


Khanti Munro (2)

maximum array watts (STC) at the applicable battery bank voltage. More often than not, the maximum array watts for different battery bank voltages are listed on the controller's spec sheet, allowing the designer to simply divide the system's array size (in watts) by the controller's maximum allowable watts, to determine how many controllers will be needed.

Another option, especially when a controller spec sheet does not list the maximum allowable watts, is to use the manufacturer's controller string-sizing tool on its Web site to determine allowable array configurations. If no string-sizing tool is available, make sure that the calculated array size meets the given controller specifications, mainly "maximum input current." In the example here, the controller spec sheet does specify an STC nameplate rating of 1,500 W for a 24 VDC battery bank. Lastly, the above calculations also verify that at the coldest expected low temperature, the maximum array voltage will not exceed the controller's maximum open-circuit voltage rating.

## Step 5: Inverter Sizing

A battery-based inverter must handle all the household AC electrical loads that could be on simultaneously (AC total watts). An inverter must also be able to handle the expected surge or in-rush of current that some large loads draw upon startup. While a conservative method for estimating surge requirements is simply to multiply the total AC watts by three, realistically, many household loads do not surge. In this sizing example, likely only the clothes washer and well pump will surge significantly, although we also include the base load of the other appliances that may also be consuming power. Always be sure to compare the surge rating of an inverter with the expected surge requirements of the system.

Other design criteria include matching the inverter's input voltage with the nominal battery voltage, choosing the desired AC output voltage (120 or 240 VAC), considering environmental conditions (indoor or outdoor, mountainous or coastal, etc.), and weighing different optional features, such as an internal battery charger.

**2,356 W total AC loads = minimum inverter continuous watt rating (round up to 2,500 W typical inverter size)**

**[(1,560 W pump + 480 W washer) x 3] + 316 W base load = 6,436 W minimum surge rating**

**Desired AC output: 120 VAC**

**Desired features: Integrated AC-DC battery charger, digital display**

An inverter with a continuous rating of 2,500 W and a minimum surge rating of 6,436 W will meet the household's instantaneous power and surge requirements. The inverter model chosen must have an input voltage of 24 VDC to match the nominal voltage of the battery bank, and have an AC output voltage of 120 VAC to meet the needs of household loads. There are no 240 VAC loads in the Ackerman-Leist home, but if there were, the following options would be available: specify an inverter with 120/240 VAC output; stack two 120 V inverters in series; or use a step-up transformer for the loads that require 240 VAC. Inverter features are also important to consider, such as an inverter-integrated AC-DC battery charger. This feature is convenient for use with a backup generator when the batteries need supplemental charging. A digital interface can also be a helpful feature.

## System Recap

This system was sized appropriately given the design parameters and, along with the backup generator, should provide the family with a reliable and long-lasting PV system. The daily and annual energy production of any PV system is largely dependent on how much available sunlight there is and weather patterns, which vary from year to year.

It is interesting to examine how the system design would change if a backup generator was not incorporated. Using the month with the lowest peak sun-hours (December, 2.8 daily sun-hours) and increasing the days of autonomy from three to five would require 20 batteries and 20 modules—a 66% increase! Of course, higher-capacity batteries and larger modules could be used, but the increase in cost would still be substantial.

Since it was installed in May 2004, the Ackerman-Leist system has performed well and has provided the family with almost all of their electrical needs—minus about 30 hours per year of generator run time to equalize the batteries and make up for occasional shortages during the winter months. Although the system was sized for 12 modules, they started out with 10 for budgetary reasons. But with the addition of two children to the family (making them a family of five) and a few new loads, they will be adding the other two PV modules soon. In addition to the use of efficient appliances, the family is also in-tune with the weather and their energy usage patterns; they only do laundry on sunny days and only use a clothesline to dry their clothes. The system powered the entire construction of their three-level home and has since served as an educational model for them, their community, and students at Green Mountain College, where Philip Ackerman-Leist teaches.

It's inspiring to see a family of five use so little energy and yet live so comfortably—a system of this scale would be vastly undersized for almost any other full-time residence, at least here in the United States. A testament to energy conservation, efficiency, and awareness, the Ackerman-Leist family lives *with* their system, paying close attention to the ebb and flow of energy.

## Access

Khanti Munro (khanti@solarenergy.org) is a Green Mountain College alum, an ISPQ-certified PV instructor, and SEI's PV online coordinator and instructor trainer. Tied to the grid since childhood, Khanti lives vicariously through his off-grid friends and clients, with ambitions to someday unplug.

 Omitted from this sizing exercise were some technically complex aspects including nonoptimal tilt and orientation derate factors, conductor and conduit sizing, overcurrent protection sizing, grounding, and PV mount selection.

# RE-Sources

## 2010 Energy Fairs

Get RE-charged—brush up on the basics and learn about new trends in renewable energy by attending an energy fair near you. Most RE fairs offer fun for the whole family, with workshops by experts, good food, solar-powered entertainment, and educational and fun activities for kids.

### NORTHWEST & ALASKA

1. **Douglas County Earth Day & Energy Fair**
   April 24 • Roseburg, OR
   www.recyclepower.org

2. **Northwest Solar Expo**
   April 30–May 2 • Portland, OR
   www.nwsolarexpo.com

3. **Shoreline SolarFest**
   July 17 • Shoreline, WA
   www.shorelinesolar.org

4. **SolWest Renewable Energy Fair**
   July 23–25 • John Day, OR
   www.solwest.org

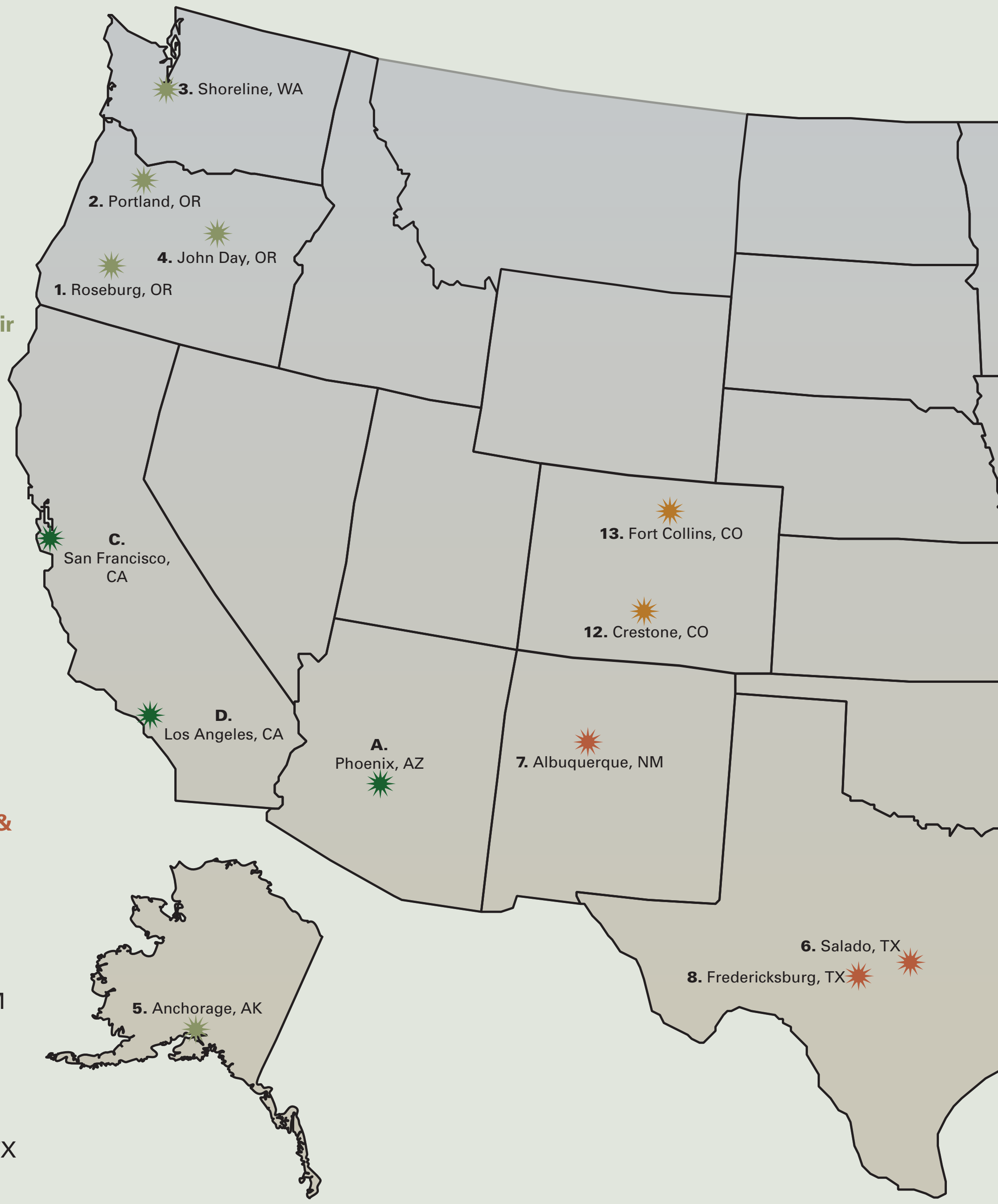
5. **Alaska Renewable Energy Fair**
   Aug. 7 • Anchorage, AK
   www.realaska.org

### SOUTHWEST

6. **Renewable Energy Stampede & Green Living Fair**
   April 17–18 • Salado, TX
   www.saladostampede.com

7. **Solar Fiesta**
   Sept. 18–19 • Albuquerque, NM
   www.nmsea.org

8. **Renewable Energy Roundup & Green Living Fair**
   Sept. 24–26 • Fredericksburg, TX
   www.theroundup.org



## MIDWEST

**9. The Energy Fair (aka MREF)**
June 18–20 • Custer, WI
www.the-mrea.org

**10. Illinois Renewable Energy & Sustainable Lifestyle Fair**
August 7–8 • Oregon, IL
www.illinoisrenew.org

**11. Harvest Festival & Energy Fair**
September 11 • Duluth, MN
www.theharvestfestival.org

## CENTRAL

**12. San Luis Valley Energy Fair**
August 28–29 • Crestone, CO
www.slvenergyfair.com

**13. Rocky Mt. Sustainable Living Fair**
Sept. 18–19 • Fort Collins, CO
www.sustainablelivingfair.org

## SOUTH

**14. Southern Energy & Environment Expo**
August 20–22 • Asheville, NC
www.seeexpo.com

**15. Bluegrass GreenExpo**
Nov. 13–14 • Lexington, KY
www.bluegrassgreenworks.org

## NORTHEAST

**16. Midcoast Sustainable Living Expo**
April 16–17 • Damariscotta, ME
www.midcoastgreencollaborative.org

**17. Solar & Wind Expo**
May 7–9 • Timonium, MD
www.thesolarandwindexpo.com

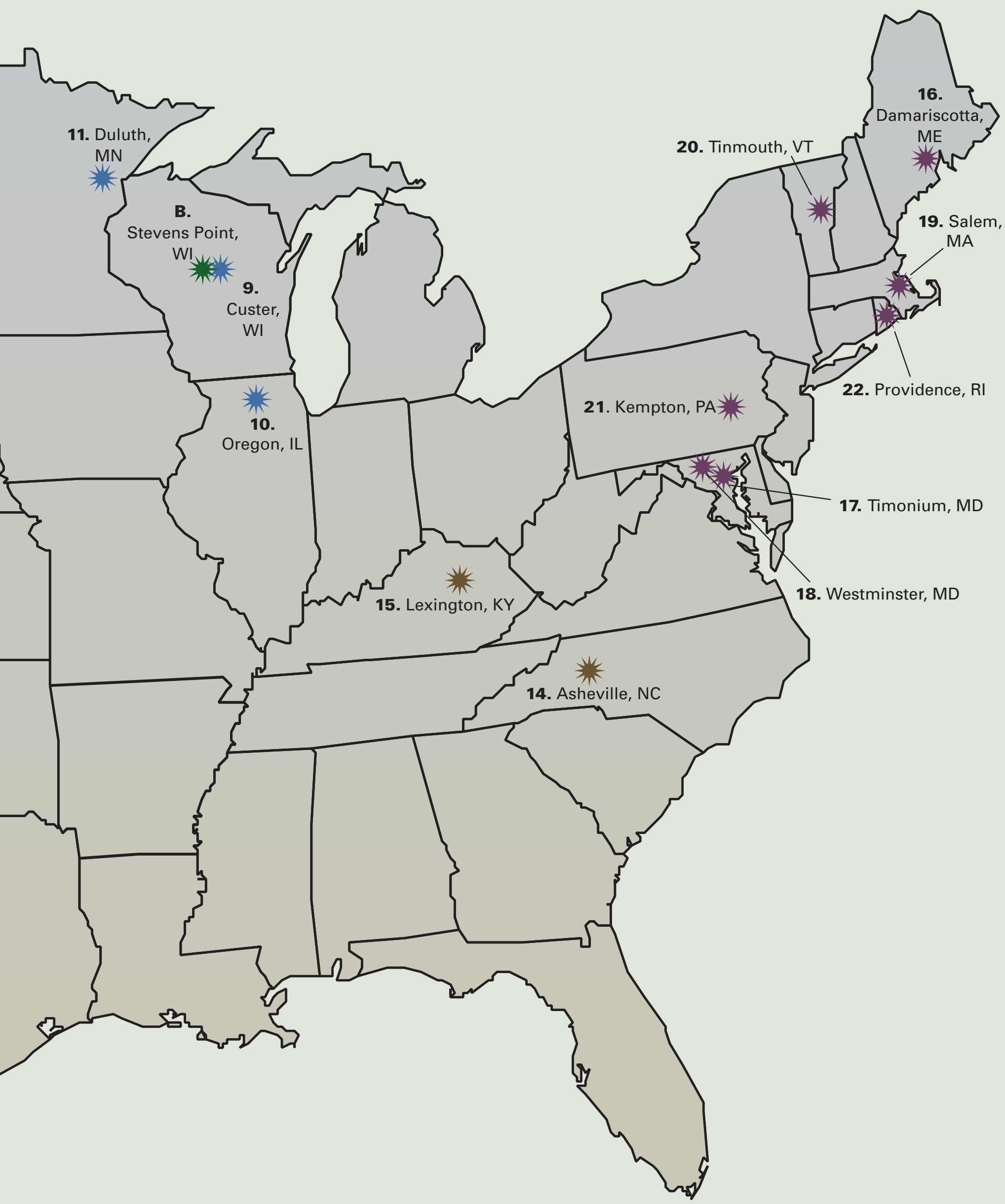
**18. Maryland Heartland Sustainable Living Fair**
May 22 • Westminster, MD
www.sustainablelivingmd.org

**19. Living Green & Renewable Energy Fair**
June 12 • Salem, MA
www.salem-chamber.org/livinggreenfair34.html

**20. SolarFest: The New England Renewable Energy Festival**
July 16–18 • Tinmouth, VT
www.solarfest.org

**21. Pennsylvania Renewable Energy Festival**
Sept. 17–19 • Kempton, PA
www.paenergyfest.com

**22. Providence Sustainability Festival**
Sept. 25 • Providence, RI
www.livingfest.org




## FOR THE PROS

**A. Solar 2010**
May 17–22 • Phoenix, AZ
www.solar2010.org

**B. Small Wind Conference 2010**
June 15–16 • Stevens Point, WI
www.smallwindconference.com

**C. Intersolar North America**
July 13–15 • San Francisco, CA
www.intersolar.us

**D. Solar Power International 2010**
Oct. 12–14 • Los Angeles, CA
www.solarpowerinternational.com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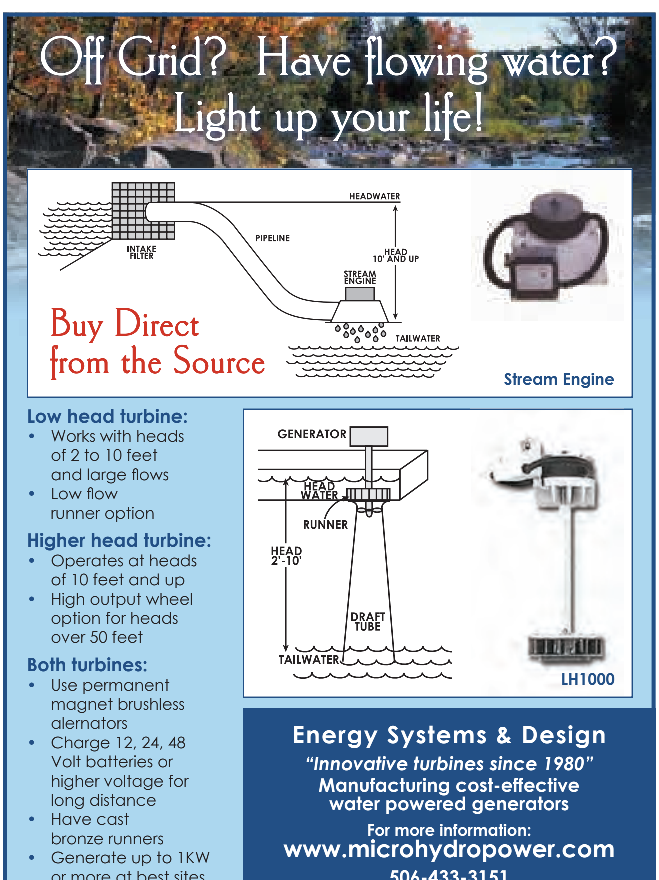
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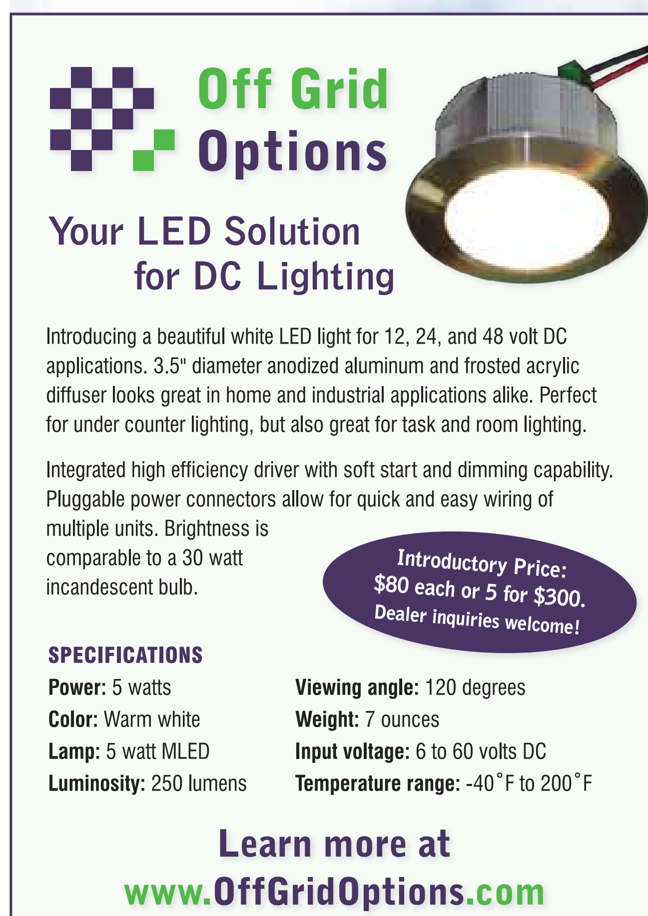
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Troubleshooting Small Wind-Electric Systems

# Noise & Heat

by Hugh Piggott

Courtesy Jytte Piggott

**The author inspects a time-worn turbine.**

## What's That Noise?

Although manufacturers may claim that their wind turbines are virtually silent, the reality is that wind turbines make a variety of sounds. Blades swish, and an electrical hum is audible in most conditions. If you do not know what to expect, listen to a few wind turbines before you buy one. You will get to know the sounds that a productive turbine typically makes.

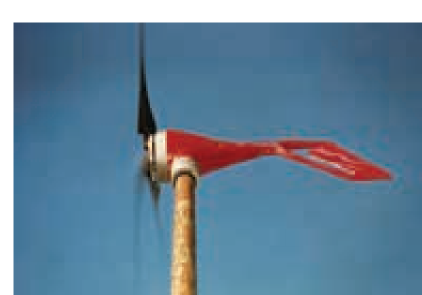
Noise is subjective and may be a problem in its own right, especially if your neighbors object to it. Sometimes you can do something about wind turbine noises, but often they are inherent in the design. The only solution may be to shut down the turbine in certain conditions, such as high winds or at night, if the noise causes complaints. It's a pity that not everyone enjoys the music of wind energy, but if you respect your neighbors, it's more likely that they will honor your request not to cut firewood with their chainsaws on Sunday mornings.

When a new sound arises, it may be a symptom of a problem that is worth investigating or it may be "normal" for this make of turbine in a particular wind. For example, one manufacturer produced a turbine without any furling system. Rather than protecting them from overspeed, the design allowed the blades to flutter (oscillate)—with a very loud noise. Thousands of these turbines were sold before the problem was fixed with an electronic braking system.

This is a case of "buyer beware." Make sure you know what sort of noises the turbine is expected to produce because some of them are quite loud in strong winds. You can listen to some examples of rather loud turbines at Mike Klemen's Web page (see Access).

### Swishing & Chopping Noises

Whooshing, chopping, and whistling noises are fairly normal, but can be objectionable. Some turbines have special blade



Hugh Piggott

**Early models of this turbine had severe noise issues in high winds.**


High speeds and long hours of operation will erode the blade material, literally digging holes in the leading edge. This damage can cause imbalance, noise, and reduced efficiency.

shapes that are intended to reduce noise, but the most important factor is the speed at which the blades run. If the turbine has a high cut-in rpm, then its blades will run unloaded in low winds and make a whistling sound. Loud noises in high winds may be due to a control system that disconnects the turbine when the battery is fully charged. In both cases, it helps to put a load on the turbine to slow the blades.

Defects in the blade profile can cause whistling noises that sound more like squeaking bearings. A small hole or notch in the blade tip will often make a squeak. This is easy to fix with some car body filler. Balance the blades after making such repairs.

## Rattling & Tapping Noises

Out-of-balance blades will shake the turbine such that it rattles audibly. Imbalance may be due to blade damage—maybe from a bird strike or from wind erosion. Or water may have gotten into a blade. The main symptom of this (low-frequency) vibration is a shaking tail. The solution is to repair and balance the blade assembly (see sidebar on blade balancing).

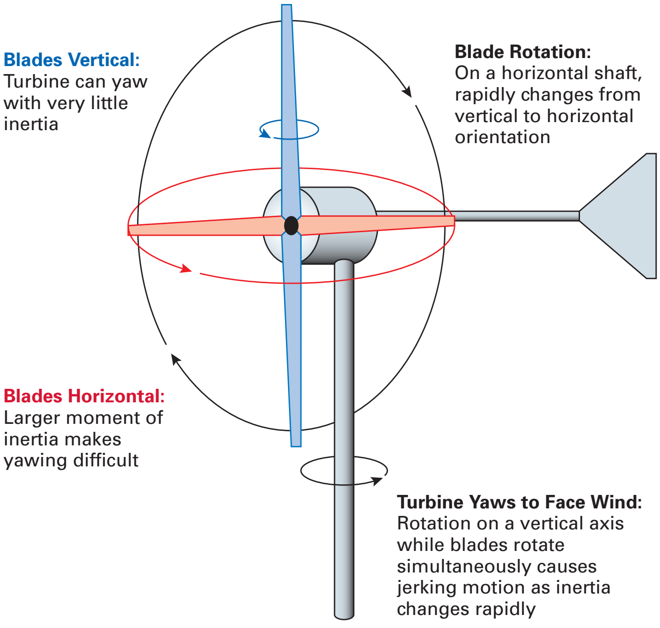
Two-bladed turbines have inherent vibration issues. In turbulent conditions, the wind shifts from side to side, and a wind turbine will yaw around to follow it. When a two-bladed turbine yaws, it shakes. The best things you can do to mitigate this problem are to avoid turbulent sites and make sure that the tower does not resonate at the same frequency as the turbine. For instance, the natural frequency of a guyed tower can be increased by adding guys at more levels. Keep everything bolted down tight and you will have no accidents.

Persistent, violent shaking due to imbalance and resonance can result in fatigue failure of the tail, or can possibly even bring down the whole machine with or without its tower.

Although rattling sounds usually mean imbalance, they may also indicate that something is working loose, like blade or alternator mounts. If your turbine makes a rattling sound without shaking, you need to stop the turbine and investigate the cause. Loose fastenings can lead to parts falling off. Check all nuts and bolts, and check for slack bearings.

Another very similar noise is the sound of internal parts touching. For example, magnets can come loose inside the alternator, or the stator may shift on its mounts so that these parts scuff each other once per revolution. You can best verify this by listening as you turn the shaft by hand. If this is the cause of the noise, the alternator needs to be dismantled and repaired.

## Vibration of Two-Bladed Turbines




The tail is usually the first casualty from an out-of-balance rotor. Here, the upper boom has cracked.

# Blade Balancing

Balancing is a procedure for adjusting the center of gravity of the blade and hub assembly to the exact center of its rotation. There are several good methods for balancing the blades. This one consists of two stages:

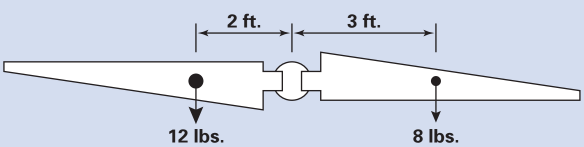
1) Check that each blade has the same moment of weight, and

2) mount the three blades symmetrically on the turbine.

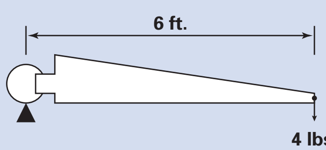
It is not sufficient to simply check that each blade weighs the same since the centers of gravity might be in different places. The final test is to compare the "moment of weight" of one blade with another—the turning effect produced by the blade's weight. The moment of weight depends on how far this weight is from the center of the shaft. Multiply the weight by the distance.

Make a balancing jig that allows a blade to pivot on an axis passing through its center of rotation. The blade tip must be the same distance from this axis as it would be from the center of the wind turbine. You can then measure the moment of weight by weighing the tip of the blade or by comparing two blades teetering on the same pivot axis. Take care to measure the weight of each blade at the same distance from the pivot so that you obtain an accurate comparison. The actual weight does not matter, but it is important that they all weigh the same when measured at that point and, therefore, have the same moment of weight. It is equally accurate to compare two blades by mounting them on the same pivot axis but projecting them in opposite directions—if they balance, then their moments are effectively the same.

## Determining Moment of Weight




Although one blade is heavier than the other, these two blades balance because they both have a moment of weight of 24 foot-pounds.



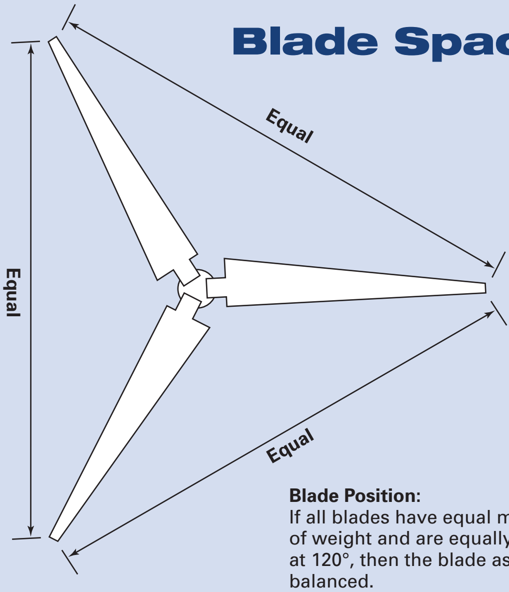

If the fulcrum is set at the shaft center, and the scale at 6 ft., then both blades will weigh 4 lbs.

**A balancing jig allows the fulcrum to be at a point equivalent to the center of rotor rotation.**


**The point of contact with the scale must always be the same distance from the fulcrum. If the weights that the blades exert are different, then add weight to the the lighter ones until they all read the same.**

Hugh Piggott (3)

## Blade Spacing




**Blade Position:**
If all blades have equal moments of weight and are equally spaced at 120°, then the blade assembly is balanced.

To adjust a blade's weight, add some mass somewhere. In the case of hollow blades, you can inject some filler paste inside the tip. Drill one or two holes into the interior, very close to the tip. Then find out how much body filler is needed by trial and error, placing the paste on a scrap of paper or plastic on the blade tip. When you have discovered the desired weight, mix the paste with hardener and force it all through the holes, smoothing and sanding the surface.

If the blade is solid, you will need to add weights to the root. Much heavier weights will be needed here because they work at a much smaller radius from the axis. Often, blade-fixing bolts are used to attach these balancing weights. Longer bolts may be needed if the weights are thick.

When the blades are identical, mount them symmetrically on the rotor hub and check the distances between the three tips. Each pair of tips must be the same distance apart (±0.5%). Try to pull the blades in the direction of their rotation as you tighten the bolts, so that they will not move thereafter when they are cranking out power.

Verify that the tips of the rotating blades track each other precisely in the same plane, neither upwind nor behind the others, and have the same angle or "pitch."

**Adding the same amount of weight to a blade tip has more effect than adding it to the base. The discolored patch on this blade shows where resin paste has been used to fill a hole and then smoothed.**

Hugh Piggott (2)

**Worn bearings can produce noise. They also can produce heat, which can lead to catastrophic failure.**

## Grinding & Growling Noises

A failed bearing in the alternator will produce a steady grinding noise that grows slowly louder over a period of weeks. It is a scratchy growl, akin to the low-pitched white noise of static on the radio. If you hear this, plan to dismantle the machine and replace the bearing before it fails completely and damages the alternator.

Humming or growling vibrations are usually electrical in origin. A clearly tonal vibration suggests an electrical imbalance. Alternating current consists of a series of pulses. Current in the wires equates to torque in the alternator. Pulses of torque produce noise. Most turbines have a three-phase arrangement of coils in the alternator that shifts the timing of these pulses until they blend into an almost smooth torque (with a slight whine due to "ripple"). But if a single wire or a diode fails, the current in the wires become unbalanced and the alternator will vibrate or growl. This vibration is much higher in frequency than the vibrations caused by unbalanced blades. It's closer to a hum than a shake, but it can make the turbine rattle and buzz. Acute vibration can produce dangerous cracks in the structure of the turbine if it is allowed to persist for long periods.

If you begin to hear a new growl in the turbine and its tower, check the wiring with a multimeter. Compare the voltages and the currents. Investigate any asymmetries. Check the rectifier (see "Troubleshooting Small Wind Systems" in *HP134*).

Sudden, loud roaring noises are most likely due to "flutter" of the blades. This is an oscillation caused by torsional instability of the blades when overspeeding. The best solution is to shut down the turbine and/or adjust its control systems so that it protects itself from such conditions.

## Whines & Whistles.

Most small wind turbines will produce a slight whine as they generate electricity. This is due to the ripple current in the rectifier. In most cases the sound is very muted, but it may occasionally be loud enough to be bothersome to some listeners. The bearings also can affect the machine's resonance. Tapered roller bearings can be adjusted with a nut. This may reduce the sound level, but take care to stay within the correct range of adjustment.


Hugh Piggott (3)

**An insulation failure in these high-voltage windings led to arcing between wires.**

Pulse-width-modulated (PWM) load controllers also produce noise. These controllers divert a precisely controlled current into the dump load by switching it on and off rapidly. Diverting some current away from the battery helps prevent overcharging and holds the battery voltage at its optimum level. Pulse-width modulation does create a high-pitched whistling sound, both in the controller and in the dump load resistance/heater. If this sound is a nuisance, there are options for fixing it.

The crude solution is to manually consume more energy from the system so that the controller no longer needs to divert it. A better fix is to install a relay-based charge control device that switches heaters on and off for seconds or minutes. This will not keep the battery voltage under precise control, but, besides silent operation, this strategy has the added advantage of working with standard AC heating elements, which can be energized via the inverter.

Alternatively, it may be possible to find a heater that makes less noise. "Wire-wound" resistors and heaters are the most common, but also the noisiest dump loads. Heaters surrounded by bricks or in a tank of water are much quieter because the mass deadens the noise. Underfloor heating wires are also silent. Why not make your dump loads both useful and peaceful?


**PWM controllers switch heating loads on and off very abruptly to avoid dissipating heat in their transistors. This creates a sharp-edged current wave form containing audible high-frequency harmonics.**

# Overheating & Burned-Out Parts

All electrical circuits and devices lose some energy as heat. Overloaded systems will overheat, and this can lead to failure or even fire. It's a good idea to keep an eye on the instruments from time to time, and check that the turbine is working within its design limits in high wind speeds. It is difficult for wind turbine designers to anticipate what a particular machine will do in every condition. Very high and sustained winds may produce overheating from excessive current, sometimes resulting in electronics failure. It is wise to install the electronic and electrical parts on incombustible surfaces.

Even small turbine design "improvements" can produce overheating. For example, a new blade design can behave differently and defeat the overspeed controls, overheating a turbine that previously limited its output at a safer level.

Electrical overload can burn out the alternator on the turbine, but so can mechanical failures. Worn alternator bearings can overheat or allow the moving magnet-rotor of the alternator to rub on the stator, producing more heat and resulting in burnout of the stator windings.

## Wiring & Connections

If the installer uses an undersized wire in the system, it can overheat dangerously when the turbine has high output in strong winds. Fitting a fuse or breaker to the wire will make it safer, but if it blows or trips you will have a runaway turbine. Disconnected from its load, it will run alarmingly faster and may produce dangerously high voltages in the wires. Be aware that the current in three-phase wiring will be about 80% of the current in the DC side of the rectifier (and not 33% of it, as some people assume). Check the ampacity of the wiring. Thicker wires are both safer and more efficient, so make sure there is a generous safety factor in the wiring design.

Current in wires and connections produces heat in proportion to their resistance. A loose connection becomes warm and corrodes over time. Corrosion is accelerated by the heat, and increases the resistance, in a cycle that ends up with failure and/or scorch marks. Experienced electricians will tighten all electrical connections to their rated torque. Antioxidant paste helps to prevent corrosion of connections. If a connection feels warm or looks tarnished, clean and tighten it, or better yet, replace it.

## Electronic Overloads

Rectifiers are a place where overheating can cause persistent problems in a hard-working wind system. High temperatures shorten the life of the diodes. Make sure that the connections are clean and tight. If the heat sink is getting too hot to touch, keep it clear of obstructions and dust, upgrade its size, or fit a fan.

## Hot Batteries

If the charge controller fails to divert surplus energy into a dump load, the battery will overcharge and get hot. For a short while, this may not harm the battery (and may even be therapeutic for it), but it will gas vigorously and may spatter the surroundings with acid. If this situation persists and the

A burned diode can imbalance turbine load and produce electrical noise.

battery loses much of its electrolyte, it may explode. The *National Electrical Code (NEC)* Article 690.72(B)(1) requires solar-electric systems that use a diversion charge controller as the primary means of regulating battery charging be fitted with a second, independent means to prevent overcharging the batteries, and this is also good practice (although rare) in wind systems.

## Tune In to Your Turbine

It's very satisfying to produce your own electricity from the wind. The sound of the turbine gently converting the free wind into useful electricity is part of that experience. It's well worth listening to that sound and paying attention to any warning signals. And if the sound becomes a nuisance or the warnings become too worrying, it is good to be ready to stop the turbine.

High power output impresses some people, but what actually matters is the total energy production, and that comes from sustained, useful power in normal winds. High peaks of power in exceptional weather conditions will not add much to the energy total, but they may well overheat things and lead to damage or even danger. Keep an eye out for overloaded parts in the system and stay one step ahead of failures.

## Access

**Hugh Piggott** builds, installs, and troubleshoots wind generators at his home in northwest Scotland and beyond. He has written several hands-on books about small wind turbines and RE systems.

www.ndsu.nodak.edu/ndsu/klemen/Audio_and_Video.htm • Audio files of small-wind turbine sounds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# hydro-electric turbine
# BUYER'S GUIDE

by Ken Gardner
& Ian Woofenden

Co-author Ian Woofenden holds a 4-inch pitch diameter Pelton runner while standing in front of an 96-inch pitch diameter Pelton runner at turbine manufacturer Canyon Industries.

Courtesy Dana Brandt

If your stream or pond has sufficient head (vertical drop) and flow, a microhydro-electric system can be a cost-effective and reliable choice to provide renewable electricity for your home. To tap the power in falling water effectively, you need to understand basic physics, how each component works, and how to select and install the appropriate turbine and balance-of-system components for your site.

## Head & Flow, Energy & Power

Hydropower results from the marriage of two forces—gravity and the flow of water—both used to determine how much power and energy can be had. Gravity is what creates the pressure between the inlet and outlet of the turbine. For every 2.31 feet of vertical drop in the pipe, 1 pound of pressure per square inch (psi) is gained. This vertical drop is also called "head"—the vertical distance between where water is taken out of a stream and where it leaves your turbine. The horizontal distance between the source and turbine is also important because of pipe cost and friction losses in the pipe—but it does not affect the basic head measurement.

Flowing water, whether measured in gallons per minute, cubic feet per second, or some other measure, is the other key factor in the hydropower equation. A continuous flow of falling water is needed to make electricity. Measuring this flow accurately is crucial to hydro site assessment and system design.

Once you have these two measurements, you can make at least a rough estimation of the power available. Multiplying the gross head (in feet) by the flow (in gallons per minute) and dividing by a specific factor will give you the potential output wattage. The factor, which is derived from real-world experience with hydro systems, will vary from 9 for larger AC systems to 13 or more for smaller battery-based systems.

Once you have figured power (watts), it's easy to calculate energy (watt-hours): Just multiply by 24 hours in a day to arrive at daily watt-hours, since hydro turbines run around the clock. The relationship of power production with water flow and head is linear, meaning that a site with 1 unit of water flow times 2 units of elevation difference will give roughly the same power production as a site that experiences 2 units of water flow times 1 unit of elevation difference, if all other things are equal. For example: If your stream has 120 feet of head and 45 gallons per minute of flow, you might expect to generate about 11 kilowatt-hours per day.

**120 ft. head x 45 gpm ÷ 12 factor x 24 hrs./day = 10,800 watt-hrs./day**

### Hydropower Equation

Power in kilowatts can be determined by the following equation:

**kW = H x Q x 62.4 x 0.746 ÷ 550 x e**

where

H = head, in ft.

Q = flow, in cubic ft. per second

62.4 lbs. = weight of 1 cubic ft. of water

0.746 kW = 1 hp

550 foot-lbs./sec. = 1 hp

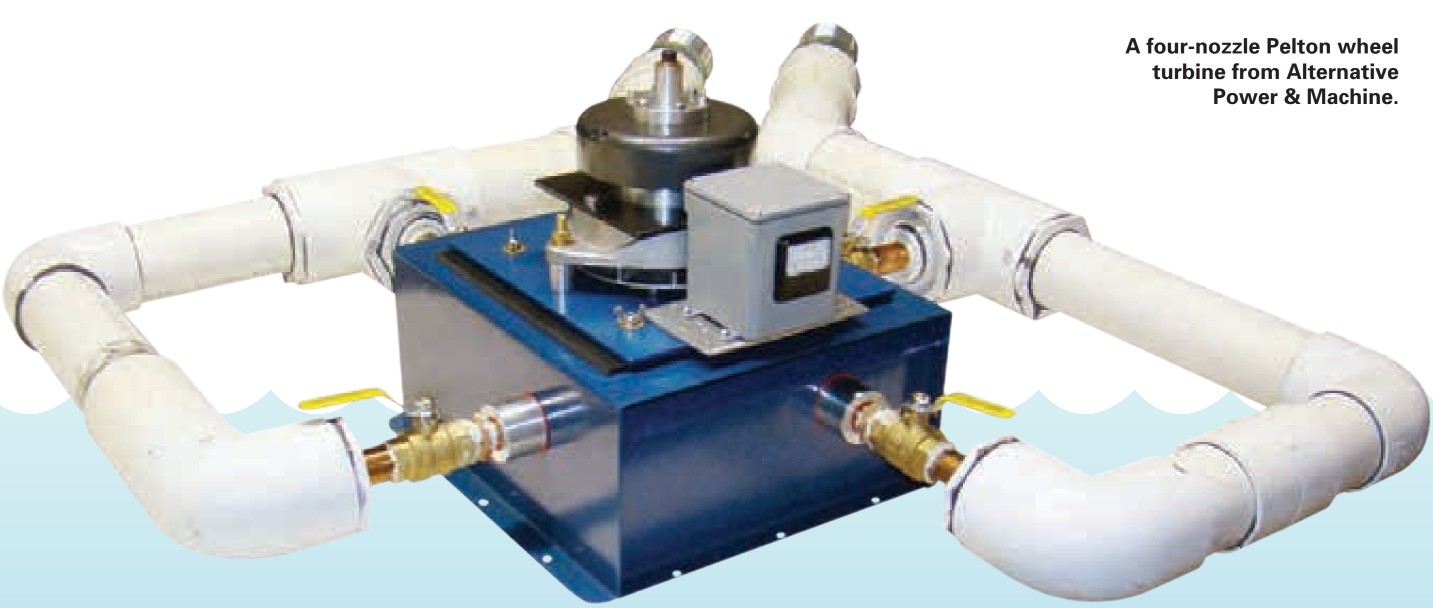
e = an overall efficiency factor* (usually 0.5 for small microhydro systems)

Combining and reducing all these factors results in the following equation:

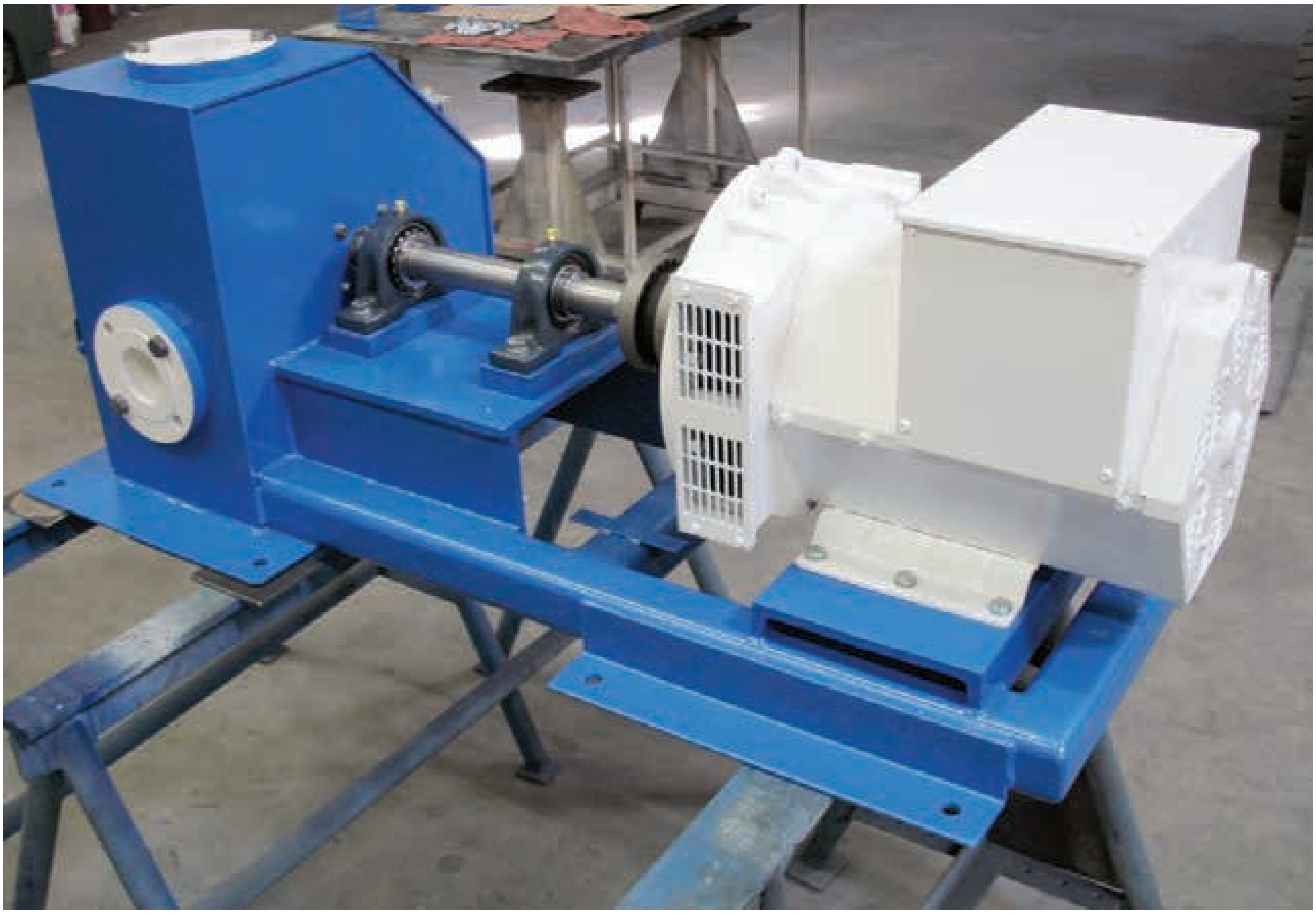
**kW = H x Q ÷ 24, when using cfs; or**

**W = H x Q ÷ 12, when using gpm**

*Note that the efficiency factor can range from 9 for larger AC systems to 13 or more for smaller battery-based systems, and will need to be estimated for your specific site.



**A four-nozzle Pelton wheel turbine from Alternative Power & Machine.**



A two-nozzle Pelton wheel turbine from Dependable Turbines.

## Basic System Components

A hydro-electric system, like any renewable electricity system, is a collection of components. Buying only the turbine will get you nowhere. Hydro systems typically contain these basic components, listed here with their basic purpose:

- Intake structure and screen: Direct clean water into the pipe
- Penstock (pipeline): Carries water to the turbine
- Diversion or weir (used in some systems): Diverts or backs up water to be delivered into the penstock and/or turbine
- Turbine: Converts falling water to electricity
- Controls: Manage turbine and electrical components
- Dump or diversion load: Removes excess energy
- Battery bank (not used in some systems): Stores energy and provides surge capability
- Metering: Monitors system performance
- Disconnects and overcurrent protection: Provide a way to shut the electrical system down and to protect wires from too much current

Hydro system design is not simple, nor is it recommended for those with little experience with electrical, mechanical, and hydraulic systems. Because good hydro sites are few and far between, it is sometimes difficult to find expertise. Many systems are also deep in the back woods and not on public display, so you may need to do some research and networking to find the right people to help you.

## System Configurations

Hydro systems come in four primary configurations, with other variations and permutations. Which type you choose depends on your site, goals, budget, and energy needs.

**Battery-based off-grid systems** are appropriate for smaller systems far from the utility lines, where the peak load exceeds the peak generation on a regular basis. If your hydro system produces 800 W, you'll generate about 19 kWh per day, which is substantial. But without a battery bank and higher-powered inverter, you could not run many appliances or electronics simultaneously, and many loads, such as an 1,100 W microwave, would be impossible to power.

**Batteryless off-grid systems** are appropriate when the generating capacity is 2 kW or more. As household loads decrease and increase, load-control governors constantly adjust the amount of energy to the diversion load to maintain a constant voltage and frequency. Because the system cannot store energy, considerable amounts of power are typically diverted to the diversion load. For this reason, it's worth considering how to use it most effectively. One of the most common ways to use the excess energy is for heating water for domestic use.

**Battery-based on-grid systems** are very similar to their off-grid counterparts. The first of two primary differences is that excess energy can be sold to the grid for payment or credit. The other is that the grid can be used for backup if the hydro system doesn't provide enough energy.

**Batteryless on-grid systems** use the grid as the "dump load," sending excess energy back to the utility's grid for their customers to use. These systems still may require a controller and dump load which only come into play in the event of a utility outage. Batteryless grid-tied systems are perhaps the simplest and most reliable systems because they incorporate no batteries but have the grid available. Their drawback is the lack of backup for any utility outages.

An LH1000 turbine from Energy Systems & Design, capable of 1 kW.

## Turbine Types

All hydro-electric turbine generators, like electric motors, work on the principle of electrons moving through wire as a result of wires passing through magnetic fields (the electromagnetic effect). Hydro-electric turbines use the moving water to turn a wheel and provide the rotational movement necessary to cause the electromagnetic effect in their generators.

Microhydro turbines are generally classified in the range of 100 W to 100 kW, though most turbines used by homeowners are less than 25 kW. Another classification is based on the "head" (water pressure) that drives the turbine.

The ES&D turbine without its draft tube, showing the propeller.

**Low-head** turbines are used in systems with 3 to 20 feet of head. **Medium-head** turbines are for 20 to 60 feet of head, and **high-head** turbines can use 60 to 1,000 feet (or more) of head.

Low-head turbines are typically "reaction" turbines, in which the turbine blades are submerged and produce electricity as an integral reaction with the water pressure. Because they work with low head, these turbines normally require a significant amount of water to produce useful power. For instance, the Energy Systems and Design LH-1000 low-head propeller turbine requires 1,000 gpm of water operating at 10 feet of head to produce 1,000 W.

Medium-head turbines are often reaction turbines. A Francis turbine is a common type. Medium-head turbines often have adjustable flow-control devices to deal with variable water flow under the same head conditions.

A two-nozzle Pelton wheel turbine from Canyon Hydro.

Another type of reaction turbine is a pump that runs in reverse as water flows through its centrifugal works (see the "Pumps as Turbines" sidebar). These can be a simple and cost-effective solution in the right situations.

High-head turbines are the most common microhydro turbines installed in residential systems and are known as impulse or impact turbines. Water is passed through nozzles, converting pressure into velocity and sending a jet of water that "impacts" buckets or vanes attached to a rotating wheel, making it turn.

Electricity produced by most micro-hydro turbines is unregulated and is normally converted from "wild" (unregulated voltage and frequency) AC to DC using a rectifier. DC is then used to charge batteries from which an inverter can provide true 60 Hz AC electricity.

Larger (2 to 100 kW) microhydro turbines can produce 60 Hz electricity directly through regulation using an electronic load governor, which maintains a constant load on the generator through dump loads when electricity is not needed.

Off-grid microhydro turbines require the means to "dump" excess energy when batteries are full or AC loads are reduced. Generally it is best to have redundant (duplicate) diversion loads and/or an overvoltage trip device for protection in the event that a dump load or charge controller fails.

## Turbine Specifications

**Model** is dependent on each manufacturer. Each manufacturer should be contacted to verify a turbine will suit a particular site.

The **generator type** associated with microhydro power is normally either a permanent magnet, a wound-field, or induction. Most smaller turbines use permanent magnet generators, some of which have adjustable gaps between the magnets and the windings for tuning the output. Stand-alone synchronous generators have a wound-field that produces its own magnetic excitation, and induction generators receive their magnetic excitation from the stator, either via capacitors or the grid.

Hydro Induction Power's four-nozzle turgo turbine.

An Energy Systems & Design turbine.

**This Francis runner is an example of a reaction turbine, which is submerged in water and rotates with the force of water flowing through the equipment.**

**A turgo runner which accepts water from nozzles that point down on the spoons from above, at an angle.**

**In a Pelton runner design, water impacts the wheel's spoons parallel to the plane of rotation.**

## Pumps as Turbines

A pump-as-turbine (PAT) microhydro plant is just what it sounds like—the turbine is actually the impeller of a centrifugal pump "running backward" and the generator is simply the pump's induction motor. PAT installations have been running reliably and efficiently for years. Utilities around the world also use the concept in massive pumped-storage installations. For village and household scales, the technology was pioneered by Arthur Williams in his book *Pumps as Turbines: A User's Guide,* published by Intermediate Technology Development Group (ITDG, www.itdg.org). The Canadian hydro-power controls company Thompson & Howe uses PATs to power its factory. I've been working with the Border Green Energy Team (BGET) building PAT systems in Thailand for the past six years.

One key advantage of PATs is that centrifugal pumps are robust, mass-manufactured, more readily available, and less expensive than manufactured microhydro turbines. They're also easier to fix, since it's a lot easier to find a pump mechanic than a microhydro mechanic. A disadvantage is that unlike Peltons and turgos, a single installation is not efficient over a wide range of flows. This can be mitigated by having multiple PATs of different sizes each optimized for a different flow, and turning them on in combination to suit specific flow regimes. We generally design just for dry-season flow and use that year-round. Pump selection (head, flow, and mechanical characteristics) is key—if you're serious about it, read Williams's book.

A PAT system generally uses the pump's induction motor as an AC generator. For grid-tied installations, induction motors are usually the easiest rotating generation to interconnect directly. For stand-alone installations, capacitors are required to provide reactive power that allows the pump's induction motor to generate AC electricity. The process is not difficult, and is described in Nigel Smith's *Motors as Generators for Micro-Hydro Power*, also published by ITDG press. You can find the essential equations from both Williams's and Smith's books in a PAT design spreadsheet at www.palangthai.org/docs/.

—Chris Greacen

**Maximum power** is determined by the watts produced by the turbine at maximum water flow and net head. This number is used to calculate the size of charge controllers and dump loads necessary to protect turbines and battery banks, adding a safety factor.

**Voltage** of the type of generator used. Alternating current (AC) generators are used for either standard 60 Hz electricity or to produce "wild" unregulated voltage and frequency electricity, which is rectified to DC to charge batteries. "Wild" indicates that the turbine is not producing steady 60 Hz AC, and the frequency and voltage may vary. High-voltage generation (hundreds of volts instead of dozens of volts) can be useful in overcoming line losses.

**AC/DC** stands for alternating current and direct current. Most smaller (100 to 1,000 W; less than 2 kW; 48 kWh/day) hydro-electric turbines use permanent-magnet, "wild" AC generators. Most larger microhydro systems (2 to 100 kW) use either an induction or synchronous AC generators. Virtually all spinning generators make AC natively, and how it is transferred and conditioned is based on the application. Battery charging turbines end up producing DC. The grid and your home loads are AC systems, so turbines designed to directly interface with them produce AC in the end.

**Grid connection** is possible with certain makes and models. The grid connection for a smaller (less than 2 kW) hydro system commonly uses a grid-tied inverter, as for PV systems. Larger systems (2 to 100 kW) are connected through switchgear and inductive generators or synchronous generators and governors.

**Runner type** identifies the turbine wheel used to convert water power to rotational power, and is determined by the head and flow available. Through testing, manufacturers have determined the best runner types for various head and flow conditions. Common types are the Pelton wheel, the turgo, the crossflow, and the propeller. Your turbine supplier and contractor can give good advice about the choices.

**Runner Material.** Runners for microhydro applications are commonly made of an alloy, since these materials resist corrosion and are easily cast and machined into shape. Stainless is most common in larger systems. Stainless steel and various bronze alloys are common, long-lasting materials. Plastics are used for smaller, less expensive runners.

*(continued on page 108)*

# Microhydro Turbine Buyer's Guide

| Manufacturer | Model | Generator Type | Max. Power (W) | Voltage | AC or DC | Grid Connection Possible? | Runner Type |
|---|---|---|---|---|---|---|---|
| **Alternative Power & Machine** www. apmhydro.com | 1032 DC | Permanent magnet | 750 | 12 – 120 | DC | Direct | Pelton |
| | 1032 AC | Permanent magnet | 1,100 | 24 – 480 | Wild AC | Direct | Pelton |
| | 1038 DC | Permanent magnet | 960 | 12 – 120 | DC | Direct | Pelton |
| | 1038 AC | Permanent magnet | 1,200 | 24 – 480 | Wild AC | Direct | Pelton |
| | 36 | Wound field | 3,300 | 12 – 120 | DC | Direct | Pelton |
| **Canyon Hydro** www. canyonhydro.com | 6010 | Synchronous or induction | 20,000 | 120, 240, 480 | AC | Direct | Pelton |
| | 751 | Synchronous or induction | 40,000 | 120, 240, 480 | AC | Direct | Pelton |
| | 1051 | Synchronous or induction | 80,000 | 120, 240, 480 | AC | Direct | Pelton |
| | 1215 | Synchronous or induction | 100,000 | 120, 240, 480 | AC | Direct | Pelton |
| | 1220 | Synchronous or induction | 80,000 | 120, 240, 480 | AC | Direct | Pelton |
| **Dependable Turbines** www. dtlhydro.com | Pelton | Wound field | 2,000 | 12/24/48 | DC | Direct | Pelton |
| | Pelton | Synchronous or induction | 27,000 | 120 – 480 | AC | Direct | Pelton |
| | Pelton | Synchronous or induction | 70,000 | 120 – 480 | AC | Direct | Pelton |
| | Turgo | Synchronous or induction | 90,000 | 120 – 480 | AC | Direct | Turgo |
| | Fixed Flow Pumps | Synchronous or induction | 250,000 | 120 – 480 | AC | Direct | Pumps |
| **Ecoinnovation** www. ecoinnovation. co.nz | PowerSpout - BE | Permanent magnet | 1,200 | 12/24/48 | DC | No | Pelton |
| | PowerSpout - ME | Permanent magnet | 1,200 | 100 – 120 | DC | Yes | Pelton |
| | PowerSpout - GE | Permanent magnet | 1,200 | 300 – 400 | DC | Yes | Pelton |
| | PowerSpout - HE | Permanent magnet | 1,200 | 300 – 500 | Either | No | Pelton |
| **Energy Systems & Design** www. microhydropower. com | LH 1000 standard | Adjustable PMA | 1,000 | 12, 24, 48, 120, 240 | Either | Inverter | Propeller |
| | LH 1000 low volume | Adjustable PMA | 500 | 12, 24, 48, 120, 240 | Either | Inverter | Propeller |
| | Stream Engine/ standard | Adjustable PMA | 2,000 | 12, 24, 48, 120, 240 | Either | Inverter | Turgo |
| | Stream Engine/ low flow | Adjustable PMA | 2,000 | 12, 24, 48, 120, 240 | Either | Inverter | Custom |
| | Stream Engine/ Easy Tune | Adjustable PMA | 3,000 | 12, 24, 48, 120, 240 | Either | Inverter | Turgo or Custom |
| **Harris Hydro** 707-986-7771 | Harris 12v | Adjustable PMA | 750 | 12 | DC | Direct | Pelton |
| | Harris 24v | Adjustable PMA | 1,500 | 24 | DC | Direct | Pelton |
| | Harris 48v | Adjustable PMA | 1,500 | 48 | DC | Direct | Pelton |
| **Hydro Induction Power** www. hipowerhydro.com | HV1200 | Induction | 1,200 | 240, 440 | Either | Direct | Turgo |
| | HV2000 | Induction | 2,000 | 240, 440 | Either | Direct | Turgo |
| | HV4000 | Induction | 4,000 | 240, 440 | Either | Direct | Turgo |
| | LV750 | Permanent magnet | 750 | 12, 24, 48 | DC | No | Turgo |
| | LV1500 | Permanent magnet | 1,500 | 12, 24, 48, 120 | DC | Direct | Turgo |
| **PowerPal** www.powerpal. com | 200LH | Permanent magnet | 200 | 110 | AC | No | Propeller |
| | 500LH | Permanent magnet | 500 | 110 | AC | No | Propeller |
| | 1000LH | Permanent magnet | 1,000 | 110 | AC | No | Propeller |
| | 200HH | Permanent magnet | 200 | 110 | AC | No | Turgo |
| | 500HH | Permanent magnet | 500 | 110 | AC | No | Turgo |

[a]For use with step-down transformer/rectifier to DC system; [b]Turgo runners have 7-inch outside diameter (pitch diameter listed); [c]Built-in shunt reads from the supplied DMM. Charge controllers & dump loads are extras.

| Runner Material | Runner Diameter (In.) | Number of Nozzles | Nozzle Sizes (In.) | Head Range (Ft.) | Flow Range (gpm) | Controls & Overspeed Control | Controls, Dump Load & Metering Included |
|---|---|---|---|---|---|---|---|
| Plastic (SS optional) | 5.4 | 1 – 4 | 1/16 – 3/4 | 4 – 1,000 | 3 – 240 | N/A | Ammeter |
| Plastic (SS optional) | 5.4 | 1 – 4 | 1/16 – 3/4 | 4 – 1,000 | 3 – 240 | N/A | Controls & load optional |
| Plastic (SS optional) | 5.4 | 1 – 4 | 1/16 – 3/4 | 4 – 1,000 | 3 – 240 | N/A | Ammeter |
| Plastic (SS optional) | 5.4 | 1 – 4 | 1/16 – 3/4 | 4 – 1,000 | 3 – 240 | N/A | Controls & load optional |
| Plastic (SS optional) | 5.4 | 1 – 4 | 1/16 – 3/4 | 4 – 1,000 | 3 – 240 | Field control only | Ammeter |
| Bronze alloy | 6.0 | 1 – 2 | ≤ 1.0 | 80 – 200 | 100 – 650 | Yes | Yes |
| Bronze alloy | 7.5 | 1 – 2 | ≤ 1.0 | 80 – 350 | 100 – 800 | Yes | Yes |
| Bronze alloy or SS | 10.5 | 1 – 2 | ≤ 1.0 | 200 – 600 | 100 – 1,000 | Yes | Yes |
| Bronze alloy or SS | 12.5 | 1 – 2 | ≤ 1.5 | 80 – 500 | 100 – 1,900 | Yes | Yes |
| Bronze alloy | 12.0 | 1 – 2 | ≤ 2.0 | 60 – 200 | 100 – 2,250 | Yes | Yes |
| Bronze | 6.5 | 1 – 4 | Custom | < 1 80 | < 66 | Optional | Optional |
| Bronze | 8.0 | 1 – 2 | Custom | < 285 | < 660 | Yes | Optional |
| Bronze | 10.0 | 1 – 2 | Custom | < 415 | < 1,190 | Yes | Optional |
| Bronze | 8.0 | 1 – 2 | Custom | < 265 | < 2,400 | Yes | Optional |
| Bronze | 12.0 | | Custom | < 295 | < 6,200 | Yes | Optional |
| Glass-filled nylon | 9.2 | 2 | 0.12 – 0.9 | 10 – 330 | 2 – 127 | External voltage regulator & dump load | Optional |
| Glass-filled nylon | 9.2 | 2 | 0.12 – 0.9 | 10 – 330 | 8 – 127 | 120 VDC voltage controller | Controls & load |
| Glass-filled nylon | 9.2 | 2 | 0.12 – 0.9 | 10 – 330 | 8 – 127 | 400 VDC voltage controller | Controls & load |
| Glass-filled nylon | 9.2 | 2 | 0.12 – 0.9 | 10 – 330 | 8 – 127 | External voltage regulator & dump load | Optional |
| Bronze | 5.0 | N/A | N/A | 2–10 | 500 – 1,000 | Not included | Ammeter[c] |
| Bronze | 5.0 | N/A | N/A | 2–10 | 250 – 500 | Not included | Ammeter[c] |
| Bronze | 4.0[b] | 1 – 4 | 1/8 – 1 | 5–100s | < 100s | Not included | Ammeter[c] |
| Bronze | 4.0 | 1 – 4 | 1/8 – 1/2 | 20 – 100s | 100s | Not included | Ammeter[c] |
| Bronze | 4.0[b] | 1 – 4 | 1/8 – 1 | < 100s | 100s | Not included | Ammeter[c] |
| Bronze | 4.0 | 1 – 4 | 1/8 – 1/2 | 25 – 300 | 3 – 200 | Not included | Ammeter |
| Bronze | 4.0 | 1 – 4 | 1/8 – 1/2 | 25 – 300 | 3 – 200 | Not included | Ammeter |
| Bronze | 4.0 | 1 – 4 | 1/8 – 1/2 | 25 – 300 | 3 – 200 | Not included | Ammeter |
| Hardened SS | 4.0 | 4 | 1/8 – 5/8 | 60 – 600 | 5 – 600 | Optional | Meter |
| Hardened SS | 4.0 | 4 | 1/8 – 5/8 | 60 – 600 | 5 – 600 | Optional | Meter |
| Hardened SS | 4.0 | 4 | 1/8 – 5/8 | 60 – 600 | 5 – 600 | Optional | Meter |
| Hardened SS | 4.0 | 1 – 4 | 1/8 – 5/8 | 15 – 100 | 5 – 100 | Optional | Meter |
| Hardened SS | 4.0 | 1 – 4 | 1/8 – 5/8 | 50 – 600 | 5 – 100 | Optional | Meter |
| Cast iron | 4.5 | 1 | N/A | 4.9 | < 550 | Auto. ELC | Air heater load |
| Cast iron | 8.5 | 1 | N/A | 4.9 | < 1,100 | Auto. ELC | Air heater load |
| Cast iron | 12.4 | 1 | N/A | 4.9 | < 2,130 | Auto. ELC | Air heater load |
| Cast iron | 7.0 | 1 | 1.1 | 16 – 20 | < 100 | Auto. ELC | Air heater load |
| Cast iron | 7.0 | 1 | 1.1 | 23 – 36 | 120 – 145 | Auto ELC | Air heater load |

PMA = Permanent magnet alternator; SS = Stainless steel; Auto ELC = Automatic electronic load controller

**Runner diameter** selection is associated with the velocity of water impacting the runner, which is directly related to available head. The higher the head, the smaller the runner diameter for a given/constant shaft speed. Under ideal conditions, the runner velocity is approximately half the water jet velocity. For practicality, runners for smaller turbines are usually limited to just a few. The runner's speed is adjusted by means of the generator field in relation to battery voltage, or using belt pulley ratios in relation to the output frequency of direct AC systems Again, your suppliers are your best resources for helping make this choice.

**Number of nozzles** is a choice dependent on the range of water flow available to the turbine. Nozzles are opened or closed (manually for most small turbines, and occasionally automatically for larger turbines) to maintain maximum pressure in the turbine pipeline while taking advantage of available flow. Having multiple nozzles is especially important where stream flow varies widely over the year, so you have the option of using more or less water.

**Nozzle size** options are associated with available water flow. Smaller-diameter nozzle sizes are used for lower-flow situations. Nozzles are sized by manufacturers based on potential range of flow. Generally, these parts are removable and replaceable. Larger systems sometimes have adjustable "needle nozzles" or "spear valves."

**Head range** is associated with types of turbine runners that can be used. Higher-head turbines use impact runners, which are generally Pelton or turgo designs. Mid-range turbines (suitable for 20 to 60 feet of head) use reaction runners, which are submerged fully or partially, and include Francis and propeller runners. Low-head turbines (3 to 20 feet) may also use propeller reaction turbines.

**Flow range** will vary for every project site. The table shows the actual flow used in the turbine, which may be 10% to 50% of the stream flow.

**Controls and over-speed control** are necessary for stand-alone AC turbines to maintain 60 cycles per second output under varying load conditions. Electronic load governors usually provide this control for AC units, shunting energy to resistive loads. Control is also necessary for grid-tied systems when utility outages occur. Without the load of the utility grid, a hydro turbine will over-speed, possibly resulting in mechanical and electrical failure.

**Controls, dump load, and metering included** describes what comes with a turbine and what must be purchased separately.

## Turbine Selection

Turbine selection usually begins with determining the site's available head and flow, including variation in seasonal flows. Selection is also based on whether your system will be grid-tied or off-grid, and with or without batteries. Most turbine manufactures provide online questionnaires to assist in turbine selection.

Most turbine manufacturers publish test results for their turbines at various heads and flows, and with various turbine runners. Charts are prepared and compiled for various nozzle sizes and will be used by the manufacturer to recommend a specific turbine.

A PowerPal turgo turbine, rated at 200 W.

The intended use of energy will further determine turbine sizing. There is no point in generating more energy than can be used. Unlike PV systems, hydro-electric turbines generate electricity 24 hours a day, seven days a week. Unused energy must be shunted through to the grid, or to diversion loads—typically water or air heaters—to protect the generator. Inverters and battery banks for hydro-electric systems are normally sized to meet peak load, and store excess energy for these loads and motor-starting surges.

The location of a turbine relative to its interconnected battery bank or loads normally dictates turbine generation voltage. A distance of 100 feet or less may permit use of a low-voltage DC generation turbine. Transmission wire size and voltage drop beyond 100 feet may be excessive at low voltage and will often dictate the selection of an unregulated high-voltage AC turbine (400 to 500 V wild AC) feeding transformers at the battery shed, depending on the wattage.

## Beyond Turbines

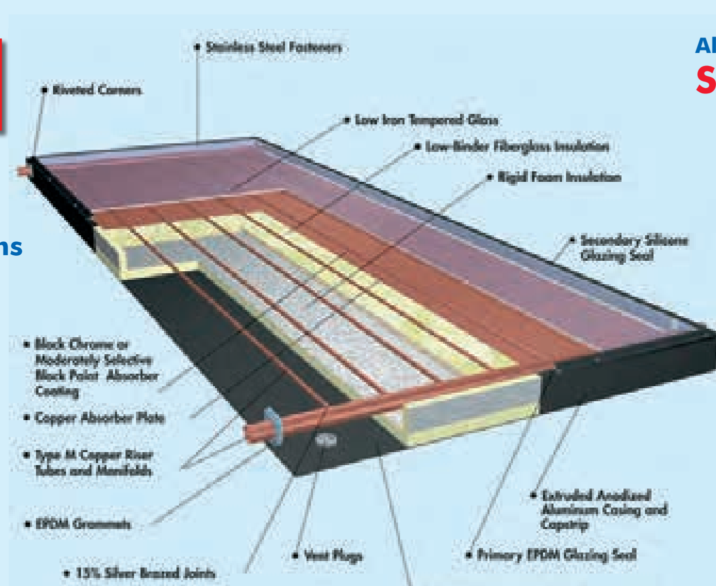
Careful planning is called for, even beyond the selection of the turbine. Each system component must be selected and integrated into the whole. For instance, the design and installation of valves, and connection and discharge pipes, are critical to the proper operation of hydro-electric turbines, because water discharging from a turbine will mix with air and commonly double in volume as it leaves the turbine. Advice from turbine manufacturers is also helpful when considering inlet and outlet piping size.

## Access

Ken Gardner (ken@gardnerengineering.net) is a consulting civil engineer and master electrician. He owns an RE company in Ogden, Utah, and teaches classes for Solar Energy International.

Ian Woofenden (ian.woofenden@homepower.com) teaches and writes about hydro electricity and other renewable sources in North and Central America. He dreams of head and flow at his solar- and wind-powered homestead on his flat island property.

Chris Greacen (chris@palangthai.org) builds picohydro-power projects in rural Thailand and Vanuatu when he's not living on another flat island near Ian Woofenden.



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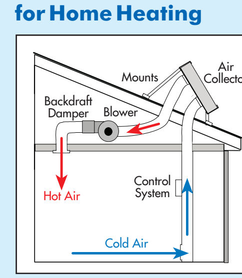

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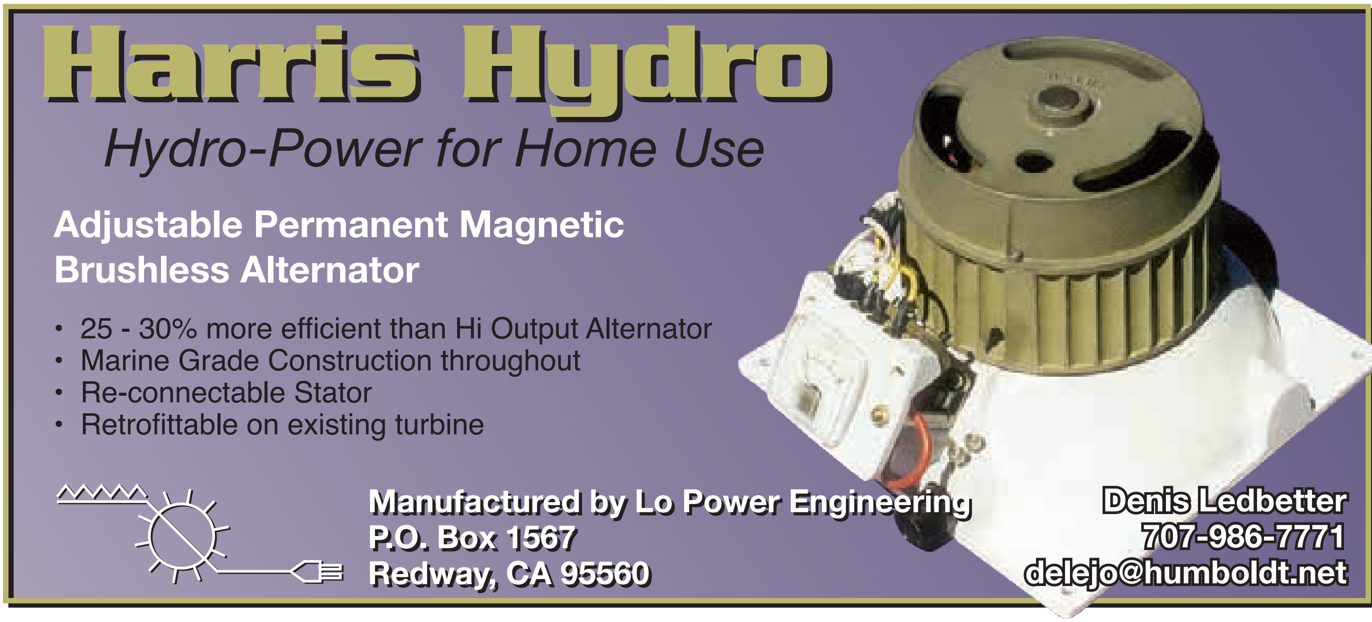
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# Microinverters

## & AC PV Modules

**by John Wiles**

No discussion of PV systems would be complete without a look at the newest inverter technologies that installers and inspectors will encounter. These new technologies include microinverters and AC PV modules.

**Two Enphase inverters, showing their DC input connections, and AC input and output connections.**

### Microinverters

Most grid-tied inverters are "string inverters"—they operate with a string of series-connected PV modules. These inverters range in power from 700 watts up to 1 megawatt. DC maximum system voltages can be as low as about 125 volts.

Enphase's microinverter, which hit the market in 2008, is a tiny inverter—about the size of a video cassette—that is designed to work with a single PV module and operate at a maximum of about 70 VDC (for one Enphase model). The inverter is electrically connected directly to the PV module using the existing conductors and connectors attached to both the module and the inverter.

Microinverters are grid-tied inverters with DC ground-fault protection (*National Electrical Code* Section 690.5) in the current offering. Enphase's microinverter internally grounds the positive DC module conductor. That internal grounding bond (via the DC ground-fault protection circuits; *NEC* 690.5) requires that the inverter have a DC grounding electrode terminal and that the terminal be on the outside of the Enphase microinverter case. Other types and brands of microinverters may ground differently or switch to an ungrounded configuration using modules with the new "PV Cable" required by *NEC* 690.35 for such systems.

With both AC input and output connections, microinverters have been UL-listed to allow multiple inverters to be connected on the same cable and circuit. With a power output in the 175 to 210 W range (depending on the model), the rated AC output current at 240 V will range from 0.73 to 0.88 A. On 14 AWG cable with a 15 A overcurrent device, the rated current for that circuit is limited to a maximum of 12 A. This rating will allow up to 16 inverters for the 175 W version and up to 13 inverters for the 210 W version to be installed on the same AC output cable.

### AC PV Modules

Take a standard DC PV module and connect a microinverter to it, fasten the microinverter to the back of the module and cover the exposed DC conductors so none of them are accessible, and secure a listing to UL1741 for a pre-assembled module/inverter device, and you have an AC PV module. At least one AC PV module is available—Akeena Solar's Andalay AC PV module. Since the DC wiring between the module and inverter is no longer accessible and has become an integral part of the product, *NEC* DC requirements no longer apply to the AC PV module.

Akeena's module has a unique frame that serves as the module mount. Because each module is connected with stainless steel threaded rods to the adjacent modules, only one equipment grounding connection is needed for the array. The AC PV module has no requirement for DC grounding electrode terminals, and the single AC equipment-grounding conductor from the module/frame rack may be all that is needed in many installations. In ground-mounted arrays, Section 690.47(D) requires an additional grounding conductor from the array frame to a grounding electrode.

### DC Connections

Should the microinverter or module fail, the microinverter's DC connection to the PV module will need to be disconnected for replacement. With today's inverter designs, the maximum voltage will be about 70 V and the current may be in the 3 to 8 A range—posing risk of damage (and creating a possible safety hazard) to the connector. While some inspectors may request a costly and impractical load-break rated disconnect, the code-compliant solution is really quite simple: Covering the module with a thick blanket or other opaque material per *NEC* 690.18 will drop the DC output voltage and current (and the AC current from that inverter, but not the other inverters connected to the same cable) to near zero, allowing the module/inverter DC connectors to be opened safely. Opening this connection with the module covered will likely be safer than opening the same connectors on a module in a high-voltage string of modules. The AC PV module has no accessible DC connections, so this issue is avoided.

## AC Connections

Each microinverter or AC PV module has an AC input/output cable to allow multiple parallel inverter connections. Under bright sunlight conditions, this cable may carry currents ranging from 0.7 A at 240 V from the first module/inverter in the set to as much as 12 A at 240 V through the last connector of a set with multiple devices. Servicing a single AC PV module or utility-interactive microinverter could be accomplished by covering the module to reduce the DC (and hence the AC) current to zero. However, only covering the module in question in the set would still allow current from the other modules/inverters to flow through the cable. Although inverter anti-islanding circuits minimize the hazard somewhat, since they shut down very rapidly and reduce arcing when the AC connector is opened. Opening these 240 VAC connections under load could damage the connector and pose a shock hazard.

A safer solution would be to open the AC circuit at the PV back-fed breaker in the building service entrance panel—but only if that breaker can be locked open. However, breaker lock-outs are few and far between and lock-out/tag-out procedures are often not used in residential and commercial electrical systems. *NEC* Section 690.14(D) addresses this situation and points to a solution: Installing a separate AC disconnect near the AC PV modules or microinverters meets *NEC* requirements and enhances system safety. A common 60 A, unfused, pull-out air-conditioning disconnect (less than $10) can serve as the disconnect, a place to terminate the AC output cable from a set of microinverters or AC PV modules, and a place to originate the field-installed wiring system to the AC load center in the house.

Since a microinverter and an AC PV module work individually, each inverter extracts the maximum power from its matched module—independent of the other module/inverter pairs in the array. The outputs of the microinverters or AC PV modules are connected in parallel rather than in series, which isolates the performance of one from another.

The outputs are at 240 VAC, with the AC output circuits acting much like AC branch circuits. When utility power is removed at any disconnect in the circuit, all the inverters go dead and do not pose the safety hazards associated with daytime, "always-energized" DC circuits, which operate at hundreds of volts between the modules and a string inverter. If a short circuit or ground fault were to occur in these AC output circuits, the dedicated branch circuit breaker would open and the circuit would be de-energized. Opening the main service disconnect or the back-fed PV breaker will de-energize those PV AC output circuits—a boon to firefighters.

Numerous microinverters and AC PV modules are being installed. They are even being sold in home improvement centers, building supply houses, and electrical supply houses—so the general public is buying them. PV installers are best equipped to design and install these devices and understand the *NEC* requirements that apply to them.

## A Word of Warning

The microinverter or AC PV module system using load-side connections, just like conventional string inverters, must be connected on a dedicated circuit per *NEC* 690.64. See recent *Code Corner* articles for details on how to properly interconnect single and multiple output circuits to the grid. They should never be connected to a circuit protected by a GFCI or AFCI, since neither of these devices has been tested or listed for back-feeding.

**Akeena Solar's Andalay AC PV module has no requirement for DC grounding electrode terminals, and the single AC equipment-grounding conductor from the module/frame rack may be all that is needed in many installations.**

www.akeena.com

## Access

**John Wiles** (jwiles@nmsu.edu; 575-646-6105) works at the Institute for Energy and the Environment (IEE) at New Mexico State University. John provides engineering support to the PV industry and a focal point for PV system code issues.

Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist, previous "Perspectives on PV" and *Code Corner* articles, and *Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices*, by John Wiles

# In Hot Water

by Kathleen Jarschke-Schultze

*Home & Heart*:
Tales of off-grid life from seasoned homesteader Kathleen Jarschke-Schultze.


For years, we coveted a hot tub. However, living off-grid as we do, that would not be as easy as just going to a local retailer to purchase a conventional spa. We wanted a real wooden tub—no plastic or fiberglass for us—and a way to heat the water that did not suck back a huge amount of electrons.

## Terminal Tub

Several years ago, we attempted a hot tub coup. My brother found a used 4- by 6-foot redwood tub that had been continuously filled with water—a sign that it might be sound and leak-free. The seller wanted $200. There was just the tub, nothing else, yet it seemed like a good deal. We picked it up, and loaded it on its side in the back of our pickup.

I was all enthusiasm—I checked out library books on hot tub structures and placement. Where we live, there are no flat places—you have to make one. We chose a spot beyond the large PV tracker, on a steep, short rise.

Our friend, Jose, built the structure I picked from a book. Steps lead up to a covered deck that curves around the tub. In the tub, you could be under the roof or under the stars.

My husband Bob-O dug a trench and buried electrical conduit and a gas line. We planned on heating the tub with solar hot water, with propane backup. Under the deck, with access from the side, was room for all the pumps, filters, and heater.

Our plans never bore fruit. We could not get the tub to hold water. We set up a sprinkler inside the tub and ran solar-pumped water to it every day, as long as the sun shone. Although the wood was saturated, 3 inches of water was all we could get the tub to hold. After a lot of wasted water, we gave up. Upon closer inspection, we found rot under the hoops that hold the staves in place. We would not try to save it.

## Water Wishes

For eight years, the project sat frozen in time. Through all the sun, rain, and snow the "tub that needs no towel" stood upright and unused. Bob-O wanted to tear down the structure. Over those years, our tracking PV array had been expanded so that now the hot tub building shaded the modules in the late afternoon, decreasing the PV system's output at certain times of the year.

I kept putting off the demolition. I wanted to find some way to move the structure, *in toto*, to a new location. I was not willing to give up the hot tub dream. But unsure about how to accomplish this, and even with much discussion, we did nothing.

Then my sister Mary got a Snorkel hot tub. It's a wooden hot tub with a wood stove that sits right in the water, on one side of the tub, with a fence between for safety. All stove openings are above the water level, so water cannot get into the stove—hence, the name "Snorkel."

My sister Tamra also got a Snorkel. Although used and years old, her tub performed as well as Mary's. We began to re-evaluate our hot tub dream.

Our property is in continual need of having its dead and downed wood removed, since that could keep a wildfire going until the live trees also catch fire. Usually this wood is cleaned up and stacked in large piles to be burned when the wet weather starts. Locally, this is called "burning slash."

We realized that we had a seemingly endless supply of small, dry, dead wood for the Snorkel. We would not have to burn any of the wood we buy and stack in the woodshed for the house.

We called Snorkel and ordered our tub, while we considered where to place the new tub. I wanted a location with some solar access so we could install a passive solar preheater on the tub. But every place we chose needed a lot of site preparation before we could send for the tub. Snorkel was willing to hold our order until our new pad was ready.

## A Salvaged Site & Seasonal Salvation

One day, while Bob-O was at work, I climbed inside the old tub. I could see daylight through the cracks in the staves. I wiggled one and it slipped out of the hoops. I threw it aside. Each stave was easier to wiggle out and discard. Eventually, the hoops fell around the round bottom. I took the bottom wood pieces to be used as a round, level deck for my solar cookers over by the greenhouse.

When Bob-O got home, I showed him the cleaned-up site. "Look's like we'll put it here," he said, "Tell them to ship it."

Snorkel advises that you assemble your tub within two weeks of its arrival. This is because it is shipped with a certain amount of moisture content in the wood. Leave it too long in the weather and the staves will be more difficult to assemble.

We put the tub together on the flat, clean, concrete shop floor. With the very cool rubber mallet and wrench that comes with the tub, we set to work. All totaled, it took us about six hours until we were looking at the beautiful cedar tub.

We used our tractor's forks to move the tub from the shop to the site. Making a cradle between the forks with a large, flat piece of cardboard, we rolled the tub onto the forks. A tie-down strap secured the tub across the middle.

Bob-O slowly drove the tractor into position. We rolled the tub off the forks and onto the foundation. The stove did not take long to place in the tub. While Bob-O did that, I assembled the wood safety fence that attaches to the stove side. Then we filled the tub with water—400 gallons.

That first night, we lost only 3 inches of water. In the morning, we added more water and started a fire in the stove. The warm water hastened the swelling of the wood and lessened or stopped any leaks.

And that night, we took the plunge. Soaking in our wood-fired hot tub was bliss. We gazed at the stars and made plans to improve the pavilion. The future looked warm—and a little steamy. We did not know then that in a few short weeks the nighttime temperature would drop to 7°F or below—and stay that cold for days. Up on the hill our spring froze, and the hot tub became our only watery solace.

## Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is planting only open-pollinated seeds at her off-grid home in northernmost California.

# RE happenings

*For more energy fair listings, see "RE-Sources: 2010 Energy Fairs" on page 88.*

## ARIZONA

May 17–22, '10. Phoenix. SOLAR 2010, ASES National Solar Conference. Info: ASES • www.solar2010.org • conference@ases.org

## CALIFORNIA

Apr. 21–22, '10. San Ramon, CA. Solar Leadership Summit. Network, problem-solve & share with solar industry leaders. Info: SolarTech • www.calsolarsummit.org

Arcata, CA. Workshops & presentations on RE & sustainable living. Info: Campus Center for Appropriate Technology • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

## COLORADO

May 20–23, '10 (again Jun. 10–13, Jul. 22–25 & Aug. 19–22). Crestone, CO. Solar Heating & Natural Building Design workshop. Info: www.crestonesolarschool.com

Paonia, CO. Workshops & online courses on PV, water pumping, wind, RE businesses, microhydro, solar hot water & more. Info: Solar Energy Intl. • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

## IOWA

Apr. 13–May 25 '10. Monticello, IA. Solar Thermal Energy. Learn to design & build a SHW system, hands-on & classroom. Info: Kirkwood Continuing Education • www.kirkwood.edu

Iowa City, IA. Iowa RE Assoc. meetings. Info: 319-341-4372 • irenew@irenew.org • www.irenew.org

## MARYLAND

May 7–9, '10. Baltimore. The Solar and Wind Expo. Business-to-consumer show on RE. Solar, wind, geothermal &EVs. Info: www.TheSolarandWindExpo.com

## MASSACHUSETTS

Hudson, MA. Workshops: PV, wind & solar thermal. Intro to advanced. Info: AltE Univ. • http://workshops.altenergystore.com

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West Branch, MI. Intro to solar, wind & hydro. First Friday each month. Residential system design & layout. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

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## NEW MEXICO

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## NEW YORK

May 24–28, '10 (again Jun. 14–18, Jul. 5–9 & Aug. 2–6). Delhi, NY. PV Design & Installation Basics training. Info: SUNY • 607-746-4545 • communityservices@delhi.edu

## OREGON

Jul. '10 EORenew workshops. John Day, OR. Jul. 19–22: Cob Bench Sculpture & Construction; Jul. 23: Cob Techniques & Materials Lab; Jul. 26–27: Earthen Plasters. Info: (see EORenew)

Jul. 23–25, '10. John Day, OR. SolWest RE Fair. Exhibits, workshops, speakers. Info: EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech. internships. Info: Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

## TENNESSEE

Summertown, TN. Workshops on PV, alternative fuels, green building & more. Info: The Farm • 931-964-4474 • ecovillage@thefarm.org • www.thefarm.org

## TEXAS

Austin, El Paso, Houston, North TX & San Antonio. TX Solar Energy Society chapters and affiliates have regular meetings across the state: Info: www.txses.org

## WASHINGTON STATE

Guemes Island, WA. '10 workshops: Apr. 5–9: Solar Hot Water; Apr. 10–12: Solar & Radiant Heating; Apr. 13–17: Microhydro Power. Info: (see SEI listing in CO)

## WISCONSIN

Jun. 15–16, '10. Stevens Point, WI. Small Wind Conference, for installers and industry. Info: www.smallwindconference.org

Jun. 18–20, '10. Custer, WI. The Energy Fair (a.k.a. MREF). Exhibits & workshops on solar, wind, green building, transportation, energy efficiency & more. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: See MREA listing below.

Custer, WI. MREA '10 workshops: Basic, int. & adv. RE; PV site auditor certification test; veg. oil & biodiesel; solar water & space heating; masonry heaters; wind site assessor training & more. Info: MREA • 715-592-6595 • info@themrea.org • www.the-mrea.org

Amherst, WI. Artha '10 workshops: Intro to SHW & Space Heating Systems; Installing a SHW System; Living Sustainably & more. Info: Artha • 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

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**Direct-beam radiation** is often associated with desert environments but can appear anywhere on Earth on any given day. On clear, sunny days, most solar radiation is direct-beam radiation. This bright sunlight, when blocked, gives a very distinct shadow, and is the radiation that produces the most energy in PV and solar thermal systems. The rays from direct sunlight can be intensified for various uses. For example, they can be focused with a magnifying glass to light a fire, or they can be manipulated with lenses or mirrors—often used with tracking systems in concentrating solar equipment.


Courtesy Greg Egan

**Besides direct solar radiation, reflected sunlight off the snow provides an additional source of energy for these PV arrays.**

**Diffuse solar radiation** is more common in most areas. When sunlight is absorbed or "diffused" by clouds, haze, or air pollution, its energy is reduced. Diffuse radiation cannot be concentrated because the sun's rays are not in an orderly, parallel arrangement. Diffuse or scattered sunlight casts light shadows or none at all. Although diffuse sunlight doesn't have as much energy as direct-beam, it can be significant—that's why you can get a sunburn on a partly cloudy day. Similarly, although there is less energy available, photovoltaic, flat-plate, evacuated tube, and swimming pool solar systems can all use diffuse radiation to generate at least some energy.

**Reflected radiation** can cause unexpected output gains from solar energy systems. Snow or any light-colored surface in front of an array can aid in energy production. White-painted surfaces and aluminum reflect 80 to 90% of solar radiation and can "bounce" direct or diffuse sunlight onto collectors and modules. Reflected radiation is specific to an installation site and varies depending on the color and area of reflecting surface and the sun's position in relation to that surface.

More direct beam radiation results in a greater total solar resource. Areas with high humidity and predominately cloudy weather have less solar energy available than arid, sunny climates. Sizing programs and designers use solar insolation data from the National Renewable Energy Laboratory's *Redbook*—an out-of-print manual that originally had a red cover—to predict solar system output. This data is available online at http://rredc.nrel.gov/solar/pubs/redbook/.

Redbook data displays total solar radiation (direct plus diffuse) at various tilt angles for various locations, which illustrates how solar radiation varies widely throughout the United States. For instance, the desert sunbelt has more than double the solar radiation that's available in Alaska, since that state's resource is diminished by the lower direct radiation from its high latitude. Even on a clear day, at latitudes from the equator, the solar radiation hits the earth's surface at an angle and will diminish due to the increased amount of atmosphere it has to permeate.

The Redbook lists Las Vegas, Nevada, as having an average insolation of 6.5 kWh per square meter, per day (aka "sun-hours") and Pittsburgh, Pennsylvania, at 4.2 sun-hours, when collectors or modules are tilted south at an angle equal to the location's latitude. At this tilt angle, without compensating for ambient temperatures that can influence solar production, a system in Pittsburgh would need about 55% more collection surface than a system in Las Vegas to produce the same energy. If you gamble on some reflected radiation in Pittsburgh, the system might need only 50% more area—perhaps not a bad bet for systems in the snowbelt.

—Chuck Marken


Bending over
backwards
for you