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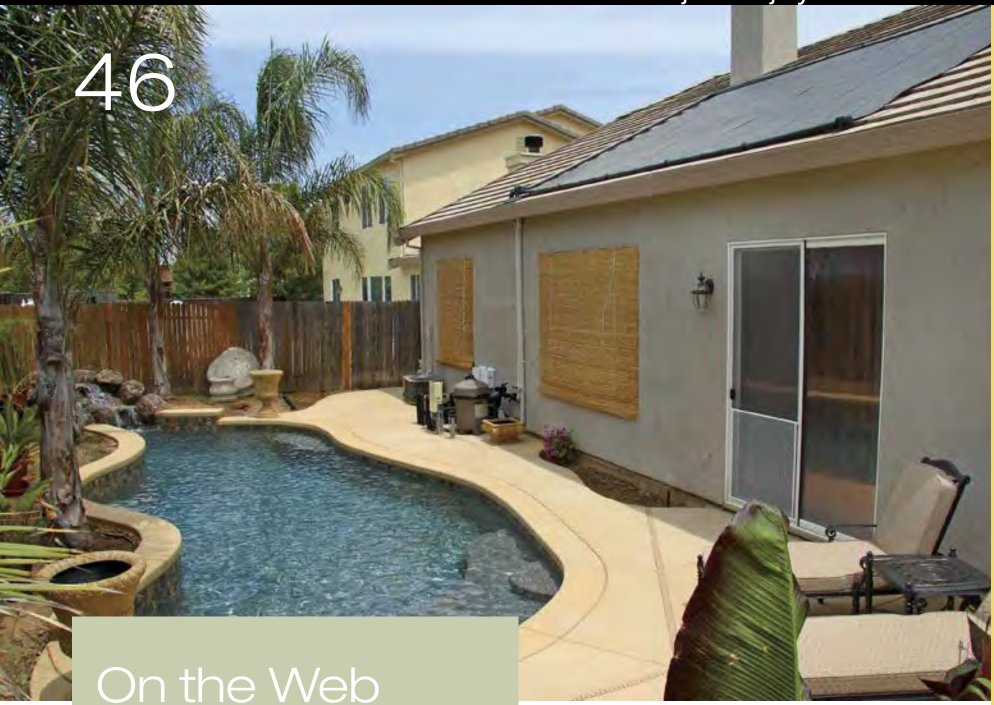

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Main Features

Photos, left to right: Aztec Solar, Feit, Nunatak Alternative Energy Solutions, Jenny Heinzen, Nunatak Alternative Energy Solutions, Andy Kerr

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On the Cover

Solar pool heating systems are a cost-effective and efficient solution for extending the swimming season.

Photo courtesy Aztec Solar

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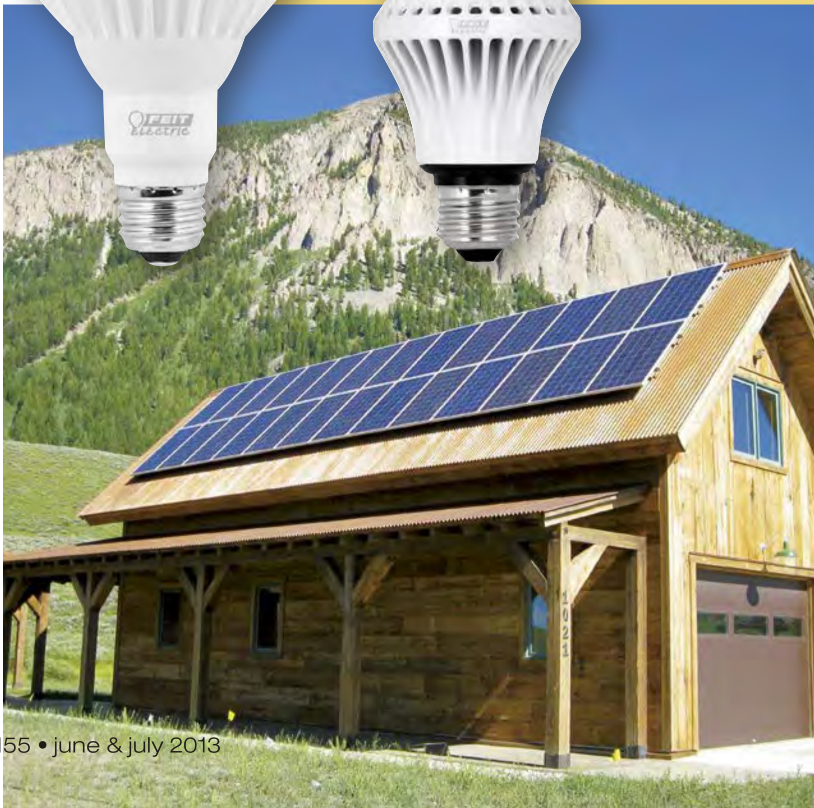

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Hard Times are a Good Time for Renewables

With a struggling economy, government deficit and debt rising, prices on basic commodities jumping up, and concerns about the future widespread, you might think that the solar industry would be struggling. After all, many people see renewable energy (RE) systems as luxuries, not necessities. And indeed, residential-scale grid-tied RE is still primarily a middle-class-and-up phenomenon.

Despite all this, recent reports show that the U.S. solar market grew more than 70% in 2012. Why?

The cost of RE systems—especially solar electricity—has dropped substantially. And we have already taken the easy pickings when it comes to fossil fuels, which is reflected in their rising prices. I don't hear anyone predicting reduced energy costs from the nonrenewable sector.

Meanwhile, I see some of the common motivations for investing in RE systems coming to the forefront. Motivations include environmentalism, independence, reliability, cost, and "the cool factor." Some of those motivations get trumped by more pressing needs in a tight economy. But for people who have enough money (or access to it at low interest), the combination of *reasonable cost* and *excellent reliability* is a big draw, especially in hard times.

Some years ago, I worked with a potential client who told me he'd "think about it" when I proposed a $25,000 PV system for his home. He called me back after his two-week vacation and said that, unfortunately, he'd lost about that much money in a stock market dip, and would not be able to buy the PV system. I couldn't help but think that a RE system would have been a better investment. That $25,000 could have been on his roof, generating electricity for the rest of his life.

When times get hard, we are pushed toward scrutinizing our expenses and jettisoning things we don't really need or want, while finding more economical ways to supply our core needs. Of course, people focused on sustainability and living with a small footprint do this in good times and bad. For me, that means questioning every purchase and bill, and asking whether I really need something, whether I can get it at lower cost, and whether it will help take care of me and my family for the long term. I love buying things that increase the productivity of my property, and shedding those that don't. The orchard I planted 24 years ago has delivered fruit for a couple of decades, and will continue to do so. On the other hand, many things I've purchased have given fleeting pleasure, frustration, or have even cost me a great deal to maintain.

A wise investor in the future.

Investing in energy efficiency and RE looks sensible when you take a long-term view. PV modules purchased today may still be producing energy 40 to 50 years from now, and insulating your home will save energy for the home's whole lifetime. These purchases provide not only stability in energy conservation and supply, but in energy need, availability, and cost—for the purchasers, and in the grander scheme, for society.

Hard times help smart people focus on what is reliable, long-term, and important. Renewable energy systems give all that and more—the satisfaction of investing in something that is good for your family, community, and planet.

—Ian Woofenden, for the *Home Power* crew

Think About It...

"Our dependence on fossil fuels amounts to global pyromania, and the only fire extinguisher we have at our disposal is renewable energy."

—Hermann Scheer, former General Chairman of the World Council for Renewable Energy

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PV Reincarnation

Most modern PV modules are warranted to produce electricity for 20 to 25 years and have a projected lifetime of 35 years or more. But what happens to modules that die prematurely due to transportation, installation, or other damage, or when their life span is up?

Whether damaged or no longer producing power, PV modules should be recycled.

Courtesy Jim White

Until recently, the recycling of broken or end-of-life PV modules was not mandatory in Europe. In 2012, the European Union (EU) Parliament officially changed the guidelines for its Waste Electrical and Electronic Equipment (WEEE) directive. Under the amendments, 85% of all used PV modules must be collected by the "producers" at the end of their lives and at least 80% of the solar module (by weight) must be recovered. Who constitutes a producer is at the discretion of each of the 27 member states, which must implement the new law by February 2014.

Today, the majority of producers selling in the European market offer *voluntary* take-back and recycling through one of two programs, PV Cycle or CERES. But now, with the introduction of the new WEEE directive, each producer will need to *guarantee* its PV modules' take-back and recycling.

European solar companies started PV Cycle to be proactive, hoping to avoid formal inclusion in the WEEE. Some companies were dissatisfied with the business model and founded CERES. Since 2010, nonprofit Brussels-based PV Cycle has collected and recycled more than 5,600 tons of PV waste (80 tons in 2010; 1,400 tons in 2011; and more than 4,000 tons in 2012 and early 2013). The majority of collected modules have come from Germany.

The service is free to module owners, supported by annual fees (ranging between €1,000 per year to €25,000) paid by members—more than 500 module manufacturers, importers, and associations as of March 2013, up from 236 in 2011. Discarded modules are collected at 283 collection points throughout Europe (up from 185 in 2011). After collection, the modules are taken to recycling plants for dismantling and processing. Recovered materials include glass, ferrous and nonferrous metals, and certain semiconductor materials, junction boxes, and cables.

Paris-based CERES—a nonprofit association created under French law—has collected about 600 tons of PV waste since 2012. The company claims to be the only program in Europe that recycles every element of a PV module, including the cell. Like PV Cycle, the collection program is also free to end users, supported by annual membership fees (between €600 and €5,000). So far, the program has signed up 50-plus producers, importers, and integrators. Waste, including manufacturing scrap, can be deposited with electronic waste management companies that already have necessary permits.

Recycling and recovery companies in Europe are stepping up to meet the new WEEE directive. Many waste treatment companies are exploring the new business opportunity. Most have established collection systems for e-waste but would need to add technology to handle to PV items, according to Karsten Wambach, a PV waste consultant in Germany and the former president of PV Cycle.

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"There are some pilot activities running, but it might be too early for significant investments due to the small quantities of PV waste present and the highly dispersive waste streams. With current technology, there will be no problem to fulfill the targets of the waste laws," Wambach says. "One can expect the market to steadily grow, with the first significant amounts coming back in the 2020s."

U.S.A.

In the United States, end-of-life disposal of solar products is governed by the Federal Resource Conservation and Recovery Act (RCRA) and state policies that govern waste. To be governed by RCRA, modules must be classified as hazardous waste, which means that a product fails the Toxicity Characteristics Leach Procedure (TCLP) test. It all depends on whether the chemicals (such as lead or cadmium) leach out when the glass and other materials are crushed. Because many companies have phased out or reduced lead content to trace levels and have improved manufacturing to reduce hazardous chemical content, most newer modules may pass the TCLP test. Older modules may not.

Some states, like California, have considered adopting regulations that supersede federal standards, and add broken or end-of-life PV modules to the broad category of potentially toxic or hazardous products commonly known as e-waste. California's hazardous waste criteria and leaching tests are more stringent than the federal criteria. If the state's new regulations are implemented, certain modules that are excluded from classification as hazardous waste under federal rules could be regulated as a hazardous waste in California.

Although the chemicals in PV modules do not pose any threat during the modules' operational life, modules disposed of in a landfill or burned in an incinerator could release toxins into the groundwater or air. For example, some thin-film technology—mainly used in large commercial installations—contains cadmium, a carcinogen that may pose a serious health risk if ingested or inhaled. The metal is considered highly toxic by the U.S. Environmental Protection Agency and Occupational Safety and Health Administration, and is banned by the European Union's Restriction on Hazardous Substances directive, though the policy allows an exemption for its use in solar modules.

"The U.S. industry as a whole is not doing enough to ensure safe handling of current end-of-life modules," says Dr. Vasilis Fthenakis, senior scientist at Brookhaven National Laboratory and the director of the Center for Life Cycle Analysis at Columbia University. "We need an industry-wide recycling program liked the one in Europe."

The Solar Energy Industries Association is pushing a voluntary environmental responsibility pledge. So far, only seven of the 81 members have signed. The association also has established an internal task force to develop a program model that can be adopted at the state level. The association has been collaborating with European industry associations, as well as European take-back and recycling programs, in hopes of learning the best practices—and missteps to avoid.

Additionally, SEIA is participating in discussions conducted by the International Energy Agency's Photovoltaic Power Systems Programme, an international framework for safety, health, and life-cycle practices for the PV industry.

"One potential problem that needs to be addressed is whether it should be the installer, the manufacturer, the distributor, the developer, or the end user who is responsible for recycling the module," says Thomas Young, vice president of investor relations for Trina Solar. "Then there's the issue of jurisdiction. What if the module is shipped from the United States to a distributor in Spain, who then sells it to a developer somewhere in Africa? Do we follow the recycling regulations in the country of origin or the country where it is ultimately installed? And how do we track that? We can only hope that the laws will be unified, but if not, there could be potential conflicts."

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What's in a Module—& What Can Be Recycled?

Glass: By weight, about 80% of a crystalline-type module is glass, which encapsulates the thin layers of semiconductor materials and protects them from exposure to the weather. The glass can be recycled.

Metals & plastics: About 10% of a PV module's total weight comes from metals such as aluminum and copper. Plastics, used for connections and in frames or laminates, compose a smaller percentage. Ferrous and nonferrous metals are recyclable.

Semiconductors: Several forms of silicon (monocrystalline, multicrystalline, and amorphous) are most commonly used as semiconductors, converting sunlight to electricity. Other materials that compose polycrystalline thin films include copper indium diselenide and cadmium telluride. They constitute between 1% and 2% of the module, by weight. Certain semiconductor materials can be recycled.

First Solar's in-house PV recycling facility.

Courtesy First Solar

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New Life for PV Parts

"There is demand for end-of-life solar panel recycling now, and our growing business is proof," says Jennifer Woolwich, founder of PV Recycling in Tempe, Arizona. Several big-name waste management companies are rumored to be experimenting with PV recycling, but none have entered the market yet. For now, PV Recycling is the only independent recycler of PV products in the United States.

Founded in 2009, the company got its start serving small- to medium-sized installers with broken or end-of-life modules on hand, but now its core business has shifted to include several large installers and manufacturers, including SolarWorld and Trina Solar.

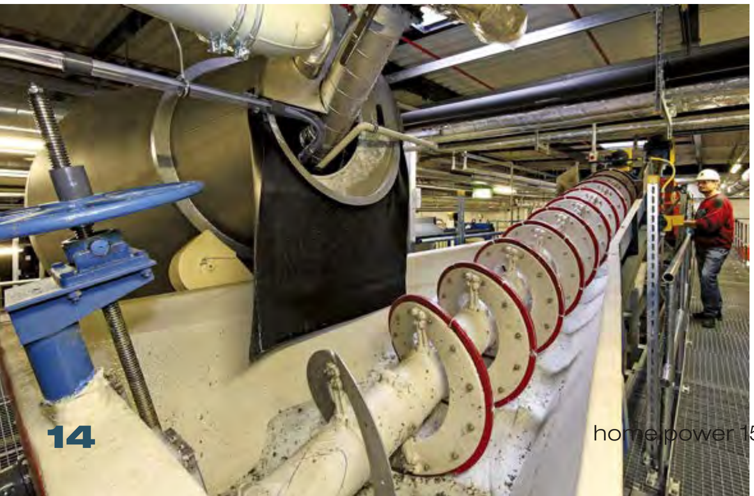
"The decision-makers at the larger companies have been slow to decide whether to recycle these products in-house or send them elsewhere, but I'm now fielding more and more calls from big companies that are beginning to feel a sense of urgency," Woolwich says.

By definition, PV Recycling is a commodities broker, which means the company is not subject to the same regulations as a waste facility. The facility collects and reclaims commodities (metals, minerals, and chemicals) from PV products, mainly crystalline-silicon technologies—though the company is considering branching out to thin-film cadmium telluride technologies. (The company recently reached out to Abound Solar, a bankrupt Colorado-based solar manufacturer, with a $2.2 million proposal to recycle the company's unsellable thin-film products.) The reclaimed commodities are sold to companies that can reuse them.

Last year, PV Recycling established a referral agreement with CERES, the voluntary European take-back program, to offer recycling and take-back solutions for European manufacturers that also sell PV modules in the United States.

In 2005, First Solar became one of the first companies in the industry to implement an in-house recycling program. The company produces thin-film modules that contain cadmium and tellurium, metals that are scarce in supply and highly toxic. Though safe when encapsulated in the module, these materials require special handling and operating standards during a module's manufacturing and at its end of life.

First Solar recovers 90% of the glass and 95% of the semiconductor material for reuse in more First Solar modules.



Courtesy First Solar

"We're a young industry compared to other electronic industries. I think it's fair to say that we have learned what not to do. We started our program because we wanted to get it right from the start," says Laura Abram, First Solar director of sustainability and community affairs.

The company provides packaging for the modules, and collects and transport the modules to one of its processing centers where components are treated and processed for recycling. The process recovers an estimated 95% of the semiconductor material, which is purified by a third party for reuse in First Solar modules. Approximately 90% of the glass is recovered and reused in new glass products.

First Solar has recycling operations at each of its manufacturing plants in Perrysburg, Ohio; Kulim, Malaysia; and Frankfurt, Germany. The company does not disclose specific vendor information, but says it has agreements with vendors in each region—material recovered at the Ohio facility, for example, is processed for reuse by vendors in the United States and Canada.

Most U.S. manufacturers have chosen not to establish in-house recycling facilities, largely because they say the current waste stream is not sufficient to support facility costs. Though First Solar's quantities have been relatively low, Abrams says the "experience has prepared the company to handle high-volume recycling as more modules reach their end of life."

The program started with a prefunded payment model, where, with the sale of each module, the company set aside funds to meet the costs of module collection and recycling. As of February, the prefunded option will only apply to European Union and pre-2013 sales. All U.S. module recycling will be funded by their customers, which, in First Solar's case, are mainly utility-scale power plants.

"Although we are not experts in landfill disposal and related costs, from what we understand of current landfill disposal costs in California, our recycling prices are a commercially attractive alternative to landfill disposal," says Alan Bernheimer, a First Solar spokesperson.

As a privately held company, PV Recycling does not disclose numbers, and since there is no coordinated industry effort to track waste data yet, it is difficult to assess the actual demand for recycling services. Over the next few years, the majority of PV modules ready to be recycled will be those damaged during distribution or installation.

SEIA estimates that annual PV end-of-life modules will not exceed 10,000 tons until after 2014, and will not exceed 100,000 tons until after 2017. Smirnow says the estimate is based on historical and projected PV installations.

"Products today must be designed with recycling and material recovery in mind, so they are made with materials that have reuse value," says Sheila Davis, executive director for the e-waste watchdog group Silicon Valley Toxics Coalition. "It takes time to build the necessary infrastructure. The [solar] industry is essentially starting from scratch, and it needs time to work out the kinks and get this right. There's too much at stake. We only have a small window of opportunity to ensure that this industry remains truly clean and green."

—Kelly Davidson


Nature provides us with the gift of energy through the sun, but unfortunately, nature's wrath may not be all that friendly to your PV system under stressful conditions. Snow, wind, extreme heat or cold, and seismic activities can wreak havoc on underengineered, underdesigned and insufficiently tested racking structures. Only UNIRAC solar structures have been engineered and third-party tested to withstand the harshest of elements and events for a long and enduring service life. Complies with IBC, IRC, ASCE-7-05, ADM, AISI, AISC, NEC and UL. For the highest level of engineering and construction with the lowest cost of ownership in the business, Unirac is the 24/365 solution for performance in and out of the sun. Visit unirac.com for more information.
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Looking to put your spare change or maybe even your tax refund to good use? Crowd-funding websites are making it easier than ever to support your favorite cause, back an entrepreneur, or help someone in need. Browse, point, click, and your dollars go into a virtual collection jar for the project of your choice. There are more than 50 crowd-funding sites in the United States alone, serving a variety of purposes from disaster relief to artist support. Most sites charge a small transaction fee, but compared to traditional ways of fundraising like sending direct mail or putting on a charity events, crowd-funding platforms provide an inexpensive and efficient way to raise money—meaning your donation goes further. Here's a roundup of a few sites that showcase renewable energy and sustainable building projects.

Crowdrise.com

Launched in 2009, this company uses a combination of mocking humor, unconventional antics, and rewards to engage donors to give and spread the word via social media—and it seems to be working. Named "Top 25 Global Philanthropist" by *Barron's* and a "Top Fundraising Website" by *Mashable*, the site has raised more than $400 million for charitable causes (including a host of sustainable building initiatives)—in part due to the star power of cofounder actor and activist Edward Norton. Special challenges, like Groupon's Earth Day Challenge or Mozilla Firefox's Challenge, pit charities against each other in fundraising battles for cash prizes. While Power to the People didn't come out on top in the Mozilla Firefox Challenge, the group raised $5,300 for solar lighting in Nicaraguan villages.

How it works: All fundraisers on CrowdRise must benefit U.S.-based, 501c(3) nonprofits, which are vetted by a third-party service called GuideStar. Some campaigns offer bonuses for donations—anything from the chance to be Norton's guest at a movie premiere to a cowbell autographed by Will Ferrell. Donors also earn reward points for prizes, like T-shirts, hats, and wristbands.

$$$ Contributions are tax-deductible donations, paid to charities via Network for Good (networkforgood.org). Campaign sponsors pay a 5% processing fee on each donation—though donors can opt to cover the fee with their donations. Monthly or annual memberships cater to nonprofits with higher donation volumes, with added features and services.

Indiegogo.com

Founded in 2008, this international platform made headlines for several high-profile campaigns. Solar success stories include $2,660 for a solar education youth center now under construction in Nicaragua; $15,441 to launch a revolving fund for community solar projects in California; and $51,829 to produce and distribute solar-rechargeable inflatable lamps to rural schools, homes, and small-business owners in India.

How it works: Anyone can start a campaign for any reason, and from anywhere, as long as they have a valid bank account. While this gives everyone the opportunity to raise money, it also means donors need to do their own due diligence. Payments for nonprofits are processed through First Giving (firstgiving.com), which issues tax receipts, verifies that the beneficiary is a legitimate 501c(3) nonprofit, and then sends the funds directly to the recipient organization.

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Courtesy Steve Woodward

A student receives a solar-powered LED (the S1 by d.light) at his school as part of the Lighting Schools Campaign.

Courtesy Steve Woodward

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$$$ Your contributions are donations; there is no repayment. The company collects a 4% fee if a campaign reaches its goal, and 9% if a campaign does not reach its stated goal, plus fees for credit card processing and wire transfers for non-U.S. campaigns. (Note: The latter 9% fee is higher by design to encourage campaigns to set realistic goals, but as with most other crowd-funding sites, campaigns receive the raised funds even if they fall short of the target.) There is a 25% discount for registered nonprofits.

Joinmosaic.com

Known in some circles as the "Kickstarter for Solar," Mosaic (formerly Solar Mosaic) has been making headlines for breaking new ground. The for-profit company earned approval from the U.S. Securities and Exchange Commission to adopt a first-of-its-kind mutual fund type of investment structure for RE installations and offer investments to accredited investors nationwide. Though the company remains true to its solar roots, the San Francisco-based startup recently shortened its name to "Mosaic" and opened the platform to other clean energy projects. Since its 2011 start, this B Corporation has raised more than $1 million and funded 12 roof-mounted PV systems ranging from 1.5 kilowatts on the Navajo Project in Arizona, to 487 kW at a convention center in Wildwood, New Jersey.

How it works: On average, the company provides capital to developers at about 5.5%, takes a 1% fee, and pays investors a 4.5% return, typically over nine years—a stronger return than 10-year treasury notes, savings accounts, and most certificate of deposit accounts.

$$$ Until September 2012, the company operated under a zero-interest-loan model—meaning that if someone puts $100 in, they get $100 back over the number of years specified in the project. Unlike most crowd-funding sites that follow a donation model with zero return, Mosaic works with securities authorities to offer investors returns ranging from 4.5% to 6.4%. The investors are repaid their initial investment and interest with the revenue provided by the system's monthly solar power bills.

Razoo.com

Among the first names in the game, Razoo seems to have staying power. Since its 2007 debut, the platform has raised $140 million for nonprofits—nearly half in 2012 alone, in large part due to its Giving Days, 24-hour online fundraising campaigns that are structured like contests, with prizes for top fundraisers. More than 14,000 nonprofits around the country—including Grid Alternatives, Black Rock Solar, and Solar Electric Light Fund—raise money on the site. San Francisco-based nonprofit blueEnergy is running a campaign for solar installations in rural Nicaraguan communities, while the Empowered By Light Foundation is raising money to buy solar panels for a high school in Shangombo, Zambia.

How it works: While Razoo is a for-profit entity, all donations are tax-deductible at 100% and paid out via its charitable foundation (in accordance with U.S. tax laws). Individuals, or teams of individuals, can run campaigns for a cause they care about, or nonprofits can directly host fundraisers. Campaigns must benefit IRS-registered nonprofits.

$$$ Razoo is a donation platform, which means donors do not receive any repayment for their contributions. The platform collects a 4.9% fee from the funds raised, which covers administrative costs, including credit card fees. There are no setup or subscription fees.

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Dream Big, Build Small

Sicily Kolbeck is no ordinary 12-year-old. As a part of her seventh-grade curriculum for the school year, the Marietta, Georgia, preteen is building her own solar-powered house—what she calls "La Petite Maison."

"A tiny house is a way of life. I love the compactness and the simplicity," says Kolbeck, who was inspired by Kirsten Dirksen's documentary, *We, The Tiny House People*. "No one really understood why I would want to do this. Tiny houses, in my opinion, symbolize freedom and independence. You peel away all of the accumulated stuff and then there you are, the real you."

In January, the young entrepreneur turned to the crowd-funding platform Indiegogo.com to raise the remaining funds she needed. In three weeks, she had exceeded her $1,500 goal, bringing in $1,660 total. Those funds, combined with supplies donated by various companies, have made it possible for Kolbeck to realize her vision: a 128-square-foot, energy-independent house, complete with a 30-square-foot loft, a full bathroom, and a full kitchen.

Follow her progress at tinymaison.blogspot.com.

Continued from page 18

SunFunder.com

Launched in July 2012, this newcomer is off to a good start, with five solar lighting and mobile phone charging projects fully funded and several others underway. Founder Ryan Levinson worked on clean energy strategy at the World Resources Institute before working in the banking industry as vice president of environmental finance. Now, he is leveraging his experience to finance off-grid solar projects in East Africa and Asia. In its first six months, the startup raised $70,000 from roughly 325 investors in 27 countries, including $50,000 for SunnyMoney to purchase and sell solar-powered lights to families in Zambia; $15,000 for Angaza Design to provide pay-as-you-go solar light and mobile phone charging to families in Kenya; and $4,000 for Hybrid Social Solutions to bring 100 solar-powered lamps with mobile charging capability to households in the Philippine islands of Palawan.

How it works: SunFunder partners with solar businesses and organizations that are too large for microfinancing and too small for commercial financing. Investments are collected online, and those funds provide low-interest loans for projects. As the loan is paid back, SunFunder returns the principal to project investors. Two of the five fully funded projects are already paying back their loans.

$$$ A zero-interest repayment platform, which means "investors" are repaid the amount they invest without any interest—put in $25, and you get back $25. The company collects a 5% administrative fee from the amount raised—plus variable interest over the repayment term, typically 12 months or longer. The minimum investment is $25.

Microcredit Crowd-Funding

kiva.com

This microcredit platform collects "loans" in increments of $25 and up, and uses those funds to provide microloans. Since its inception in 2005, the San Francisco-based nonprofit has issued $416 million in microloans to more than 1 million borrowers in 67 countries. With a 98% repayment rate for its loans, Kiva has earned praise from the likes of President Bill Clinton, Oprah Winfrey, and others. The loans fill a variety of needs: a $3,600 loan helps a family in Mongolia purchase building and insulation materials to repair their home; a $7,500 loan helps a Kenyan man buy solar chargers to start a solar charger rental business in his community; and a $125 loan helps a Filipina food vendor purchase a solar lantern to cut fuel costs and extend her working hours.

How it works: Lenders browse different loans and select which ones they'd like to fund. Kiva (a Swahili word meaning "unity") relies on a network of more than 160 "field partners" to vet prospective borrowers, upload loan details to Kiva's site, and administer the loans. These partners (microfinance institutions, social businesses, schools, and nonprofit organizations) are approved on a case-by-case basis. The level of vetting depends on the dollar amounts of the loans. "Little to no due diligence is conducted" for credit lines of up to $20,000, whereas higher credit lines require onsite visits and a financial analysis. Once a borrower's loan request is funded through lender contributions, the field partner collects the loan repayments from the borrower, with interest (on average, 1.66%) to cover their administration costs. Field partners keep the interest and return the principal to Kiva. The funds are credited to the appropriate lenders, who can choose to re-lend the funds to another borrower, donate the funds to Kiva (to cover operational expenses), or withdraw the funds via PayPal.

$$$ Unlike most crowd-funding sites, Kiva does not profit from its loans. The nonprofit depends upon optional donations or "tips" from its lenders—on average, 40% of lenders "tip" about $7 per loan. These tips cover about 50% of Kiva's operational costs; grants and donations from foundations and corporations account for the rest. In-kind donations of time from more than 400 volunteers around the world keep administrative costs low.

zidisha.org

Zidisha's (Swahili for "grow") peer-to-peer approach connects lenders to low-income entrepreneurs in developing countries. Since its 2009 launch, the Northern Virginia-based nonprofit has paid out $973,575 in microloans to finance 1,879 businesses in 91 countries. Volunteers and interns travel to countries where Zidisha has lending programs and work with borrowers. They assist borrowers with the application process and teach them how to use the Zidisha website to post loan requests and project updates. In one active proposal, a businessman in Kenya makes his case for a $500 loan that will be used to buy new shaving equipment and a solar module for his barber shop. Zidisha's website also allows lenders to contact borrowers and ask questions about the business.

How it works: Unique to Zidisha is a bidding process, in which lenders place bids to fund portions of the loan at or below the borrower's proposed interest rate (between 5% and 15%). If the total amount of bids received exceeds the amount requested by the loan applicant, then only the bids with the lowest offered interest rates are retained. The loan is disbursed directly to the borrower, who repays the loan (with interest) in monthly installments. Lenders may then use the funds to finance new Zidisha loans, or request a withdrawal of all or part of their balance.

$$$ As a nonprofit organization, Zidisha relies on voluntary contributions from its lenders and supporters to cover operating expenses. Zidisha collects the first 5% of the interest; anything above 5% is passed on to the lenders. A one-time borrower registration fee covers the cost of the credit history verification. First-time borrowers can borrow up to $100, and earn higher credit limits when they repay their loans on time. The maximum loan is $10,000, repaid over 12 months.

—Kelly Davidson

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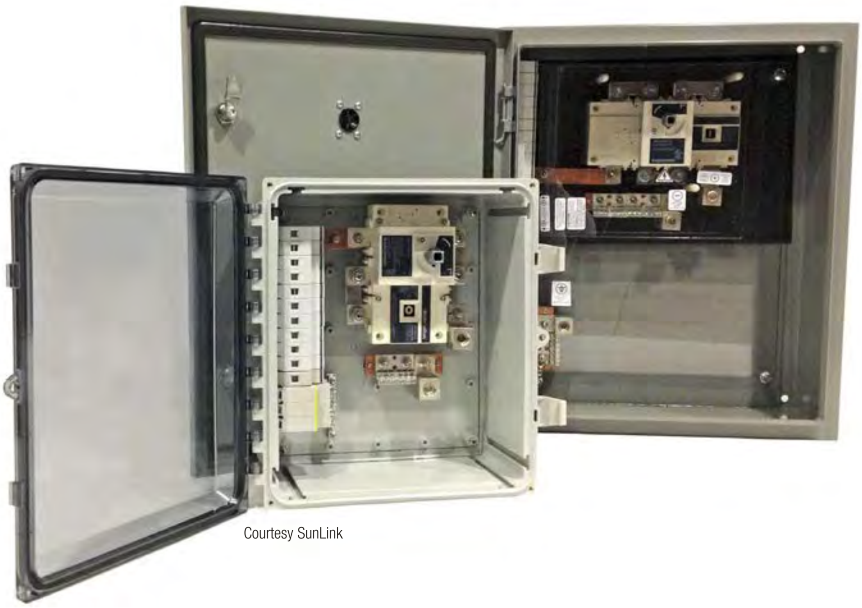
EJOT Solar Flashing

Courtesy EJOT

EJOT (ejot-usa.com) introduced its solar flashing product for use on three-tab asphalt shingle roofs. The system uses stainless steel fasteners and anodized aluminum flashing. Installation steps are predrilling with EJOT's proprietary hole saw, placing the flashing, and screwing down the fastener. The flashing provides three layers of sealing: a pre-attached EDPM washer between the fastener and the flashing, structural foam between the flashing and the top shingle; and another washer to seal the penetration of the bottom shingle. Once in place, array mounting rails are commonly attached to the fastener with L-feet.

—Justine Sanchez

SunLink HomeRun LTE Combiner Box


Courtesy SunLink

SunLink (sunlink.com) released its HomeRun LTE line of combiner boxes, which are smaller and less expensive versions of the standard HomeRun series. The combiner box can accommodate positive and negative home run wiring for up to 24 series strings. The touch-safe fuse holders can accept fuses rated up to 30 A and an integrated load-break rated disconnect switch is included to allow safe fuse servicing (per *NEC* 690.16[B]). It is ETL-listed to UL1741 and the combiner box can be ordered in NEMA 3R, 4, or 4x fiberglass or steel enclosures. Options include surge protection and prewiring with PV connectors. Operating temperature is -13°F to 122°F.

—Justine Sanchez

Evance Wind Turbines R9000


Courtesy Evance Wind Turbines

The Small Wind Certification Council (SWCC) has recently certified two wind turbines suitable for residential-scale systems: the Evance R9000 and Kestrel e400nb (opposite page).

Evance Wind Turbines' (evancewind.com) R9000 is a three-blade, upwind, passive yaw, horizontal-axis wind turbine with an 18-foot diameter and a 23.8 m^2 swept area. This pitch-controlled machine continues to generate while governing, capturing up to the full 5 kW power rating in high winds.

It has a 200 rpm nominal speed, with a permanent-magnet alternator. A 5 kW inverter provides 240 VAC, single-phase. Two 2.5 kW inverters are also available for three-phase output.

The estimated annual energy at 11 mph average wind speed is about 9,000 kWh. With 8.9 mph average, estimated energy is 5,000 kWh per year. The turbine carries a five-year warranty.

—Ian Woofenden

Kestrel Renewable Energy e400nb

Courtesy Kestrel Renewable Energy

Kestrel Renewable Energy's (kestrelwind.co.za) e400nb is a three-blade, upwind, horizontal-axis wind turbine with a 13.1-foot diameter and a swept area of 12.6 square meters. It is rated at 3 kW, and has options for battery charging (48 V) or being grid-tied via a Power-One Aurora PVI-3.6 inverter.

The machine has fiberglass blades, yaws passively, and has a mechanical brake for manual shutdown. Governing is via pitch control.

The estimated annual energy at an 11 mph average wind speed is 3,900 kWh. At an 8.9 mph average, estimated energy is 1,900 kWh per year. The warranty is two years.

—Ian Woofenden

Community Rebuilds

Courtesy Community Rebuilds

Like many living in Utah's Moab Valley, Laurel Hagen struggled to find affordable housing. As the director of a local nonprofit group, she made a good living, but her salary couldn't keep pace with escalating rents and property values in the growing resort community. She lived in several mobile homes—each worse than the last, she says—before purchasing a half-acre of land on the outskirts of town. She took up residence in a one-room shed on the property and made do without running water and electricity, all in hopes of saving enough money to build a small house. But local authorities derailed her plan with a crackdown on land-use codes that forced Hagen off the property.

Enter Community Rebuilds (CR), a local nonprofit that recruits students and volunteers to build affordable, energy-efficient straw bale homes for the low-income workforce in Utah's Moab Valley. The group had recently finished its pilot home and was looking for its next project. Hagen met the program's income qualifications and, with CR's assistance, acquired financing through a federal loan program. Within the year, Hagen was back on her property, living in a three-bedroom, one-bath straw bale home.

"Working with CR was the solution I needed, and their commitment to natural building and education fit with who I am," Hagen says. "Everywhere I went, people in town asked me how the house was coming along. It was a real community effort."

Now in its fourth year, CR is finishing its fifth home this spring, and three more homes are scheduled for summer and fall. So how is this small-town nonprofit thriving? The answer: A labor force of unpaid volunteer interns, mixed with straw, sand, clay, and wood. The "dirt-cheap" materials needed for straw bale construction make CR's homes more affordable to build—plus, the insulating 18-inch-thick walls reduce the need for mechanical heating and cooling, which is especially important considering the area's wide temperature fluctuations.

Every CR home uses the same plan developed by straw bale architect Wayne J. Bingham (wjbingham.com). The passive solar design includes southern glazing, east-west orientation, smaller west-facing windows, and 30-inch-deep eaves, which help shade the windows in the summer and protect the exterior plaster. While the $100,000 price tag (about $87 per square foot) for a 1,150-square-foot home might not seem like a bargain, the home is outfitted with quality finishes, metal roofing, new energy-efficient appliances and in-floor radiant heating—among other features. In Moab, where straw bale builders are scarce and charge a premium, the cost would be almost double without CR's construction services.

Loans for CR homes are made by the U.S. Department of Agriculture's Rural Development Housing program, which helps low-income individuals or households build, purchase, or repair homes in rural areas. CR founder and executive director Emily Niehaus convinced USDA Rural Development staff to allow Section 502 loans to be used for straw bale homes.

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"The fact that the USDA stands behind our mission gives straw bale construction and passive solar design mainstream legitimacy. It's a big step for the natural building movement," Niehaus says. "Often, the mortgage payments are lower than what homeowners were paying to heat, cool, and maintain their old single-wide trailers."

While working as a mortgage broker, Niehaus saw the need to create higher-quality affordable housing in the valley. "Roughly 35% of our local workforce lives in trailers or mobile homes that are beyond repair. Plus, these units are highly inefficient and expensive to operate. Utilities and maintenance can run $300 to $500 per month and because banks view these homes as liabilities, not assets, owners can't get conventional loans to make improvements," she says. "The idea was to replace the old single-wide trailers with new, energy-efficient homes, one at a time."

Niehaus brainstormed with local builders and began taking courses in natural building. After attending a conference held by the Colorado Straw Bale Association, she was sold on the idea of straw bale construction.

"What I learned was that there aren't a lot of professional builders educated in natural building and straw bale construction. I saw an opportunity to dovetail two needs with one program that would train emerging professionals while building affordable, energy-efficient housing," Niehaus says.

CR's program accepts eight interns for each home. Interns are unpaid, but receive a monthly food stipend and free housing in a communal house provided by CR. Working under licensed contractors and the direction of expert natural building instructors, interns build a home from foundation to finish in four months, typically working 40-hour weeks.

CR relies on interns to keep down construction costs and is strongly committed to their education and mentoring. "Every moment is a teaching moment. Not only do we show them practical skills and techniques, but we also explain the science behind our decisions, like the sizing of the eaves for passive solar design or the considerations for straw bale construction in different climates," says Erik Plourde, CR construction supervisor, who is one of four CR staff members.

Conferences, field trips, and workshops—like a two-day on-site course in basic photovoltaic installation provided by instructors from Solar Energy International—supplements the building training. The hope, Plourde adds, is that sponsorships and funding will one day allow solar-electric systems to be standard on every home CR builds.

CR building apprentice Kate Heath is a graduate of the internship program. "In a few months, I learned the building skills to go out on my own," says Heath, who came to the program with a liberal arts degree and no building experience. "Many straw bale courses have you build a shed, but part of what makes this experience so special is that you are building a home for someone and becoming a part of their story."

Hagen's story continues. A year later, she is enjoying the comforts of her new home. She pays "virtually nothing" to heat and cool her home. "The house regulates itself and remains comfortable on its own most of the year. I ran the swamp cooler for about two weeks during a heat wave and relied mainly on the woodstove for heat in the coldest months. The straw bale and passive solar design did the rest," she says. "I'll be very happy staying here for the rest of my life."

—Kelly Davidson

Courtesy Community Rebuilds (2)

Learn More

CR opened a second chapter in Gunnison, Colorado, and hopes to replicate its model in other communities. Funding for CR's administration is derived from federal grants and donations. To learn more or make a donation: communityrebuilds.org.

The Berea Solar Farm

A Creative Community PV Solution

Where solar is concerned, one Kentucky town is breaking new ground for the Bluegrass State. In a state where coal has been king—more than 90% of Kentucky's electricity is presently generated by coal-fired power plants and Kentucky is third in the nation for coal production—the City of Berea is doing something with solar power that even the big cities of Louisville and Lexington have not tackled. The City is installing PV modules that reduce the amount of outside electricity it must purchase, and is doing so cooperatively with its residents.

The City decided it would install a solar farm on city-owned land and lease the modules to interested parties. Those who were Berea Municipal Utility (BMU) electric utility customers would earn solar credits on their utility bills; and non-BMU customers could choose to allocate their modules' credits to existing BMU customers.

The initial offering of 60 modules was subscribed in four and a half days, despite a rule that limited each applicant to leasing only two modules. The response was so immediate that the planned second phase of the installation—an additional 60 modules—was moved up to become a part of phase one, and the 120-module offering was subscribed to in fewer than four months.

Each $750 module leased by a customer entitles the customer to all of the electricity that module produces for 25 years, and customers will likely recoup their return on investment over this time frame. In the first year, for example, residential customers Richard and Cheyenne Olson received a credit of $21.78, falling less than $10 short of recouping their $30 annual investment.

Of course, as electricity rates continue to increase, the economics will improve. Joshua Bills, chair of the BMU

Courtesy City of Berea

The City of Berea's Solar Farm module-leasing option was so popular with residents that the original project was doubled in size—from 60 to 120 modules.

advisory board who worked on Kentucky net-metering legislation and had a solar installation business, says, "The beauty of the arrangement is that as rates increase, the value of the generation credit increases accordingly. What is a $21.78 per-year credit today could be a $40 or more credit five or 10 years from now."

But most members are not in the project for the money. Richard Olson, a professor at Berea College, says, "We believe that locally produced renewable energy is essential to the development of a resilient community. The Berea Municipal Solar Farm makes participation in solar energy affordable to almost all Bereans, and is a model that communities throughout Kentucky and beyond can follow." The Solar Farm's contribution toward pollution-free power was recognized in April 2013 by the Kentucky Environmental Quality Commission, which presented Berea Municipal Utilities and the City of Berea with a Public Service environmental award.

The 28.2 kW solar farm began operating early in 2012. Already, the city is planning to more than double the size of the installation by adding another 132 modules. The next installation is currently in the planning and permitting phase. With the cost of solar steadily coming down, and the cost of utility energy going up, those who participate in the upcoming phase may find the economics of this solar farm even more fruitful.

—Nina Cornett

Overview

Project name: Berea Solar Farm

System type: Grid-tied PV

Installer: Solar Energy Solutions

Date commissioned: Feb. & March 2012

City: Berea, Kentucky

Latitude: 37.6°

Average daily peak sun-hours: 4.5

System capacity: 28.2 kW (existing); plus 31.68 kW (additional planned)

Average annual production: 34,833 kWh

Equipment Specifications

PV modules: 120 Sharp 235 W NU-Q235F4

Inverters: Two Fronius IG Plus 12.0-3 (3 phase)

Inverter rated output: 12 kW

Array installation: Professional Solar Products GroundTrac ground mount

Array azimuth: 180°

Tilt: 38°

PV Array Output

at Various Tilts & Orientations

It has long been taught that a PV array tilted to an angle "equal to latitude" will yield close to the maximum annual output for a fixed array. While this holds true in some locations and climates (like sunny Phoenix, Arizona, and Tampa, Florida), it's not true for every location. For example, in cloudy Portland, Oregon (latitude 45.6°), an array tilted to about 32° optimizes annual system output. This is due to the extremely cloudy winters in this location. An array with a lower tilt angle can better take advantage the high summer sun, maximizing output. Although not as extreme, another example would be Chicago, Illinois (latitude 41.8°), where a tilt angle of about 33° will optimize system output.

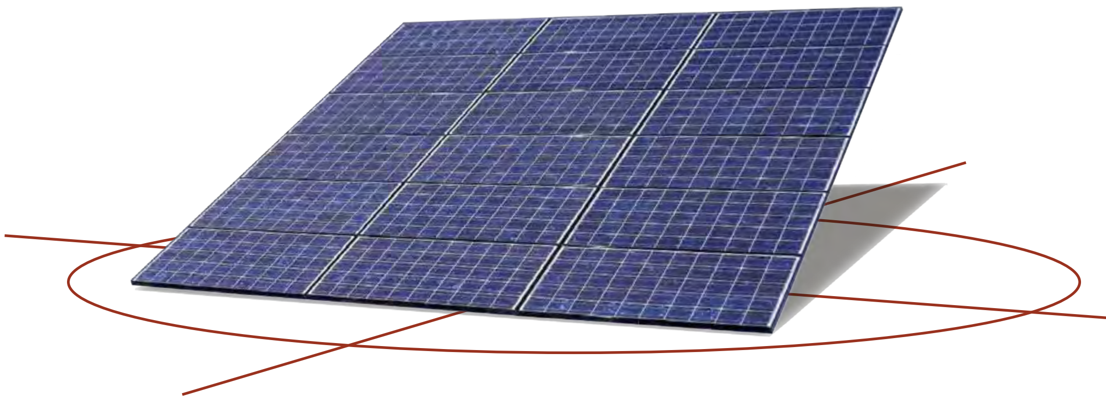
If you use PVWatts (bit.ly/PVWattsV1) to compare the output for various tilts in cities across the United States, you will find that a "slightly shallower than latitude" tilt often yields the highest output. We randomly chose several locations and found that, for a south-facing array (azimuth = 180°), a tilt of latitude minus 3° to 5° is predicted to provide the most output from a PV array. (Only one of our example locations—Portland, Oregon—suffered a greater than 1% decrease in output by tilting modules at latitude.)

Annual PV System Energy Production for Various Array Tilts

(kWh per kW: Annual kWh produced by 1 kW rated PV array)

		Tilt Range for Max. kWh		Latitude - 15°		Latitude - 10°		Latitude - 5°		Latitude	
Location	Latitude	Tilt	kWh per kW	kWh per kW	% Diff. from Max.	kWh per kW	% Diff. from Max.	kWh per kW	% Diff. from Max.	kWh per kW	% Diff. from Max.
Albuquerque, NM	35.0°	32.6° – 34.7°	1,682	1,642	-2.38%	1,666	-0.95%	1,679	-0.18%	1,681	-0.06%
Amarillo, TX	35.0°	32.8° – 34.8°	1,551	1,512	-2.51%	1,535	-1.03%	1,548	-0.19%	1,550	-0.06%
Billings, MT	45.8°	39.3° – 41.7°	1,344	1,329	-1.12%	1,340	-0.30%	1,344	0.00%	1,339	-0.37%
Boise, ID	43.6°	34.0° – 38.3°	1,374	1,365	-0.66%	1,373	-0.07%	1,373	-0.07%	1,365	-0.66%
Charlotte, NC	35.2°	30.9° – 34.4°	1,319	1,294	-1.90%	1,310	-0.68%	1,318	-0.08%	1,318	-0.08%
Cheyenne, WY	41.2°	37.0° – 39.2°	1,461	1,434	-1.85%	1,452	-0.62%	1,460	-0.07%	1,459	-0.14%
Chicago, IL	42.0°	31.0° – 35.1°	1,187	1,182	-0.42%	1,187	0.00%	1,185	-0.17%	1,176	-0.93%
Columbus, OH	40.0°	29.7° – 34.1°	1,133	1,127	-0.53%	1,133	0.00%	1,132	-0.09%	1,124	-0.79%
Little Rock, AR	34.8°	29.2° – 30.7°	1,301	1,284	-1.31%	1,296	-0.38%	1,301	0.00%	1,297	-0.31%
Montgomery, AL	32.3°	26.6° – 30.7°	1,303	1,283	-1.53%	1,297	-0.46%	1,303	0.00%	1,301	-0.15%
Newark, NJ	40.7°	32.8° – 36.8°	1,188	1,176	-1.01%	1,186	-0.17%	1,188	0.00%	1,183	-0.42%
Omaha, NE	41.4°	35.3° – 39.4°	1,317	1,298	-1.44%	1,312	-0.38%	1,317	0.00%	1,315	-0.15%
Phoenix, AZ[1]	33.5°	29.8° – 34.0°	1,617	1,575	-2.60%	1,603	-0.87%	1,615	-0.12%	1,617	0.00%
Portland, MN	43.7°	37.9° – 41.5°	1,282	1,264	-1.40%	1,277	-0.39%	1,282	0.00%	1,280	-0.16%
Portland, OR[2]	45.6°	31.7° – 32.9°	1,040	1,039	-0.10%	1,038	-0.19%	1,031	-0.87%	1,018	-2.12%
Reno, NV	39.5°	33.0° – 35.4°	1,539	1,519	-1.30%	1,534	-0.32%	1,539	0.00%	1,534	-0.32%
Sacramento, CA	38.5°	28.2° – 31.6°	1,412	1,405	-0.50%	1,412	0.00%	1,410	-0.14%	1,399	-0.92%
Saint Cloud, MN	45.6°	39.4° – 42.4°	1,285	1,269	-1.25%	1,281	-0.31%	1,285	0.00%	1,282	-0.23%
Salt Lake City, UT	40.8°	33.3° – 37.3°	1,404	1,389	-1.07%	1,401	-0.21%	1,404	0.00%	1,399	-0.36%
San Diego, CA	32.7°	29.7° – 32.6°	1,499	1,465	-2.27%	1,485	-0.93%	1,497	-0.13%	1,498	-0.07%
Tampa, FL[1]	28.0°	26.0° – 28.9°	1,364	1,328	-2.64%	1,349	-1.10%	1,360	-0.29%	1,364	0.00%

Note: Default PVWatts variables for south-facing array; your situation may vary.
1. Annual production is maximized by making tilt equal to latitude in only two of the cities listed here.
2. Only one city listed suffered more than 1% decrease from maximum by using tilt equal to latitude.



Example Annual Performance at Various Tilts & Orientations

Orientation	Latitude - 15° kWh per kW	Latitude - 15° % of Max	Latitude - 10° kWh per kW	Latitude - 10° % of Max	Latitude - 5° kWh per kW	Latitude - 5° % of Max	Latitude (40.8°) kWh per kW	Latitude (40.8°) % of Max	Latitude + 5° kWh per kW	Latitude + 5° % of Max	Latitude + 10° kWh per kW	Latitude + 10° % of Max	Latitude + 15° kWh per kW	Latitude + 15° % of Max
East (90°)	1,161	82.7%	1,140	81.2%	1,117	79.6%	1,091	77.7%	1,062	75.6%	1,032	73.5%	998	71.1%
Southeast (135°)	1,334	95.0%	1,339	95.4%	1,335	95.1%	1,323	94.2%	1,305	92.9%	1,282	91.3%	1,252	89.2%
South (180°)	1,389	98.9%	1,401	99.8%	1,404	100.0%	1,399	99.6%	1,385	98.6%	1,362	97.0%	1,330	94.7%
Southwest (225°)	1,307	93.1%	1,307	93.1%	1,300	92.6%	1,285	91.5%	1,265	90.1%	1,241	88.4%	1,210	86.2%
West (270°)	1,121	79.8%	1,096	78.1%	1,069	76.1%	1,040	74.1%	1,008	71.8%	975	69.4%	941	67.0%

Note: Example city = Salt Lake City, UT

Latitude + 5° kWh per kW	Latitude + 5° % Diff. from Max.	Latitude + 10° kWh per kW	Latitude + 10° % Diff. from Max.	Latitude + 15° kWh per kW	Latitude + 15° % Diff. from Max.
1,674	-0.48%	1,656	-1.55%	1,628	-3.21%
1,543	-0.52%	1,527	-1.55%	1,501	-3.22%
1,326	-1.34%	1,304	-2.98%	1,275	-5.13%
1,347	-1.97%	1,321	-3.86%	1,288	-6.26%
1,310	-0.68%	1,293	-1.97%	1,268	-3.87%
1,450	-0.75%	1,433	-1.92%	1,407	-3.70%
1,160	-2.27%	1,138	-4.13%	1,109	-6.57%
1,110	-2.03%	1,090	-3.80%	1,162	2.56%
1,285	-1.23%	1,266	-2.69%	1,240	-4.69%
1,291	-0.92%	1,274	-2.23%	1,249	-4.14%
1,171	-1.43%	1,153	-2.95%	1,129	-4.97%
1,304	-0.99%	1,286	-2.35%	1,259	-4.40%
1,609	-0.49%	1,590	-1.67%	1,560	-3.53%
1,270	-0.94%	1,251	-2.42%	1,226	-4.37%
998	-4.04%	973	-6.44%	943	-9.33%
1,521	-1.17%	1,500	-2.53%	1,469	-4.55%
1,381	-2.20%	1,354	-4.11%	1,320	-6.52%
1,271	-1.09%	1,252	-2.57%	1,225	-4.67%
1,385	-1.35%	1,362	-2.99%	1,330	-5.27%
1,491	-0.53%	1,475	-1.60%	1,450	-3.27%
1,359	-0.37%	1,345	-1.39%	1,321	-3.15%

We also need to consider the array's orientation—the direction it faces. In "PV Array Siting & Mounting Considerations" in this issue, we compare various PV array mounting methods. Flush-mounting is a common technique used for rooftop PV arrays, which dictates the tilt and orientation. A roof's angles are rarely perfect for maximizing system output. It is helpful to see what the penalty is, since we may choose to offset this loss by increasing our array capacity. PVWatts can also be used for this—choose the location, enter the system size, and then enter various tilt and orientation angles to pinpoint which combination maximizes output. Using this maximum kWh per year as your "optimal" value, you can compare the output at other angles and calculate the percentage of optimal for each.

For our example, let's use Salt Lake City, Utah (latitude = 40.8°). A flush-mounted PV array on a southeast-facing roof (azimuth = 135°) with a tilt of 25.8° (latitude minus 15°) will generate 95% of the site's maximum production. In this case, we could simply accept that small reduction in output or increase the array capacity by 5% to make up for the roof's nonoptimal orientation and tilt. This could be achieved either by installing more modules or by using higher-efficiency modules.

Note: This article assumes that there is no shading on the array; if there is some shading, a more complete analysis would be required to figure out the comparative loss at each tilt and orientation.

—Justine Sanchez

Compressed Earth

I was a little surprised by the omission of compressed stabilized earth blocks (CSEBs) from the discussion of high-performance wall systems in *HP154.* Human beings have been building with earth for millennia, but the modern popularity of CSEBs is largely attributable to Raul Ramirez, of the Inter-American Housing Center (CINVA) in Bogota, Colombia. Ramirez patented a clever, manually operated brick press in 1952.

CSEBs are very similar to adobe and rammed earth, but have several advantages, especially for the prospective owner-builder. As the name implies, CSEBs are strengthened by mechanical compression and a 10% cement, lime, or bitumen stabilizer.

The equipment necessary to produce CSEBs could be a few wheelbarrows, shovels, buckets, screening frames, and a basic CINVA press, or fully mechanized, trailer-mounted hydraulic machines capable of producing hundreds of bricks per hour. Numerous presses, across the entire spectrum of cost and complexity, are available from manufacturers in the United States and around the world.

CSEBs are already a part of the New Mexico building code. CSEBs use far less cement than ICFs, require only enough wood for construction, and have the added advantage of using widespread masonry trades, as opposed to specialized labor. There are countless variations on block design, which allow for structural reinforcement or architectural details. CSEBs range in strength from 300 psi to greater than 1,200 psi, and will not rot, burn, or provide food to insects. Depending on your local soil characteristics, CSEBs can be produced on site, reducing cost and embodied energy. Given these characteristics, I would love to see some more detailed coverage of this building technology in the future.

Josh Denney • Atlanta, Georgia

Courtesy Drew Jacoby and African Sky

Question Authority

The discussion of energy in "The RE Right of Way on Public Lands" in *HP154* is confused. We can use the sun without converting it to electricity. The renewable portfolio standard and the U.S. Department of Energy (DOE) forget this. The false choice—"either coal or solar power plants"—plays into the hands of our notorious "1%." Listen to John Batisky for the Quechuan Tribe (page 12 in the aforementioned article) or many other serious students of energy—we need to conserve electricity. Clotheslines, daylighting, solar water heaters, and passive heating and cooling—these strategies use the sun directly and economically, and can replace power plants and transmission lines.

The electric lobby and its stakeholders must be questioned. Whenever I read "stakeholder," I think "crony." Might the immense lies of the state unravel if we use the sun ourselves—off grid? Some people rightfully dread becoming helpless consumers of overpriced solar power from state-subsidized solar power plants.

In California during Governor Jerry Brown's first administration, conservation and passive cooling were successfully demonstrated. Why, today, do politicians recommend that citizens neglect nature and the sun on their own properties, yet crave the sun expensively converted to electricity at an alien solar power plant?

Steve Baer • Zomeworks Corp.

continued on page 36

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continued from page 34


Courtesy marutipressurecookers.com

Off-Grid Realities

I just read Allen Sindelar's timeless article, "Toast, Waffles, and Pancakes" (*HP133*) and I enjoyed it thoroughly. I have been living off-grid for the last 11 years, and encountered the article while preparing an off-grid living presentation for a self-help course that Yukon Housing Corporation provides to assist homeowners in managing the construction of their own homes. Some of them are building in remote locations, and have questions about being off-grid.

I love the relevance of the title, because it is hard to explain to people the little idiosyncrasies of off-grid living. Here in the Yukon, in northern Canada, there's a vast difference in our solar resource and temperature from summer to winter. My solar-electric system operates with virtually no diesel backup all summer, since we get nearly 20 hours of daylight. In the winter, sunlight drops to less than two hours per day. So, it is my winter routine to come home from work, fire up the generator, and get all the stuff done that I need to do—cook dinner, sometimes do laundry, watch TV, run the dishwasher, etc.—while the batteries are charging.

In the summer, I save the laundry for the weekend, during the day, when the sun is on the PV array. My dishwasher has a delay timer that I set to come on when I know the batteries will be charged. My kids have learned to turn off the lights when they leave a room, and ask before they watch TV or play video games. And they look out the window to gauge the weather before asking for waffles!

We heat the home mostly with wood and have an oil heater for backup. Our winters are long, and we require space heating for eight months of the year. Our need for air conditioning is minimal in the summer—most homes here don't require it.

Another little item that has become indispensable to me is a pressure cooker. The pressure cooker does chicken cacciatore in six minutes and a pot roast in 20 minutes—all on the stovetop. That's a device worth mentioning!

I also wanted to mention something in reference to battery versus plug-in clocks. My generator is an older model that fluctuates between 60 and 61 Hz, which causes my plug-in clocks to "gain" time. Over a week, this gain adds up. So I now use my cellphone for an alarm clock, and the kids have battery-powered clocks.

I appreciated the idea proposed in the article for using larger freezers, electric fridges, and microwaves. I put our electric fridge on a plug strip. If my battery's state of charge is low, I shut it off at night, since it doesn't need to run all the time if no one is opening the door. Ice cream in the freezer gets a bit too soft using this method, so we store it in the big chest freezer.

Karen Jahraus, Yukon Housing Corp. • Whitehorse, Yukon

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continued from page 36

Property Tax on RE System

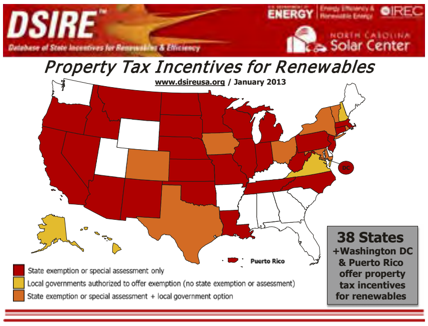
We have enjoyed our combined 20 kW wind- and solar-electric system on our farm in rural Mercer County, Kentucky, for the past two years. It provides all of our electrical needs with ample surplus, but it's a surplus that cannot be transferred or sold due to Kentucky's restrictive net-metering law (but that's another story). Due to a recent visit to our farm by the local property valuation administrator, we are grappling with the extent to which we should be taxed for our clean energy system. I wonder if you or any of your readers have any experience with this situation.

The degree to which our solar/wind system has increased our property value is a matter of debate—but not to the extent that we should pay taxes on its full purchase price. As tangible property, our system could incur a tax equaling our current tax bill. This seems lopsided, doesn't it?

This situation punishes adopting clean energy in Kentucky. There are 38 states that exempt renewable systems from any property tax—but not so here in Kentucky. If a solar or wind installation increases the value of property, perhaps the question is not by how much, but whether it should be taxed at all. One would assume the increase in property value here in Kentucky would be much less than in California or some other state that offers property tax incentives for renewables, because renewable energy systems are an oddity here. People in the southern and western portion of Kentucky have Tennessee Valley Authority to thank for the Green Power Providers program, which made the net-zero Richardsville school project possible. (By the way, thanks for featuring that school in a recent issue of *Home Power*.)

Increasing property taxes is just another way to discourage clean energy in Kentucky! Having said that, I am not discouraged, but rather disgusted at the levels to which our legislators will stoop to thwart clean energy in the state. I however remain steadfastly committed to clean energy in Kentucky.

Bill Slater • via email



Courtesy DSIRE

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Active or Passive Solar Hot Water?

Which type of solar hot water (SHW) system—active or passive—is more applicable for large commercial buildings? I would assume that the answer would be an active system, due to its greater efficiency and the flexibility in where the tanks can be located. If you could provide any insight, it would be greatly appreciated.

Will Mullins • via email

In the United States, most commercial SHW systems are active types, with the water stored in large tanks. Systems with large ground-level tanks are less expensive if the tanks are unpressurized, since pressure vessels in the United States must have an approval from the American Society of Mechanical Engineers (ASME). (Pressurized large tanks—more than 120 gallons—can be five to 10 times the cost of unpressurized ones.) Heat exchangers are used in the unpressurized tanks to transfer the heat to the building's potable water.

Many other countries in the world don't have the roof loading codes of U.S. buildings or the ASME requirements, so passive thermosyphon systems with tanks on the roof are very popular in nonfreezing climates. These systems use traditional flat-plate or evacuated-tube collectors racked on the roof with the tank above the collectors to allow the passive thermosyphon flow of water from the collector to the tank.

Chuck Marken • *Home Power* solar heating editor

Chuck Marken

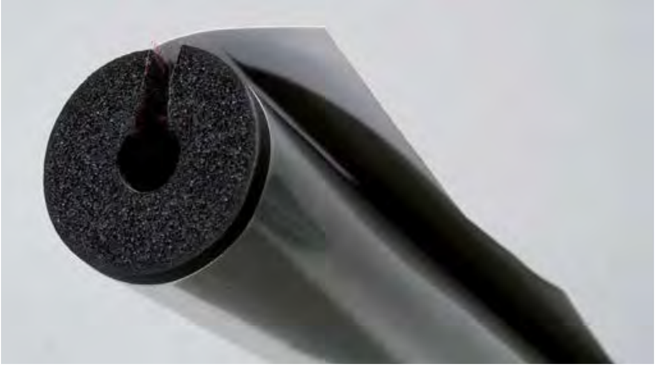
In the United States, most commercial solar hot water systems are active (pumped), instead of passive (thermosyphon).

SHW Pipe Insulation

We installed a DIY drainback SHW system with some recovered/rehabbed Grumman SHW collectors. The plumbing running to and from the roof-mounted collectors is 3/4-inch copper, which I'd like to insulate. In the past with another system, I'd tried using standard foam pipe insulation for household hot water piping, but this melted during the hottest days and did not hold up to UV light exposure.

Can you recommend an appropriate insulation for exterior SHW copper plumbing? Do I need to paint it with something to protect it from UV light? I've looked on all of the *Home Power* advertiser websites, but nobody lists insulation, besides what's on the pre-insulated tubing packages.

Exterior solar hot water plumbing calls for high-temperature closed-cell pipe insulation. The insulation below is clad with a weatherproof aluminum-finish jacket.



Courtesy kflexusa.com

Thanks for everything! I never would have pulled off this system without the confidence I got from reading *Home Power* over the years! Besides the inefficiency due to lack of insulation, the system is working great.

Matt Steiman • Dickinson College Farm

I've always used a product called Halstead pipe insulation from a local insulation company, but Halstead has been taken over by Rubatex and subsequently acquired by K-Flex, another good alternative.

Generically, you should search for high-temperature closed-cell pipe insulation if you are unable to find the above products at a reasonable cost. Expect to pay $1 to $3 per foot depending on the pipe diameter and insulation wall thickness.

Any insulation used outdoors will need to be weatherproofed. The minimum is aluminum tape, although some installers use elastomeric coatings, such as Snow Roof, or even ABS pipe over the insulation. Another option would be K-Flex Clad AL tube insulation with an aluminum-finish jacket. Expect to pay a good deal more for the covered variety, but you'll only need it where the pipes are exposed to the elements.

Thanks for your comments on the *Home Power* content—it's always appreciated.

Chuck Marken • *Home Power* solar heating editor

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The new
look of
quality.

continued from page 40

SIPs & Window Suppliers

I read the article in *HP153* on financing energy-efficient homes ("Getting the Green for Your High-Performance Home") and was interested in getting more details about the home built with structural insulated panels (SIPs). What company supplied the SIPs, and how were they installed? I know that the homeowners acted as the general contractors, but it still seems that some training and experience would be needed to install the panels.

The article also mentions that the house uses high-performance, argon-gas-filled, fiberglass windows, which is exactly what I want for my new home. What kind of coatings do the windows have, and what are their U-factor and solar heat gain coefficients?

Teresa Hopkins • Medford, Oregon

Glad you like our home, Teresa. My husband Shawn and I are really happy with its thermal performance, which can be attributed directly to a well-insulated, tight envelope; high-performance glazing; and the home's passive solar orientation.

Our SIPs are from R-Control, a Montana-based company that makes the panels from expanded polystyrene (EPS) insulation laminated with oriented strand board structural sheathing. We chose 8.25-inch-thick wall panels (R-29.3 to 31.6) and 12.25-inch-thick roof panels (R-44.7 to 48.3). (Since our house was built, I've been interested in another SIP product—Agriboard—which replaces the EPS with compressed wheat straw, and uses no-urea-formaldehyde-added OSB with nontoxic adhesives. The company is not currently manufacturing panels, but plans to start in Q1 of 2014.)

Claire Anderson

Structural insulated panels offer a quick method of creating a well-insulated, efficient building envelope.

We hired an experienced local builder to oversee the SIPs placement and coordinate the boom truck, which maneuvered the sections into place. He was the only SIPs-trained person on site. Other than that, we had four experienced framers and four others—some with more building experience than others—to help set the walls and roof.

The panels come numbered from the factory, which also provides a corresponding plan showing the relationship of the SIPs to each other. One at a time, each panel was secured to the boom truck's lift with a hefty strap and lifted off the truck. The boom truck driver "flew" the panel, while the ground crew helped put it into position over the sill plate, which had been coated with sill sealant. A couple of smart whacks with a sledgehammer was all it took to correct any errors in positioning. The ground crew then fastened the panel to the sill plate using a pneumatic nail gun. The exterior walls for our 1,452-square-foot home went up in about eight hours; the split shed roof took a little longer—about 12 hours—but that also included the framing of a supporting wall and clerestory.

Our Serious double-paned, fiberglass-framed windows were manufactured in Colorado. We "tuned" the windows, specifying the highest SHGC windows they offered for the south face of the house. While Serious may no longer offer these fiberglass units for residences, other manufacturers still do. Check out the window selection tool at bit.ly/WinSelect. When I searched for double-glazed, high solar gain, low-e, argon/krypton gas windows with a "thermally improved" nonmetal frame, eight different manufacturers turned up—Accurate Dorwin, Fibertec, Marvin, and Pella were among those offering high-performance "solar" windows. Happy building!

Claire Anderson, *Home Power* managing editor

Variable Hydro

I read Ben Root's "Microhydro Myths & Misconceptions" article in *HP146* with great interest. I wonder if you could point me in the right direction with the following question.

Every time I look into hydropower generation, the key calculation involves flow and head. Well, head is pretty static, usually, but flow can change dramatically. That's the case on our Washington property: We might have a 100-foot head, but the 8-inch-diameter pipe that carries the water might be 3/4 inch full on a rainy day in the winter, or have no flow in the summer. Can you direct me to microhydro plants that can deal with such flow variations?

Theo Eicher • Seattle, Washington

Hydropower is indeed all about head and flow. If you multiply head (in feet) by flow (in gallons per minute; gpm) and divide by a factor of about 12, you'll get a rough approximation of the power (in watts) potential. This formula tells us that head and flow are equal factors in the energy output of a hydro system. If we double the head, we double the potential power. If we double the flow, we also double the potential power. We need a combination of head and flow that will give us the power and, therefore, energy we need—or at least enough to make installing the equipment worthwhile.

Both head and flow need to be *measured*, not guessed. And with the seasonal flow variation you describe, it's wise to measure the flow at least several times during the year, if not monthly or more. With accurate head and flow numbers, you can make accurate power and energy calculations. And you need to remember that a year's data is not necessarily enough to predict energy for decades, since you may be measuring in a year that happens to be very dry or very wet.

Since head is half of the hydropower equation, maximizing the head on your property—or even on neighbors' properties, with permission—will give you the most power with whatever flow is available. I often see prospective and installed hydro systems that could be giving their owners better energy and financial return if they would simply tap the full head they have available. Of course, the longer the length of pipe, the more it will cost, and the larger the pipe diameter needs to be to avoid flow restrictions—so any additional head needs to be balanced with the extra costs involved.

A hydro turbine is ideally designed for a specific head and flow. The characteristics of the runner—diameter, bucket size and spacing, etc.—can maximize the output for a specific head and flow. If you give a runner more or less head or flow than it is designed for, you'll get lower efficiency—less power for the same potential. That said, most turbines can function over a range of heads and flows, though not optimally across the whole range. I suggest that you seek out the turbine manufacturers' websites and literature and look at their predictions for production of their products in heads and flows that will work for your site. And talk with them directly once you have specific measurements.

If your flow is variable, one strategy could be to have two or more smaller turbines, if you are willing to manage the system as the flow varies. Single-turbine system owners can also do this by varying the number and size of nozzles they use at a given time. Having multiple turbines and/or nozzles allows optimum use of most or all of the changing flows.

Again, with both head and flow, it's *very* important to get accurate measurements in advance. Without this, your design is a guess. Mapping the head across the property will show you how much you need to spend on piping for how much vertical drop. Measuring flow in various seasons will allow you to calculate the power available in various flows, and decide whether a high but rare flow is worth designing for or not. Most often, maximizing head and designing for some middle ground in flow will be best (see "Microhydro Design Considerations" in *HP132*). We're fortunate in the home-scale hydro industry to have communicative and generous turbine manufacturers who can help you sort out the best specific plan once you have good data to work with.

Ian Woofenden • *Home Power* senior editor

Ian Woofenden

Each of the hoses in the manifold go to a separate nozzle on this Pelton wheel hydro plant. Each nozzle is a different size, so that seasonal adjustment to meet flow can be made merely by using the valves on the manifold.

Rototiller Conversion Parts

I enjoyed Ted Dillard's article on his electric rototiller ("DIY Electric Tiller Conversion" in *HP150*). I'd like a list of sources for the motor and switch. I happen to own an old Merry Tiller and would like to do a conversion myself.

John Hanson • via email

It's great to hear from another Merry Tiller owner! I got the motor from Surplus Center (surpluscenter.com). Their available stock comes and goes, and you may not be able to find a motor that matches my specs exactly.

The switch is an AC power tool emergency cutoff, sometimes available at your local home center. I got mine online at Wolf Automation (wolfautomation.com). Virtually any 110 VAC, 30 A switch will do just fine, and especially one made for power tools. From a safety standpoint, having that big red emergency switch is good. If you mount the main power switch on the bars, I don't think you really need anything but a standard 20 or 30 A 110 VAC switch. Remember, there was already a switch on the motor, and I felt it was a bad idea to have to reach over the machine to turn it off in an emergency.

All the other parts and bits I just picked up at the local home center store. Let me know how you make out, and I hope you have fun with your tiller conversion project!

Ted Dillard • evmc2.com


Ted Dillard

Small backyard rototillers, like this Merry Tiller, can be retrofitted with an electric motor for quieter, emissions-free operation.

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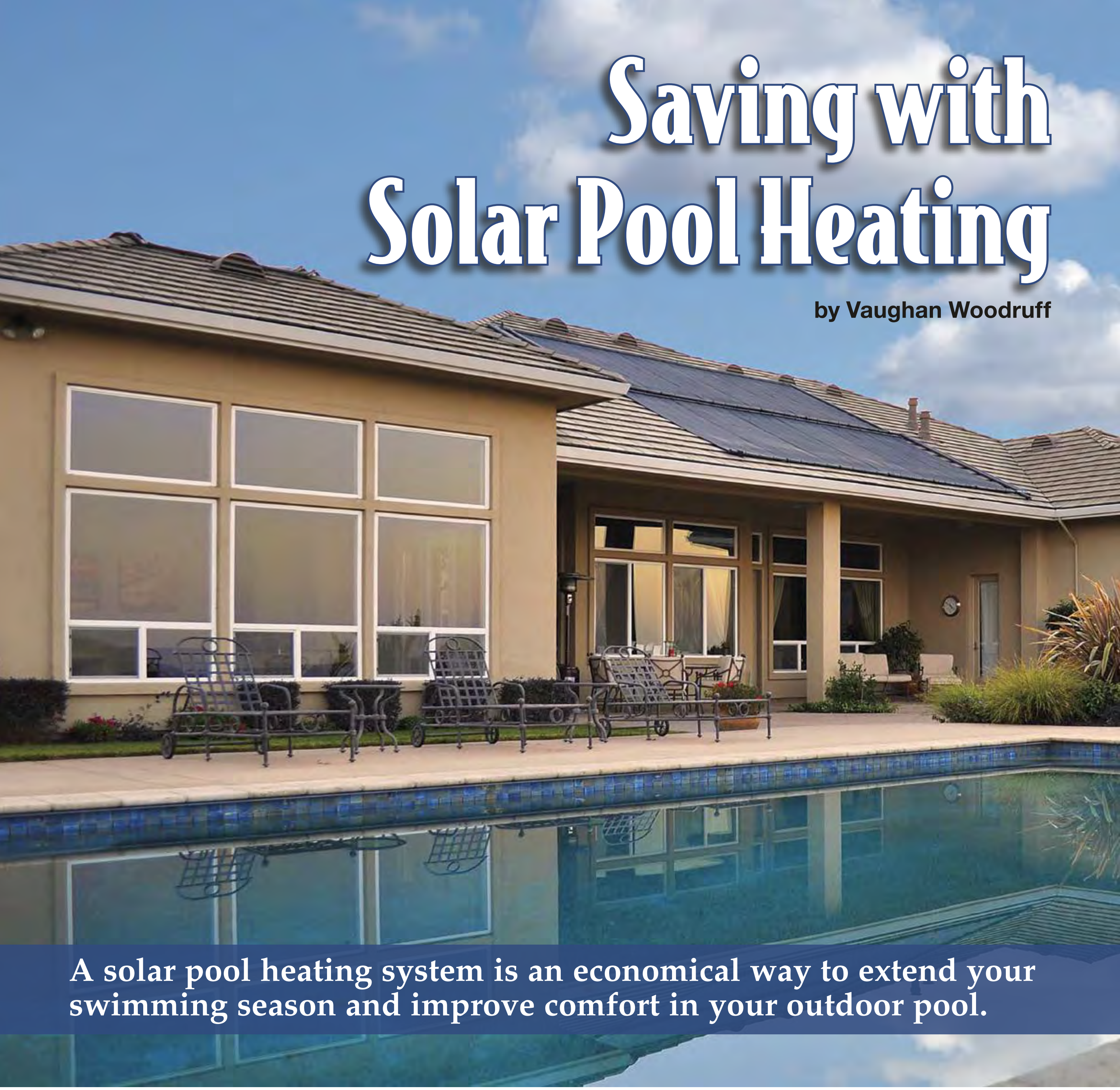
Saving with Solar Pool Heating

by Vaughan Woodruff



A solar pool heating system is an economical way to extend your swimming season and improve comfort in your outdoor pool.

By the end of 2010, the United States had 15.3 billion kilowatts of installed solar heating capacity—and roughly 85% of this capacity was used to heat swimming pools. In fact, there are more solar pool heating (SPH) systems installed in the United States than any other type of solar energy system. The widespread adoption of SPH can be attributed to the popularity of residential swimming pools in Florida, California, Arizona, and Texas. In these climates, outdoor pools can be used almost year-round, and SPH provides the most economical solution for actively heating these pools during stretches of cool weather.

Auxiliary pool heating is an option for pool owners who want to extend the swimming season and increase comfort by providing greater control over pool temperatures. For pools that are significantly shaded, are used as therapy pools, or are used so much that a cover may be impractical, active heating is typically required.

In heated pools, once water from the pool is pumped through the filter, it is sent to a solar pool heating collector array or a thermostat-regulated auxiliary heater—or both. If the water is at or above the set temperature, the auxiliary heater will not activate.

Courtesy Aztec Solar

Pool Heating Fuels & Costs

Type of Heater	Max. Output	Est. Equipment Cost	Expected Lifespan (Yrs.)	Operating Cost ($ Per 100 kBtu)
Natural gas	190,000 Btu/hr.	$2,000	5 – 8	1.30
Propane	190,000 Btu/hr.	2,000	5 – 8	3.20
Heat pump	108,000 Btu/hr.	3,000	10	0.61 – 0.88
Solar (320 sq. ft. collector)	307,200 Btu/day	2,500	10 – 20	< 0.01

Assumptions: Combustion efficiency = 85%; natural gas = $1.10 per therm; propane = $2.50 per gallon; electricity = $0.12 per kWh; heat pump COP = 4.0 – 5.8.
Sources: EERE: bit.ly/GasSPH & bit.ly/CycleCosts

A common auxiliary heater is typically fueled by propane or natural gas, or an air-to-water heat pump. Gas heaters are the most responsive—an appropriately sized heater can reasonably raise the pool temperature 5°F in four hours. A heat-pump pool heater may take six to eight hours to raise the same pool water 5°F. A properly sized SPH system may require several days. The other trade-offs between these technologies are cost and environmental impact.

Economics & Efficacy

As shown by the "Pool Heating Fuels & Costs" table, the most economical method for pool heating is a SPH system. The initial costs of a SPH system are comparable with heat pump and liquid fuel pool heaters, while the operating costs are far less.

The lower cost of SPH systems is due to their simplicity and efficiency. For most SPH systems used for outdoor pools, the only moving part is a motorized valve activated by a differential controller. The controller uses two sensors—one near the solar pool collectors, where it is exposed to the same solar radiation as the collectors, and one that measures the water temperature from the pool. When there is enough solar energy available to heat the pool water, the valve is opened. (A common temperature differential is 4°F, although this temperature can be field-set on some controllers.) The pool water is pumped through the collectors before being returned to the pool. When the pool reaches the controller's high temperature setting or there is not sufficient solar radiation to maintain a collector temperature that is 1°F to 2°F more than the pool water, the motorized valve closes and the mechanical system functions as it would in a pool without a SPH system.

Selecting Collectors

The difference in temperature between the fluid entering the collector and the ambient air temperature has a significant impact on a system's efficiency. If you are trying to heat your outdoor pool to 80°F on an 85°F day, unglazed pool collectors are the best tool for the job.

When the pool water entering the collector is equal to the ambient outdoor temperature, unglazed collectors can reach efficiencies near 90%, meaning that 90% of the solar radiation that strikes the collector is converted to heat.

If your priority is to heat an indoor swimming pool to 80°F during a 30°F winter day, then glazed flat-plate collectors will be much more effective. Since the glazing decreases the amount of sun hitting the absorber, glazed flat-plate collectors have a maximum efficiency of about 80%; the maximum efficiency of certain evacuated-tube collectors is roughly 50%. When you

Incentives?

With a quick payback, SPH systems are so much more cost-effective than heat pump and liquid fuel pool heaters that solar was specifically *excluded* from the federal investment tax credit that covers other solar energy systems. There has been little objection to this exclusion from the solar industry, though there is currently an effort to remove this restriction for commercial SPH systems.

Unglazed copolymer collectors are the most common types for solar pool heating. This version comes in various colors to blend in better with the roofing material.

Courtesy Engineered Solar

Indoor Pool Specifics

Integrating a solar pool heating system with an indoor pool is more complex due to the interaction between the pool and the conditioned space around the pool. While the mechanical system for an outdoor pool is concerned only with water quality and temperature, the systems for an indoor pool also provide space heating, manage moisture, and maintain indoor air quality.

All of these systems can function independently, but they affect one another. Suppose the water temperature feels cold and the pool owner increases the temperature setting on the pool heater. Without making other changes, the dehumidification system will have to operate more as a result of increased evaporation from the pool. Since this process is handled automatically, the owner may not be aware of the repercussions—until the increased utility bill arrives. What the owner will immediately notice is that swimmers feel colder when exiting the pool though the air temperature in the building has not changed. This is due to the relative temperatures between the pool water and the air. The air temperature in most indoor pools should be 2°F higher than the water temperature. If the pool owner increases the thermostat setting, the higher indoor air temperature would increase comfort and reduce evaporation, but the building would then lose more heat to the outdoors and the energy bill will climb even higher.

For solar pool heating systems, the differential controller defines the high limit for pool temperature. With an outdoor pool, an owner might set the differential controller to deactivate the system when the pool temperature reaches 85°F, even if 82°F is comfortable. Since the additional heat is essentially free, the only trade-off would be more evaporation. With an indoor pool, this approach would have different consequences. While the heat provided to the building from the solar pool would be free, there could be significant costs for the additional energy required to heat, dehumidify, or ventilate the building.

consider that medium-temperature collectors typically retail for four to five times the cost of unglazed pool collectors, using them does not make sense for most pool applications.

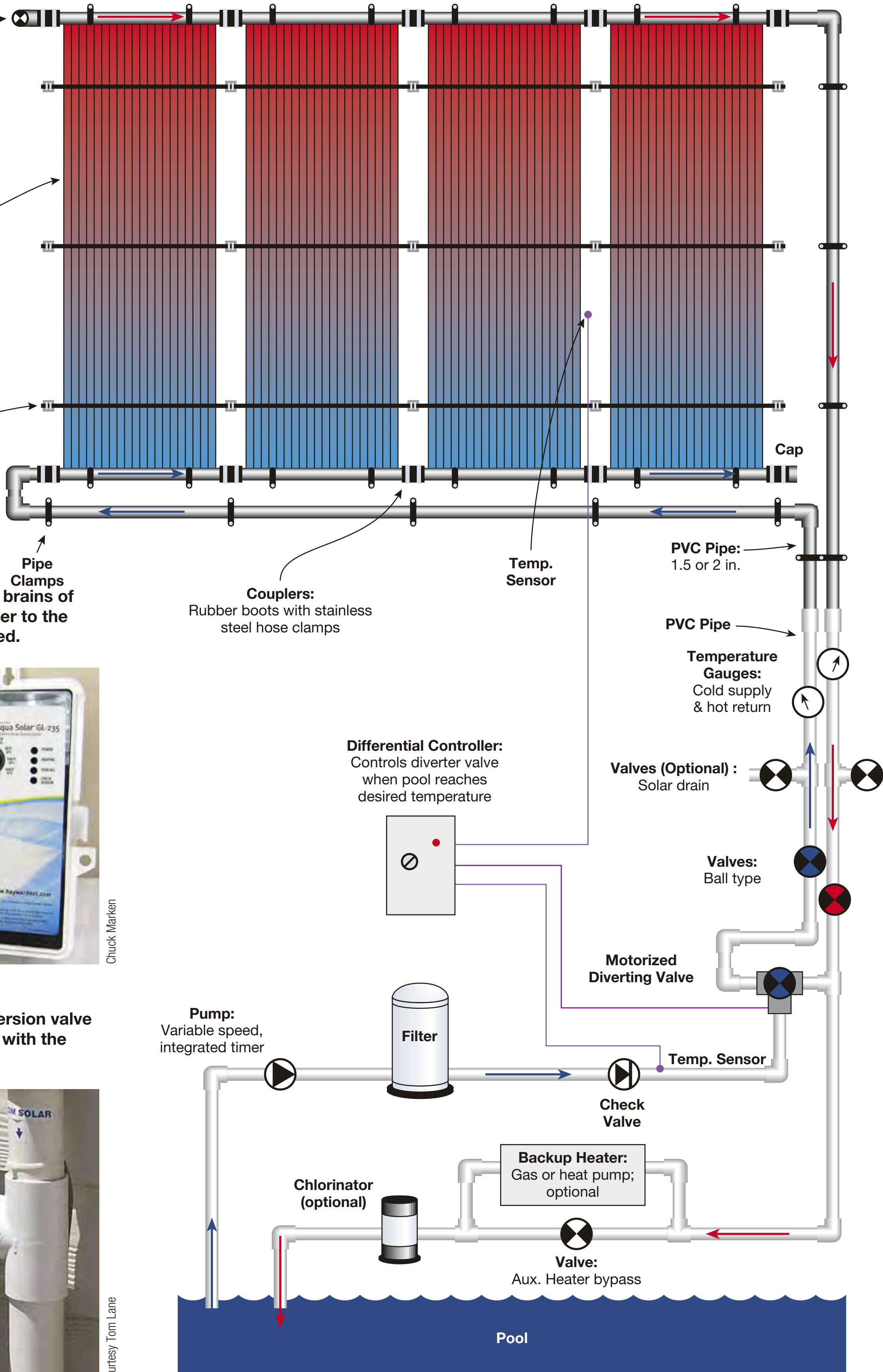
Given the popularity of pools and solar pool heating, there are a number of products on the market that are readily available in department stores and home centers. Some do-it-yourselfers and frugal types have also been known to construct their own devices that behave similarly to the manufactured collectors. When selecting a pool collector, consider these factors:

Collector type. Since UV radiation degrades plastic, appropriate UV inhibitors are important. Collectors that have been rated by the Florida Solar Energy Center (FSEC) have their absorber material listed with their performance rating. Standard materials include copolymer plastics, such as polypropylene and polyethylene. If collectors with metal absorbers are used, care must be taken to ensure that the fluid is not acidic, since this could corrode the absorbers.

To properly integrate a solar pool heating system, it is important to identify the components of a pool's mechanical system.

Courtesy Sandollar Spa & Pool

Solar Pool Heating: Common System Details



A differential controller is the brains of the system, sending pool water to the collectors when heat is needed.

Chuck Marken

The controller operates a diversion valve that integrates the solar loop with the usual filtering system loop.

Courtesy Tom Lane

Flexible unglazed flat-plate collectors require a support framework if they are mounted at an angle, and tie-downs for wind protection.

Courtesy Engineered Solar (2)

Unglazed coil-type collectors are best plumbed in parallel to reduce friction and preserve their solar collection efficiency.

Unglazed flat-plate collectors look like large plastic mats. This popular style of collector typically uses two large headers connected by several smaller risers that lie parallel to one another. This arrangement splits the flow between these risers and accommodates various pool pump flow rates, which may be as high as 75 gallons per minute (gpm).

Many unglazed flat-plate collectors are not self-supporting, and must be installed on a roof or a frame constructed specifically for the collector array. Since a strong wind could easily lift these lightweight collectors, they are strapped or clamped to the support structure.

Wind can also negatively impact unglazed pool collectors by stealing their heat. For example, a 10 mph wind can reduce a collector's efficiency by 20%. Some pool collectors feature a plastic glazing to help reduce these losses.

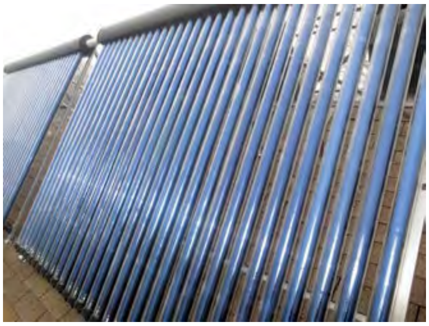
Coil-type collectors consist of black, coiled tubing that is unglazed or includes an acrylic cover. Pool water is pumped through the tubing, which may be constructed from a variety of materials, including low-density polyethylene. Only two manufacturers—SolarTech International and Gull Industries—offer SRCC-certified coil-type SPH collectors, which feature warranties of up to 20 years. Other coil-type pool collectors can be purchased through retail outlets, but typically only offer warranties ranging from 90 days to one year (see "Collector Types" table).

Coil-type collectors provide greater pumping resistance than unglazed collectors, which split the flow through multiple pathways. This increased resistance—known as pressure drop or head loss—can be minimized if multiple collectors are installed in parallel, which splits the flow between collectors.

A system that utilizes five coil-type collectors in parallel and pulls water from the pool at a flow rate of 20 gpm will have a flow rate of roughly 4 gpm in each collector. If the system used only a single coil-type collector in the mechanical loop and the flow rate of the pool water was maintained at 20 gpm to ensure proper pool filtration, the flow through the single collector would be 20 gpm. With this configuration either the head loss in the single collector would require more pumping energy or the reduced flow rate caused by the increased resistance would reduce the efficiency of solar collection and impact water quality in the pool.

Glazed flat-plate collectors (right) and evacuated-tube collectors (below) are more expensive, but may be more appropriate in colder climates or for heating indoor pools.

Courtesy Liquid Solar Systems



Vaughan Woodruff

Collector Types

Collector Type	Description	Warranty (Yrs.)	Cost ($ per Sq. Ft.)	Performance (kBtu per Sq. Ft. per Day)
Certified unglazed flat-plate	Polypropylene with 1.5 in. headers; available in 2 – 4 ft. widths & 6 – 20 ft. lengths	10	$5.00	1.2 – 1.9
Certified coil-type	370 ft. of 0.75 in. high-density poly pipe	20	5.50	0.9 – 1.6
Uncertified unglazed flat plate	Polypropylene with 1.5 in. headers; folded harp design	5	6.50	Not Specified
Uncertified glazed coil-type	66 ft. coil of 1.75 in. plastic tubing; clear acrylic cover	1	45.80	0.8

Some homeowners have installed a single, large coil-type collector. To maintain water quality and minimize additional pumping costs, a bypass can be installed. The bypass allows 4 to 5 gpm to flow through the collector, while the other 15 to 16 gpm returns to the pool.

Since the production of unglazed solar pool collectors is extremely low in cold weather, glazed flat-plate collectors are sometimes used in SPH systems for indoor pools. However, this brings an additional complication—almost every certified glazed flat-plate collector uses copper piping. If pool water is run through the collectors, it can cause deterioration of the copper and stain the pool. As a result, many indoor pool-heating systems isolate the pool water from the solar collectors with a stainless steel or titanium heat exchanger. The solar loop in a heat-exchanger-based pool heating system may be configured as a drainback or an antifreeze system to prevent freeze damage. (See “Drainback Solar Hot Water Systems” in *HP138* and “Closed-Loop Solar Hot Water” in *HP140*.)

Warranty. The quality of a collector material and construction can be indicated by the warranty. Industry-standard pool collectors typically carry a warranty of 10 years or more. When considering the strength of a warranty, it is always beneficial to do some research into the viability of the manufacturer.

Ratings. Solar pool collector manufacturers may opt to have their products certified through the Solar Rating & Certification Corporation (SRCC) OG100 protocol or through the FSEC Standard 102-10. These are the same protocols that are used to certify glazed flat-plate and evacuated-tube collectors. The program gives manufacturers an industry-recognized label for their products, and consumers can use the ratings to ensure durability and compare performance.

Because pools lose the majority of their heat from their surface, solar pool heating systems are sized based on surface area.

Courtesy Aztec Solar

Solar Pool Cooling

In hot climates, pool owners put canopies over their pools to avoid the overheating that can occur from passive solar gain. In these locales, SPH systems may be installed primarily for the shoulder seasons. Since the solar differential controller has a high limit to keep the SPH system from heating the pool above a certain temperature, there may be portions of the summer during which the system remains dormant.

Some differential controllers have a "nocturnal cooling" function that activates the SPH system when the temperature at the collector sensor is sufficiently below the pool temperature and the pool temperature is above its high limit. By pumping the pool water through the collectors, excess pool heat can be radiated to the cooler night sky. As a result, in some climates the SPH system may also serve as a solar cooling system.

Pump considerations. The flow of water through pool piping is affected by the speed at which the fluid is pumped, the diameter and length of the piping, and how high water has to be lifted to the collectors. For example, a single collector made from 200 feet of coiled $^3/_4$-inch poly pipe located 20 feet above the pool will significantly impact flow rate when compared to the same pump in a mechanical system with just a filter. When selecting collectors, consider whether the design will require more energy for pumping, or require a larger pump or even a dedicated pump specifically for the SPH system.

Cost & availability. Polymer collectors tend to be fairly affordable. Even so, homemade collectors made from materials that have been reclaimed or are readily available can reduce a pool owner's initial investment in a SPH system. When the decision is driven by cost, be sure to also consider the lifespan of the materials being used and their effectiveness.

System Sizing

It is common to initially consider sizing an SPH system based on the volume of water in the pool. Since the system will be heating the entire pool contents, this seems a logical conclusion.

However, the reality of a pool is that it is a large thermal mass that is brought up to temperature at the beginning of the swimming season and maintained at that temperature throughout the season. While a SPH system helps bring the pool up to its operating temperature, it is typically sized to offset the heat *loss* that occurs once the pool water reaches the desired temperature.

Since the primary sources of pool heat loss are evaporation, radiation, and convection from the pool surface, SPH systems are sized based on the surface area of the pool, not its volume. For simplicity, the size of the collector array is expressed as a percentage of the surface area of the pool.

The recommended size of the collector array depends upon a variety of factors, including the:

- orientation of the array with respect to true south
- extent of shading of the array and the pool
- desired pool temperature
- number of months the pool is open
- number of hours the pool is uncovered.

Evaporation

Evaporation is a function of the temperature difference between the water and the air, as well as the relative humidity and wind conditions. Evaporation is far greater in hot, dry, windy climates where the air has a greater capacity to absorb water than in cooler, wet climates where the air is closer to its saturation point.

When a pool is uncovered, evaporation will occur. For example, with a pool temperature of 82°F, an air temperature of 86°F, and a relative humidity of 50%, an uncovered 20- by 40-foot pool will lose 4.5 gallons of water per hour. If the pool temperature is increased to 86°F, the pool will lose 6 gallons per hour to evaporation. In areas where rain is prevalent, this evaporation can be replenished easily. (At a rate of 6 gallons of water per hour, it would take more than 80 hours of uncovered pool time for the water level to drop 1 inch.)

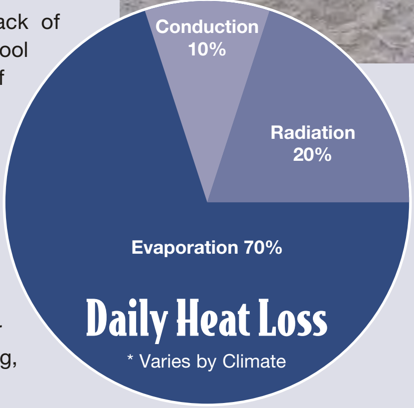
In arid regions, evaporation will be much more severe, and a lack of precipitation may require the pool owner to add water periodically. Pool chemicals also evaporate, which increases the costs and impacts of pool maintenance.

But the loss of water and pool chemicals from a pool pales in comparison to the heat loss that occurs when water is lost. When a gallon of water evaporates from a pool, it removes the equivalent of almost 8,700 Btu of heat. As a result, evaporation is the most significant source of heat loss from a pool.

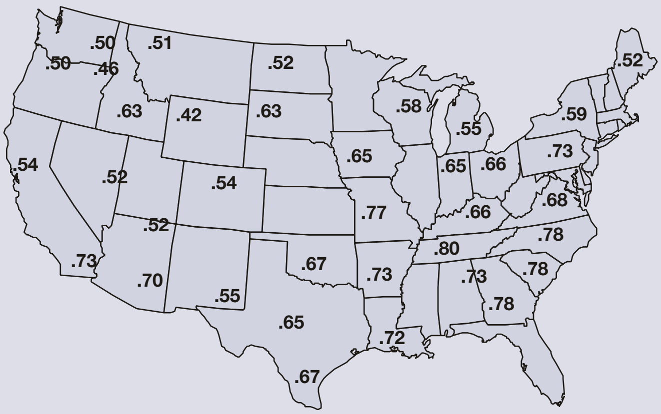
Pool covers are extremely effective at minimizing evaporative losses. In the next issue of *Home Power*, we will explore this and other efficiency measures that can be used to minimize a pool's heating, chemical, and electrical demands.


Courtesy Sandollar Spa & Pool

A pool cover can reduce heat loss due to evaporation and radiation, making a solar pool heating system even more effective.



Pool Area & Collector Size Multiplier



This map shows the recommended proportion of pool collector area to the pool's surface area for various regions in the United States. Local installers may use different ratios depending upon factors such as the desired pool temperature, shading considerations, and a less-than-ideal roof orientation.

Although the ratios may seem counterintuitive, they relate to the typical pool season in that region. For example, a SPH system in Florida may be heating the pool during nine months, while an SPH system in Wisconsin may be in operation only three months of the year.

For a site where these factors have a minimal impact on solar production, the size of the collector array in relation to the pool surface area is illustrated in the map above. If the site is shaded or the array is oriented significantly away from true south, the size of the array should be larger.

While the thermal performance of collectors is a major consideration, SPH also requires an understanding of the function of the pool's mechanical system and how a collector array best integrates with this system. Through proper selection and integration, a solar pool heating system can ensure that more time is spent pool-side and less time is spent worrying about paying for fuel for this luxury.

Access

Vaughan Woodruff (vwoodruff@insourcerenewables.com) owns Insource Renewables, a solar design/build and consulting firm in Pittsfield, Maine. A NABCEP-Certified solar heating installer, he serves on committees for NABCEP, IAPMO, and IREC, and teaches for organizations across the United States. Vaughan co-authored the NABCEP *Solar Heating Installer Resource Guide* with Chuck Marken.

Resources:

Florida Solar Energy Center • bit.ly/FSECPoolHeating • Consumer information and pool collector ratings

Residential Solar Pool Heating Systems: A Buyer's Guide, Natural Resources Canada • bit.ly/NRCAN_SPH

U.S. Department of Energy • bit.ly/DOESPH

Natatoriums: The Inside Story (Indoor Pools) • ASHRAE Journal • bit.ly/IndoorSPH

Solar Panels Plus • bit.ly/SPHcalc • Pool heater calculator

Choosing the Right Light

by Dan Fink

Comment & Discuss this article @ homepower.com/155.56

Compact fluorescents, incandescents, and LEDs each have appropriate uses in residential lighting.

Courtesy General Electric (4)

Nobody wants to waste energy or money to light their home or workspace. It seems logical to simply repopulate every fixture with the most efficient lamps available. But that may be a poor solution because it ignores a fundamental principle of lighting design: Make only as much of the right kind of light as you need, and shine it only where it is needed.

New energy-efficiency standards for electric lights, based on "lumens per watt," have been imposed in the United States and elsewhere. Lamps that don't meet these standards are being phased out and replaced by more efficient (and more expensive) products. Unfortunately, standards based solely on lumens per watt don't tell the whole story—they ignore that first fundamental rule of lighting.

Beyond Lumens Per Watt

I've been shopping for lighting based on lumens per watt since I first moved off the grid in 1991. With my first tiny solar electricity and battery system, it was critical to use as little energy as possible. That need remains, even now that I'm lighting a bigger space with a bigger PV system. I've had many lighting failures. Besides a shorter-than-expected lamp life and poor light quality, many of the lamps used more energy than claimed for the amount of light produced. Running two "efficient" lights to replace a single inefficient one doesn't make sense. So I asked acclaimed lighting engineer Howard Brandston, an outspoken critic of government lighting bans based on lumens per watt, what I had been doing wrong all these years.

"All lumens are not created equal," Brandston says. "Those metrics are simply agreements amongst scientists, and have very little to do with the human perception of light. Eyes are extremely sensitive—your visual system, all the way from eye to brain, works at 85% effectiveness in only 7.5 foot-candles of illumination. That is not much light. Mozart wrote his music under the light of only two candles, and the average person can read *The New York Times*...in only two foot-candles." To put this into perspective, full sunlight has an illuminance of about 10,000 foot-candles; an overcast day, about 1,000 foot-candles.

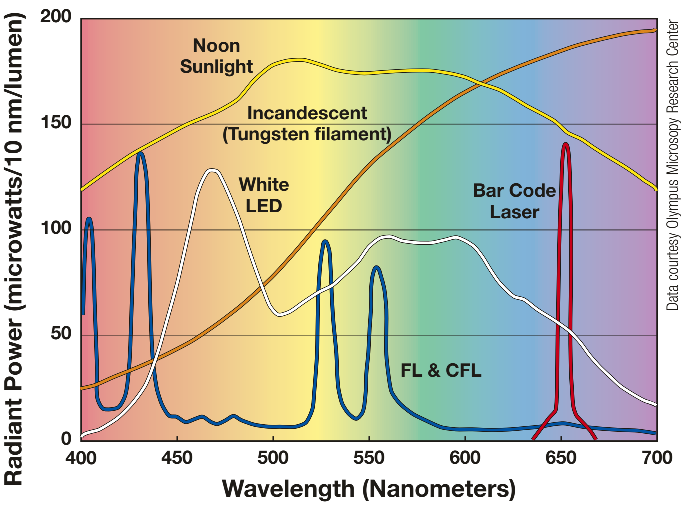
Both biology and psychology are at least as important as physics. The lumens per watt standard was developed in 1924 to compensate for the difference in sensitivity of the human eye to various frequencies of light. But it doesn't compensate for how the eye shifts its color sensitivity in different brightness conditions, or for the fact that most energy-efficient lamps emit light in a very narrow spectrum compared to the broad spectrum of sunlight. These effects can make a room seem brighter or dimmer, and also result in lighting that seems inadequate or is unpleasant in quality.

In 2011, residential lighting consumption was about 186 billion kWh or 13% of all residential electricity consumption.

—U.S. Energy Information Administration

The graph below shows the spectral distribution of light from different sources. Both sunlight and incandescent light have an even distribution of frequencies. Fluorescent (FL) and compact fluorescent (CFL) lighting have large spikes at certain frequencies, with light-emitting diodes (LEDs) somewhere in between. This is why the light from FL and CFL lamps can seem harsh and fatiguing, and also why Brandston says that incandescents are "the gold standard of lighting."

Spectral Distribution of Common Light Sources



Data courtesy Olympus Microsopy Research Center

Both the lighting industry and the U.S. Department of Energy (DOE) are aware of the limitations of lumens per watt and are developing new metrics. I asked Mark Rea, director of the Lighting Research Center at Rensselaer Polytechnic Institute, why the situation is so confusing for consumers, and what is being done to improve it.

"We need to do a better job at recasting the problem as a benefits-versus-cost decision," Rea says. "There is a lot of effort in the industry right now focused on 'bundling' the numerous benefits of different lighting choices into an easy-to-understand format. For example, if a lightbulb has good color quality, no detectable flicker, and is dimmable, it could be labeled as a Class A light source."

Rea and other industry experts are working with the DOE and its Energy Star program to make things easier, but it will take time. "It's still the wild, wild West out there with residential lighting," says Rea, "and consumers still have to choose by trial and error."

Color rendering index (CRI) is a measurement of a light source's accuracy in rendering various colors that it illuminates.

Benjamin Root

Lamp Technologies

Used judiciously, newer, more efficient incandescent bulbs can still serve a purpose in residential lighting schemes.

Courtesy General Electric

Incandescent

In the United States, the official phase-out of older, less-efficient incandescent lamps began in 2012 and will continue through 2020. New incandescents are required to produce the same amount of light with at least a 25% gain in efficiency. A variety of technologies are under development to comply with the new standards; current lamps use a clear glass envelope around the filament to help capture waste heat energy.

The quality of incandescent light is excellent, the lamps fit a wide variety of fixtures, and their performance is not affected by heat buildup. And, although they are more expensive than their progenitors, they still are the lowest-cost solution. They also contain no toxic materials and can be safely disposed of—no special precautions or procedures are necessary. The biggest downside of incandescents is their poor efficiency, which typically ranges between 10 and 20 lumens per watt.

They can be dimmed with any dimmer, though only modern electronic dimmers will save you energy. Brandston recommends putting *all* of your incandescents on modern dimmers. "If you dim by only 5% percent of the voltage, " he says, "the change in the spectrum, and your eyes' response to that, will be better. You'll get 90% of the light output, save a little energy, and extend lamp life by 275 times."

Halogen

Halogen lamps are incandescent, with the filament sealed inside a high-temperature, halogen-filled glass envelope. This lets the lamp burn hotter, resulting in a modest efficiency increase—about 24 lumens per watt. Halogens also last longer than incandescents, as the halogen gas inside helps tungsten particles recombine back onto the filament instead of depositing on the glass as standard incandescents do. They are more expensive than incandescents, but contain no toxic materials and need no special disposal.

Courtesy General Electric

Benjamin Root (2)

Halogen bulbs are made for many fixture types, are more efficient than standard incandescents, and are readily dimmable, providing added energy savings.

Fluorescent

Long the standard for brightly lighting large spaces at a low cost, fluorescent lamps (FLs) are excellent for some situations. They are the most efficient indoor lighting technology at about 80 lumens per watt, and are one of the few lamps available in large sizes. They have many downsides in lighting a home, however, and are best for workshops, garages, and other spaces where humans work, but don't live.

The light quality from FLs ranges from poor to fair due to their narrow spectrum. The old magnetic ballasts known for their hum and flicker are being phased out for more efficient electronic ballasts. Due to the uneven spectrum, FLs can be hard on the eyes and give skin, clothing, and room furnishings and decorations an unnatural color cast.

Courtesy Lithonia Lighting

Electronic ballasts and better color rendering have improved high-efficiency fluorescent lighting.

The tube or circular tube form limits your choice of fixtures, and only lamps with special ballasts can be dimmed, and then only with special dimmers. Lamp life is shortened with frequent on–off cycles, so manufacturers recommend that FLs remain on for at least 30 minutes during each use. FLs contain mercury and must be properly disposed of, and properly cleaned up if they break (see "Mercury & Fluorescent Lights" in *HP153*).

Compact Fluorescent

Although compact fluorescent lamps (CFLs) are often touted as the most cost-effective and efficient replacement for every lightbulb in your home, they are best-suited only for certain locations and applications. At 45 to 70 lumens per watt, they can be as much as four times more efficient than incandescents, but less efficient than FLs. CFLs were an attempt by lamp manufacturers to make a small fluorescent lamp tube fit into a standard incandescent fixture by bending and twisting the glass to approximate the size of an incandescent lamp.

Unfortunately, this has led to numerous consumer complaints and problems with CFL technology. I've experienced all of them since first using CFLs in my off-grid home more than 15 years ago, and the Internet echoes my experiences. Poor light quality and color are major complaints, thanks to those uneven spectral distributions. A much shorter lifespan than advertised is a common issue too, as CFLs are cost-effective only if they last far longer than the incandescents they replace. They also contain mercury and electronic components, and must be disposed of and cleaned up after just like FLs.

Courtesy General Electric

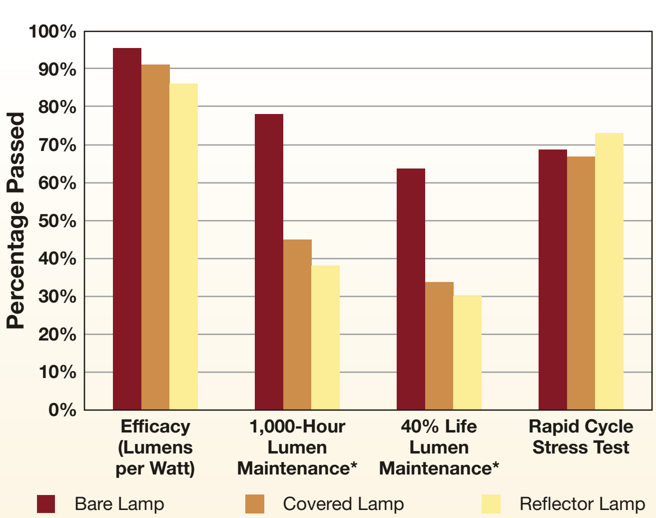
Though they are almost as ubiquitous as incandescents, CFLs aren't the best choice for every application.

CFLs now come in many sizes, shapes, and fixture types, but continue to have variation in quality and performance.

Courtesy General Electric

Lighting industry watchdog group Program for the Evaluation and Analysis of Residential Lighting (PEARL) tested 185 CFL lamp models over a period of nine years, and found that many failed prematurely or suffered a large loss in light intensity over a short period of time. An alarming percentage failed right out of the box. However, according to *Consumer Reports* testing and many lighting experts, the majority of the problem is improper usage—consumers frequently use CFLs for the wrong applications and in the wrong fixtures. Most homes were wired with incandescent lighting in mind, especially the fixtures. Incandescent lamps are not affected by heat buildup, but CFL lamps are. Heat drastically shortens their lifespan and light output, with recessed and sealed fixtures especially problematic. Fortunately, most fixture manufacturers now rate their products for the maximum wattage of both incandescent and CFL lamps allowed, and CFL manufacturers often state if the lamp should be used only base-down (for best cooling), base-up, horizontally, or in any position. This information is often printed on the package, or may be available from the manufacturer's website, but it can be hard to discern if the fixtures are already in place. If you are intent on saving energy, you may need to replace the fixture before you replace the lamp with a CFL. Though this will cut into your cost savings (whether you do it yourself or hire an electrician), the cost will eventually be recovered in both energy savings and longer lamp life. If in doubt about a fixture, use it only with lower-wattage lamps.

CFL Compliance with Energy Star Specifications



*Lumen maintenance compares the amount of light a lamp produces when it is new to the amount of light it produces at a specific time in the future.

Data courtesy PEARL

Fluorescent lights of any variety don't like being turned on and off frequently without having a chance to warm up. For longest lifespan, CFL manufacturers recommend that the lamp be allowed to run for a minimum of 15 minutes every time it is turned on—30 minutes is even better. This can make CFLs a poor choice for spaces like bathrooms, hallways and closets. CFLs are also sensitive to vibration, and should not be used in ceiling fans. They also do not work in most outdoor motion-sensing fixtures. In these locations, a lowly incandescent, especially one of the new, more-efficient varieties, would be more suitable.

Other common complaints about CFLs are the time needed to reach full brightness, poor performance outdoors in cold temperatures, and problems with dimmer switches. There are special varieties of CFLs that can deal with cold conditions and others that reach full brightness immediately, but the details are often in fine print on the box. Dimming CFL lamps takes attention on the consumer's part also—some are designed to be dimmable with older wall-dimmer switches, while others need a replacement switch.

Light-Emitting Diode

First made commercially available in 1962, light-emitting diode (LED) technology is making rapid strides in improved efficiency and reduced cost. LEDs are quite efficient, about the same as most CFL lamps and with some new models almost meeting or slightly surpassing the 80 lumens per watt of FLs. Beware of media hype, though—announcements about new LEDs reaching 100 or even 200 lumens per watt are common. In reality, it takes years for these innovations to be accepted by lighting manufacturers, go through rigorous safety and performance testing, become Energy Star-certified and UL listed, and finally make it to the stores. Worse, manufacturer's laboratories use a variety of testing standards; not all of them factor in the total power use of the lamp and its associated electronics.

Compared to other technologies, which radiate light in all directions, light from solid-state LEDs is directional—emitted in a relatively narrow beam. This makes LEDs ideal for task-lighting applications such as under-counter lighting and reading lamps, and helped give LEDs a push into the marketplace back when production was limited and prices were still very high.

Courtesy Feit

New LEDs come in many shapes and sizes for various fixtures and applications.

Courtesy General Electric

Today's LEDs are now being made to fit traditional fixtures.

Early LED lamps produced poor-quality light due to a very narrow spectrum, but advances in phosphor technology have spread their spectrum to an even distribution that's almost as pleasant to live with as incandescent. Many forms are available to fit existing fixtures, though the directional nature of LED light changes the applications for which it is best suited. It is still expensive to light a large space efficiently with LEDs, though recent developments in both lamps and fixtures have helped make this more affordable.

LEDs work well in recessed fixtures due to their inherent directional light.

Courtesy Osram Sylvania

Other advantages of LED lighting include no warm-up time to reach full brightness even in cold temperatures, no sensitivity to vibration, and no toxic waste or special disposal needed. Certain LED lamp models can be dimmed, but only with special dimmers.

LED lamps have the longest potential lifespan of any current lighting technology, but are so new that very little hard data is available about how they are affected by heat buildup and other real-world issues. "There isn't enough long-term data yet for me to put them in my commercial projects," Brandston said. "Two or three years is *nothing* in the lighting industry."

Courtesy General Electric

Task lighting is a perfect application for LEDs.

Ballasts, Bases & Dimmers

Ballasts

All FL and CFL lamps require a "ballast" that converts the supply current to high-frequency AC, exciting the lamp. Early ballasts were magnetic and used an inductor for this conversion, which was inefficient, noisy, and caused irritating flicker of the lamp. Modern electronic ballasts that solve these problems are being rapidly phased in by manufacturers.

With most FL lighting, the ballast is inside the fixture and the lamp simply attaches with pins on each end. Both FL ballasts and lamps can be replaced. Most residential CFL lamps use regular Edison screw bases with the ballast contained within the lamp; these ballasts cannot be replaced. Other CFL ballast types are available, though. "Pin-base" CFLs contain the ballast in the fixture, with the lamp connecting via two or four pins. There are a variety of different pin bases, so consumers need to be sure and get the correct lamp for their ballast. The new GU24 pin base is made to comply with new Energy Star fixture standards, but the lamp, not the fixture, contains the ballast. The new base simply prevents users from installing inefficient incandescent and halogen lamps into a new Energy Star-rated fixture.

Dimmers

Dimmer switches have long been an effective way to adjust a room's light levels, but problems with dimming new, efficient lighting technologies have become a major complaint. Older dimmer switches simply used a rheostat to lower the voltage sent to incandescent or halogen lamps. The surplus energy was converted to heat inside the dimmer switch, resulting in dimmer lighting with no energy savings.

Modern dimmer switches use semiconductor triacs to chop up the AC waveform and reduce the amount of time the lamp is actually on. This pulsing is supposed to occur faster than the eye can detect, but different people have different sensitivity to flicker. "Some lamps appear to flicker more than others due to light modulation," says Mark Rea, director of the Lighting Research Center at Rensselaer Polytechnic Institute. "However, all lamps flicker at the same rate."

Triac dimmers can also cause an audible buzz within some lamps; more expensive dimmers use more electronics to reduce this effect. Note that CFLs advertised as "dimmable" can only be dimmed by about 20%, after which they will simply shut off. Three-way switches are another form of dimmer and require special three-way CFL lamps.

On Rea's advice, I recently took a research trip to my local big-box store to check out my dimmable options. One major-brand CFL package said "dimmable" in large letters, with the fine print below reading "Works with most dimming switches." "Most" was not very helpful, so I asked store personnel—no luck there, either. It finally took a call to the lamp manufacturer to get a list of dimmers that would absolutely, positively work with that particular lamp.

"The industry does a disservice to itself and consumers by not quantifying and bundling the information consumers need to purchase lighting," Rea says. "There are easily 20 benefit factors that affect whether they will be satisfied with their purchase, but it would take too much time for the consumer to research them all."

That certainly echoes my experiences in efficient lighting over the last two decades. And until the lighting industry *does* get its consumer education act together, my advice is that when buying lamps, fixtures or dimmers...always save the receipts!

To work well with modern lighting technologies and to save energy, modern solid-state dimmers are a must.

© istockphoto.com Eltoddo

Light Right

Hang a bare lightbulb in a room and turn it on. You'll see that a large portion of the light shines on the ceiling, where it's only useful to your local spiders or to make stick-on stars glow. Very little shines where *you* need it. Now put a reflector behind the lamp, and your useful light levels have increased with no increase in energy use, and your spiders are out of luck. Your great-grandmother probably knew all about this, too—kerosene and gas lamps back in the day didn't produce much light. But by positioning the lamps at strategic locations and placing reflectors behind each, she could maximize the useful illumination. In more modern homes, lighting fixtures serve the same purpose, redirecting light to where it's needed most, but different lamp technologies cast light in a variety of patterns and intensities, called "candela distribution."

"Lumens measure light emitted in all directions," says Rea. "Candelas measure light emitted in a specific direction. With the lumens per watt standard, we completely misrepresent any situation where we are not lighting the entire room, such as with undercabinet lighting for kitchen counters."

Your great-grandmother probably would not have approved of much indirect lighting, either. Valance, cove, and soffit lighting can create ambiance, but also waste a portion of your lighting energy budget. If you have the luxury of building a new home or remodeling an old one, you can plan ahead and consider the optimum locations for your fixtures. Do you really need to brightly light up your entire home office (ambient lighting), or would your energy be better spent on illuminating just your desk and other work surfaces (task lighting)? Consider your kitchen—it doesn't take much light to navigate around a room without tripping, but you certainly want bright, high-quality light focused on the cutting board. The spillover from task lights may be enough to safely illuminate pathways. Avoid wiring lighting circuits that put more than one fixture on a switch, as you can end up lighting areas that do not need it.

At the hardware store, don't just fill up your shopping cart with a pile of energy-efficient lamps. Quality of light, brightness, candela distribution, and color temperature vary significantly between manufacturers and models, *even when*

Courtesy Osram Sylvania

Well-placed, specific-purpose task lighting can often provide ample illumination, spillover for safe navigation, and a pleasant lighting aesthetic.

© istockphoto.com/coprid

Motion sensor switches can make up for bad habits and unaware energy hogs.

Free Light

Don't forget the most efficient lighting option—daylighting. Well-placed, high-performance windows and tube skylights can eliminate the need for artificial lighting during the day. Tube skylights (aka sun tubes or solar skylights) can bring daylight to interior spaces without large windows that receive frequent daytime use, and are a great retrofit project.

Courtesy Solatube

Off-Grid Lighting

Making sure your lighting is as efficient as possible takes on even more importance in off-grid systems due to expensive battery banks that should not be overdischarged and the winter double-whammy of more hours of darkness combined with a reduced solar resource.

For off-grid homes, the lighting focus will likely be more on efficiency than light quality, but you don't have to compromise—much. As my old FLs and CFLs burn out or get dim at my off-grid home, I am slowly phasing in LED lamps. So far, I'm satisfied. The cost of LED lighting is still high, but not as high as the cost of a new battery bank or adding PV modules.

Because most modern inverters provide a nearly pure sine-wave output, FLs, CFLs, and LEDs or dimmers usually work well. However, modified wave inverters used in smaller or older off-grid installations can cause problems with these newer lighting technologies. Expect an efficiency loss of 10% to 20%—as with any appliance that has inductive or capacitive elements (ballasts, motors, computers, etc.)—and the possibility of flickering or audibly buzzing lamps.

In very small off-grid systems such as for cabins, RVs, tractor-trailers, and boats, DC lighting can make sense, though only with LED fixtures and lamps. (DC CFLs are available, but are expensive, difficult to find, and very sensitive to voltage drop in DC wiring, which shortens their life drastically.) A bonus with DC lighting is that because an inverter is not necessary, it is more efficient. The problems with premature LED burnout have been solved with the latest DC LED products, which use efficient power electronics to provide a constant voltage to the lamp no matter what the battery bank voltage, with built-in energy-saving dimming capability.

Courtesy APRS World

Although many modern off-grid homes use true sine wave inverters, allowing the same light choices as on-gridders, DC LEDs can offer improved lighting efficiency at a reasonable cost.

the lamps show similar specifications on the package. Instead, buy a variety of single lamps and try them in different rooms and fixtures until you find what you like.

Rea also cautions against relying too much on "equivalency ratings" printed on CFL and LED lamp packaging that claim, for example, a particular 26-watt CFL makes as much light as a traditional 100-watt incandescent. "Don't believe it," Rea says, "Such ratings are based on industry standard test methods that often do not reflect how the products are actually used in the home. Consumers need to try different lamps themselves, and find what works best for them."

Stick with the major lamp manufacturers. This used to be just the "big three"—Philips, Sylvania, and General Electric—but in recent years several other manufacturers have entered the market (see "Access"). However, avoid imported lamps that are not UL-listed or Energy Star-rated; some are so shoddily made that they pose a fire hazard.

Make sure the lamp you are interested in purchasing is compatible with the fixture in which you want to put it, and with any dimmers that will be involved. Write down brand names, model numbers, and manufacturer websites so you can research options on the Internet, and do your homework before you call.

"Lamp manufacturer technical support departments are used to working with large-volume buyers such as big-box stores, not directly with individual consumers," Rea says, "but if you can make your questions very specific, most will be happy to help educate you about their products via phone or email. However, vague questions about 'light quality' and so forth won't often receive a detailed response.

"Don't be afraid to put the burden back on your local retail store, either," says Rea. "Ask them if you can compare different lamps in different fixtures right there in the store."

Consider installing occupancy sensors if family and friends are in the (bad) habit of leaving lights on when rooms are not in use. The sensors present a small phantom load, though it's usually less than 1 watt.

Access

Author and educator **Dan Fink** has lived 11 miles off the grid in the northern Colorado mountains since 1991. He teaches about off-grid systems and small wind power, and is the executive director of Buckville Energy Consulting, a NABCEP/IREC/ISPQ-accredited continuing education provider. Dan is the coauthor of *Homebrew Wind Power.*

Lamp & Fixture Manufacturers:

APRS World • aprsworld.com • DC LED lamp & fixture

Cree • cree.com

Enduralite LED • enduraliteled.com

Feit Electric • feit.com

General Electric • gelighting.com

Lighting Science Group • lsgc.com

Lights of America • lightsofamerica.com

Lutron • lutron.com

Osram Sylvania • sylvania.com

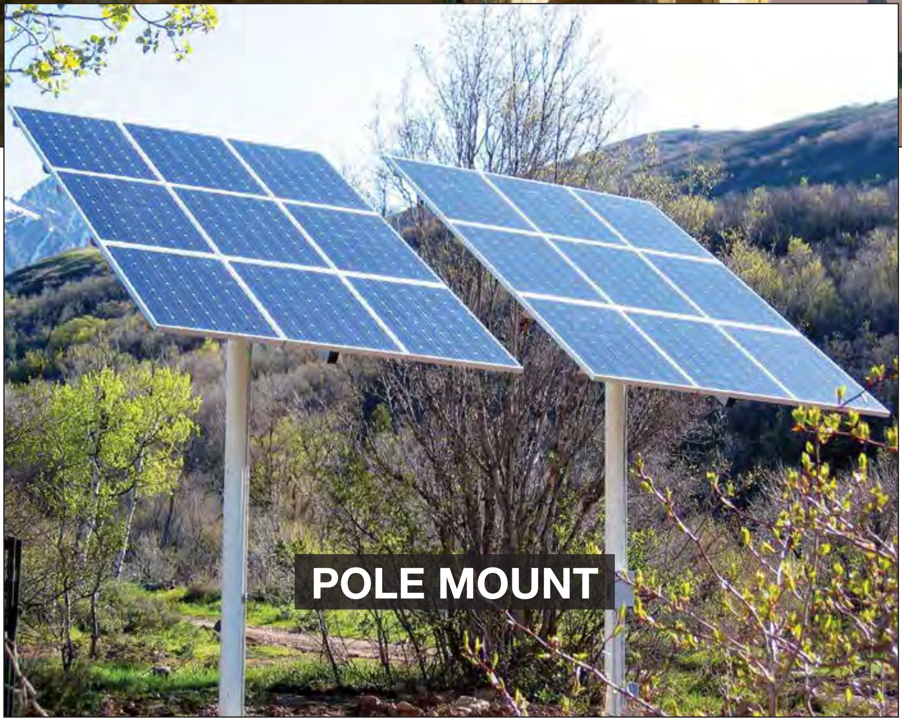
Philips • usa.lighting.philips.com

Seesmart LED • seesmartled.com

PV Array Siting

by Justine Sanchez

Courtesy Joe Villacci



Courtesy Gardner Engineering AES

Determining how and where to mount a PV array are crucial steps in the PV system design process. Will it be on the ground, a pole, or the roof? And what mounting methods will be used? Although everyone prefers a shade-free site, we are limited to what the situation offers us (like if only part of the yard has good solar access). Finally, each mounting method has its pros and cons that are important to understand before settling on a design.

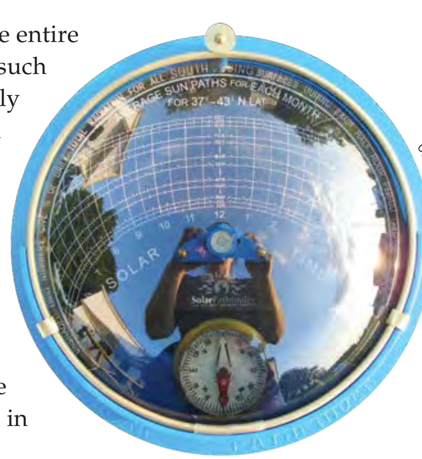
& Mounting *Considerations*

Courtesy Gardner Engineering AES

Siting Goals

The ideal is to have a shade-free array throughout the entire day, from dawn until dusk. However, obstructions such as trees, buildings, and mountains are common. Early morning and late afternoon sunlight isn't as powerful as those midday hours, so aiming for a shade-free "solar" window from 9 a.m. to 3 p.m. will give you most of the energy available at the site.

Predicting where shade will be cast throughout the day (and throughout the year) by obstructions is difficult, so system designers use site analysis tools, such as the Solar Pathfinder or Solmetric SunEye, to compare different mounting sites. These tools also establish a shade factor that can be used in system sizing calculations.



Courtesy Kelly Larson

Courtesy Solmetric

Siting tools such as this Solar Pathfinder (left) and Solmetric SunEye can help find the best solar window.

Array Tilt & Orientation

A PV system's output depends on the angle of sunlight striking the array's surface, with the highest output achieved when solar rays are perpendicular to the array. Unless you're planning to use a dual-axis tracker (see "Trackers"), the sun's position relative to the array surface is constantly changing. For a fixed PV array, we can determine an orientation and tilt to capture the maximum amount of sunlight throughout the day and year. While we may not actually mount the modules at the best orientation or tilt (for example, mounting an array flush to a roof for aesthetic reasons), we can establish a baseline for maximum system production and increase the array size to account for non-optimal tilt and orientation (see "Methods" in this issue).

Courtesy Photon Solar Power

Flush mounting is often preferred, even when the roof isn't oriented to true south or at an ideal tilt.

The increased energy production of a tilted roof mount often does not outweigh the drawbacks of rack complexity, cost, wind loading, and aesthetics. However, in off-grid systems where winter production needs to be maximized, tilted roof-mounted arrays can make sense.

Courtesy Electron Connection

Courtesy Lumos Solar

Mounting Options

Courtesy Gardner Engineering AES

This ground mount is actually a multipole mount, where the racking structure spans across a single row of vertical pipe. Fencing keeps the critters and humans out, and helps meet *NEC* requirements for protecting exposed wire.

Courtesy Positive Energy NY

Exposed wiring on the back of an array can be protected by an appropriate covering, such as this flat, expanded aluminum secured to the rack.

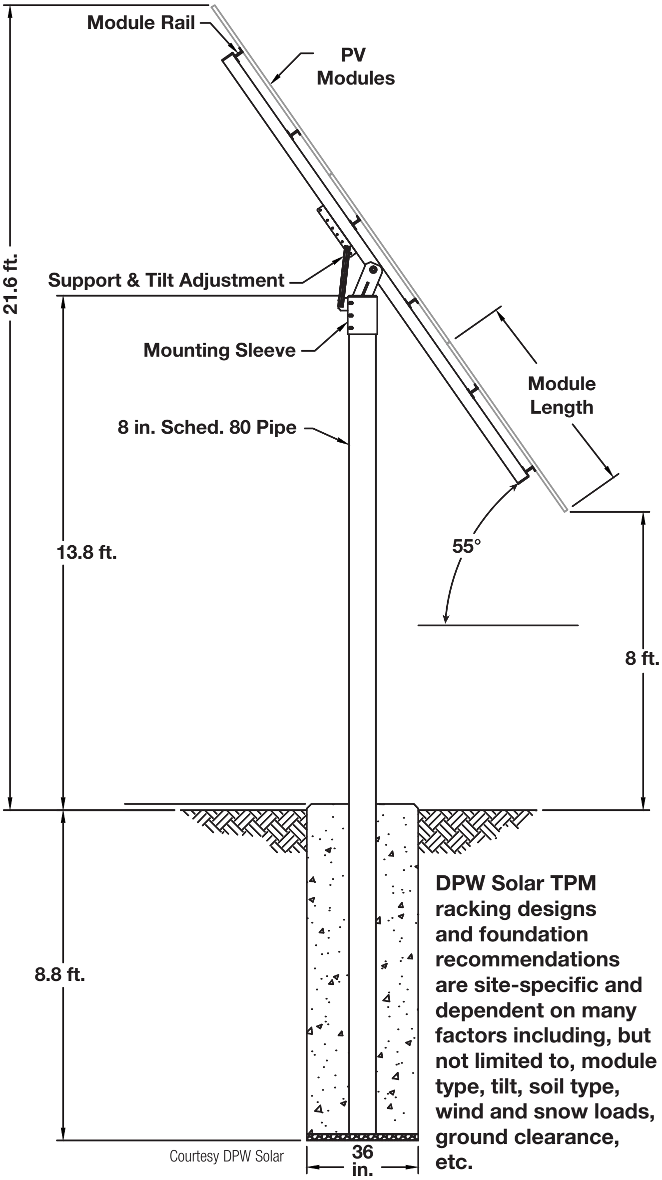
GROUND MOUNTS

Ground mounting is most common in rural areas, where there's often more wide-open, shade-free space. This method can be appealing, since installation and maintenance take place at ground level rather than on a high roof. Ground mounting also provides ample airflow behind the modules, helping to preserve efficiency, since PV array voltage decreases as PV cell temperature increases. Other advantages include more space to accommodate a larger array, and the ease of mounting modules at their optimal tilt and orientation.

Conversely, ground mounts often require excavation and concrete footings for the attachment points, which can increase installation time and cost. Because the array is accessible to animals and humans, precautions must be taken to protect any exposed wiring, per *NEC* 690.31(A). Vegetation around the array needs to be managed to avoid shading. In cold climates, the array must be high enough to keep it out of the snow. For multiple rows of modules, interrow shading must be avoided by keeping enough space between module rows (see "Methods" in *HP151*). And not to be ignored, the accessibility of ground-mounted systems means a larger risk of theft or vandalism, which may or may not be an issue at your site.

Plant growth can shade ground-mounted arrays, reducing their production.

Courtesy Brian Mehalic



Courtesy DPW Solar

SINGLE POLE MOUNTS

Single pole-mounted arrays have the same basic advantages of ground-mounted systems, plus they can be more easily adjusted for increasing peak-sun hours captured seasonally and to shed snow. Compared to a ground mount, a pole mount releases more ground area for other uses. Tall pole mounts not only keep wires running along the backside of the array from being "readily accessible" (if the wiring is above the ground by 8 feet or more), but also could reduce theft potential. However, since tall pole mounts cannot be reached from the ground, they also require a tall ladder for array maintenance and for adjusting tilt angle.

A ground mount uses multiple, lighter-weight supports, but a single pole mount has one large steel support. Depending on the ground clearance and array size (along with wind loads and soil type), that pole can be a heavy beast, commonly 6 or 8 inches in diameter and either schedule 40 or 80 steel pipe. For example, a specific design for a

Civil works can increase an installation's cost and complexity.

Courtesy Gardner Engineering AES

These two arrays are shown at different tilts to show the adjustability of these top-of-pole mounts. Typically, they would be set to the same tilt.

Courtesy Oasis Montana

Trackers

Trackers use either passive or active means to keep the array pointed toward the sun throughout the day. Trackers rotate on either a single axis, following the sun's azimuth angle throughout the day, or on a dual axis, following the sun's azimuth *and* altitude angle (see this issue's "Back Page Basics." Given a wide-open solar window, a tracked array can increase system output up to 40%, which can translate into fewer PV modules to produce the same result as a ground- or roof-mounted system.

Some trackers use motors and electronics, which can fail, translating into lost energy production. With PV module prices at an all-time low, the higher cost of the tracker mount can outweigh the cost of using more untracked modules instead. Additionally, some incentive programs give rebates on a per-watt basis (paying more for larger arrays), and thus can further increase the comparative cost of a tracking system (see "To Track or Not to Track" in *HP154*).

Courtesy Gardner Engineering AES (2)

The complexity of the mechanics and sensitive electronics of active trackers affects the cost and reliability in ways that may not be offset by the increased production at all sites.

Courtesy Oasis Montana

This passive gas tracker can follow the moving sun for increased energy production, without the use of electronics or motors.

3-kilowatt array with 8 feet of clearance to the bottom edge of the modules (at a winter tilt of 55°) will require the pole to be almost 9 feet in the ground. That's a total pole length of 22 feet of 8-inch, schedule 80 galvanized steel pipe, which will require a 9-foot-deep (3-foot-wide) hole and approximately 2.3 yards of concrete. Installing the modules on this top-of-pole mount also requires scaffolding or a scissor lift, or for the completed array to be lifted in place by a crane.

Top-of-pole mounts allow users to set the array at an ideal orientation and tilt angle for their location, and can easily be adjusted to a steeper tilt angle in the winter to shed snow.

Topher Donahue

Shawn Schreiner

Working in high places is all about safety—the equipment to avoid falls is readily available to all installers.

ROOF MOUNTS

Roof-mounted arrays take advantage of space that is otherwise wasted, leaving the yard for other uses. They are less expensive to install, since no excavation or concrete work is required, and they naturally remove ready access to array wiring. (Wire *management* is still required; see "Methods" in *HP154*.)

But roof installations often take place on high and sometimes steep roofs (as does any future array maintenance) and fall arrest systems (i.e., a body harness attached to a lifeline cable and an anchor) should be used. All roof penetrations must be flashed and sealed. The combined weight of the modules and racks, along with wind loading on the building, must be appropriately engineered. Flush-mounted arrays, even with the recommended 4- to 6-inch spacing above the roof, will have less cooling airflow than a ground- or pole-mounted array, and array orientation and tilt is often less than optimal and not adjustable.

continued on page 74

IFC Rooftop PV Siting Requirements

For the first time, the *International Fire Code (IFC)* contains references to PV systems. The 2012 edition addresses firefighter and emergency personnel access to rooftop PV systems on commercial buildings and residences. Roof access is needed during firefighting so that holes can be made to get smoke out of a building.

Residential rooftops are divided into two categories—hip roofs and ridge roofs. Hip roofs require a 3-foot-wide access path from the eave to the ridge on the face of the roof on which PV modules are mounted. Ridge roofs require 3-foot-wide access paths between the eave and the ridge on both sides of the array, since, unlike a hip roof, there is not an adjoining roof section that can easily be accessed. These access pathways must be over structural building elements, and may not be located on top of an overhang. Additionally, modules cannot be located any closer than 3 feet from the roof's ridge, regardless of the roof geometry.

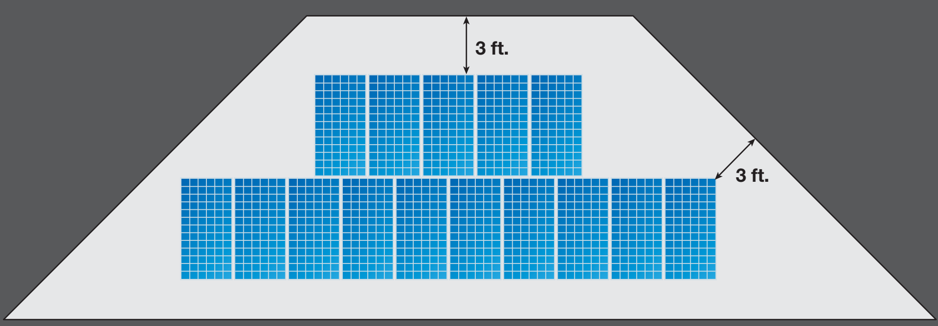
Modules placed on both sides of a valley or hip must be at least 18 inches from the center of the hip or valley. If only one side of a hip or valley has modules on it, then the modules can extend all the way to the corner of the hip or valley, provided that the adjacent surface is as long as the roof surface to which the modules are mounted.

These requirements do not apply to roofs with a pitch of 2:12 (≈ 9.5°) or less, nor do they apply to detached, uninhabitable structures, such as carports or shade structures. With permission of the local fire official, these requirements can be waived so long as it is determined that the array's position will not interfere with local methods for emergency ventilation.

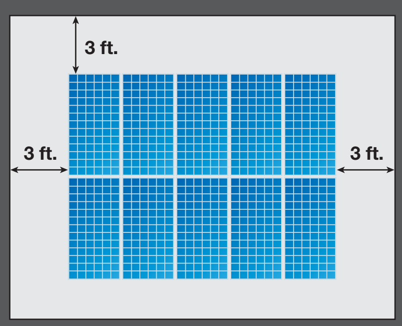
Check with your local jurisdiction regarding adoption of the 2012 *IFC*. Some jurisdictions may be enforcing these standards, or some variation of them, even if they have not yet officially adopted the 2012 *IFC*.

—Brian Mehalic

Hip Roof



Ridge Roof



The gap between the roof and the array allows for some airflow behind the modules.

Courtesy Kelly Larson SolarKelly.com

Modern flashing products decrease the chance of water leaks in the roof.

Courtesy DPW Solar

continued from page 72


Courtesy Guy Marsden

This array is still being populated with PV modules but the solar-powered attic fan means one less module will fit in the array.

Roof mounting space is usually limited, constraining the array's size. The array design must accommodate obstructions, such as vents, chimneys, and skylights. Often, setbacks around the array are required for firefighter access, pathways, and smoke ventilation. For example, California's fire guidelines call for 3-foot setbacks from the top of the array to the ridge and along one (or both, depending on the roof type) sides of the array.

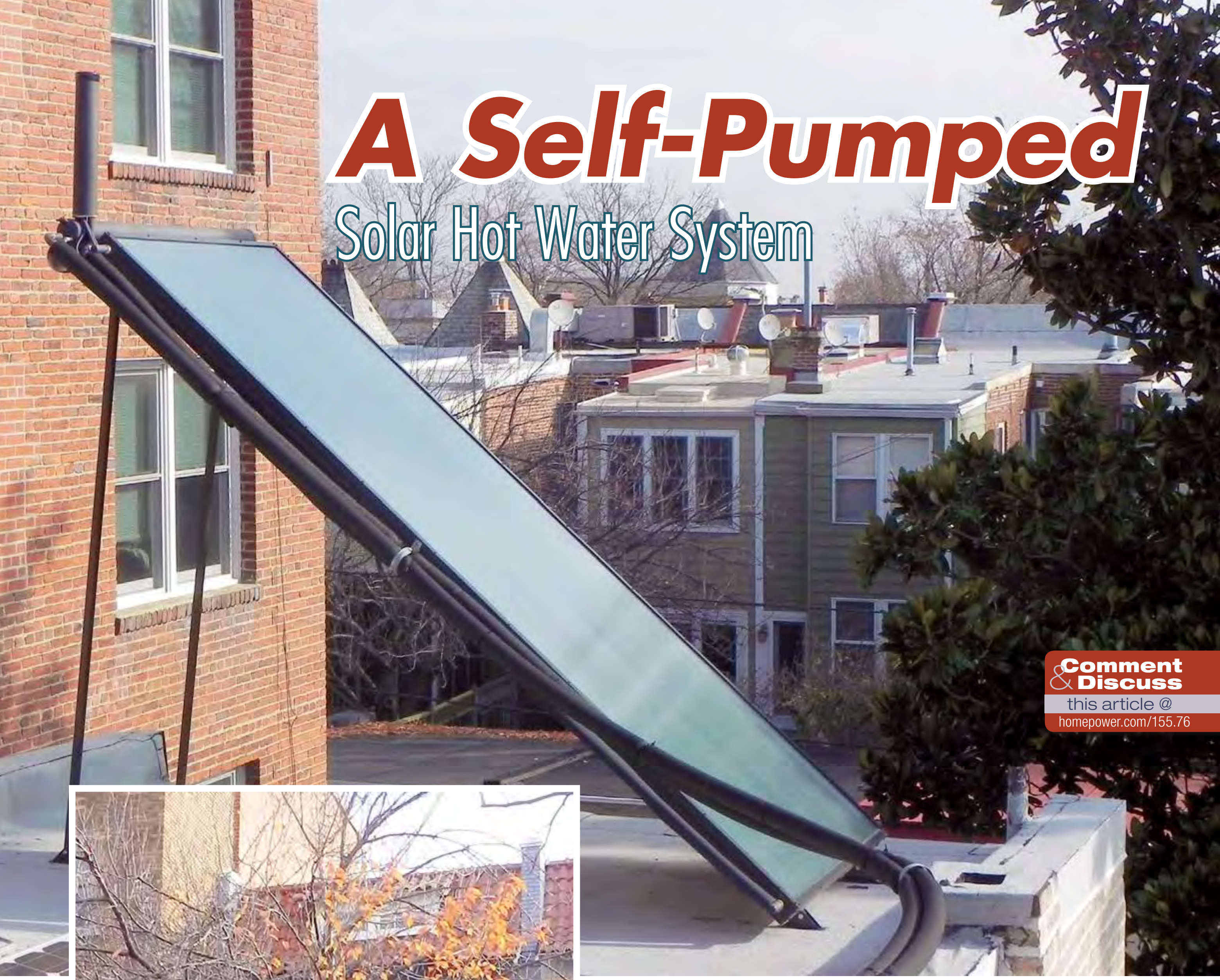
Working with a roofing contractor is a good idea, as they can properly secure attachments without compromising the roof structure, are familiar with the various code requirements for roofs, and can warranty the penetrations they work on. They can also evaluate the remaining life of the roof—an important consideration before installing a 20- to 25-year PV system on it.

Access

Justine Sanchez (justine.sanchez@homepower.com) is a *Home Power* technical editor and an instructor for Solar Energy International. She is certified by ISPQ as a PV Affiliated Master Trainer. As her house hunt continues, she's contemplating potential PV sites and mounting methods.

A Self-Pumped

Solar Hot Water System



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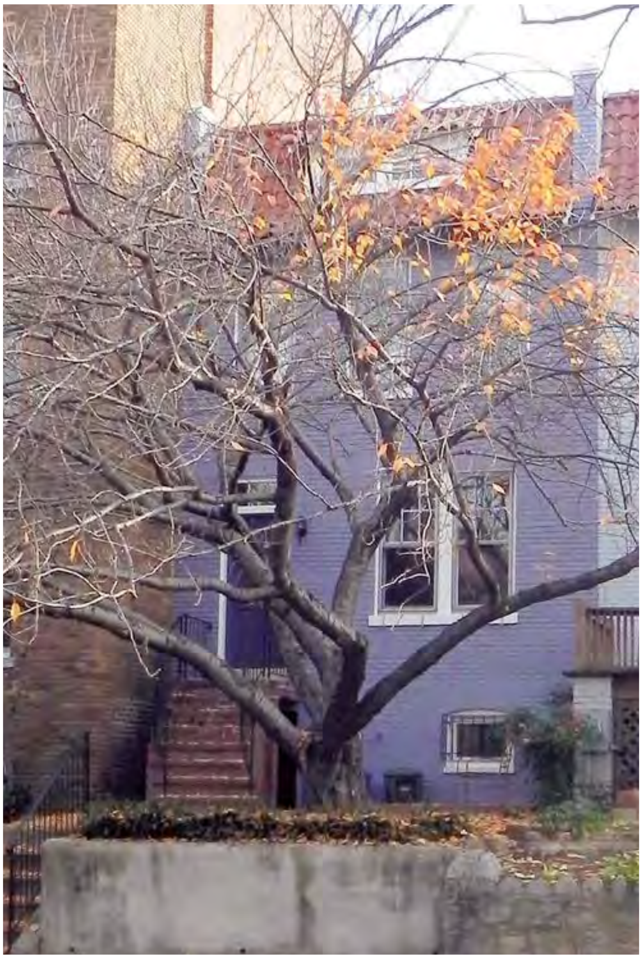


Story & photos by Andy Kerr

Above: The PV array placement left room for a solar hot water collector. Note the vertical riser of the geyser pump, a characteristic of the Sunnovations system.

Left: Although this Washington, DC, townhouse has a fairly small, flat roof, it still accommodates both PV and SHW systems.

When my fiancée and I were ready to have a solar hot water (SHW) system installed at our Washington, DC, townhouse, I figured our only choice was to buy an active system that required mechanical valves and electronic controllers, and electricity to operate them. Of the four SHW systems I have owned, two were "active" (electrically pumped) systems and two were "passive" (self-pumped) systems, the latter with no moving parts. I prefer the latter because moving parts are subject to failure.

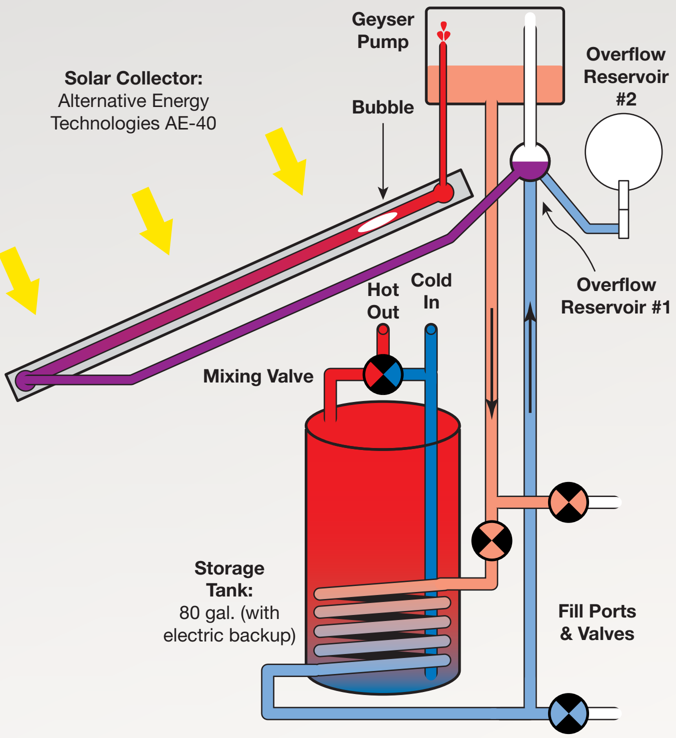
Then I ran across a start-up company—Sunnovations—touting its "geyser pump," which also has no moving parts. Sunnovations drew on—and then improved upon—the simultaneously famous and infamous Copper Cricket design—a passively (self-)pumped collector that was produced several decades ago (I was a satisfied owner of two of them).

Like most SHW systems of that era, the Copper Cricket was far from perfect. Despite its main advantage of having no moving parts, the Copper Cricket had two major shortcomings: it operated under a vacuum that could fail and frequently did; and it could overheat and "cook" the antifreeze solution that served as the heat-transfer fluid (HTF) between the collector and the storage tank.

Inset: This concept model has clear glass to view the geyser's pumping action.

Above: The vertical part is the geyser pump and the horizontal is the overflow reservoir, which prevents overheating of the heat-transfer fluid.

Geyser Pump SHW System



As in any solar hot water system schematic, the color shades between red and blue represent the relative temperatures of the heat transfer fluid (HTF) between hot and cold. The purple indicates the HTF that is preheated in Overflow Reservoir #1 by the condensing steam from the Geyser Pump.

Tech Specs

Overview

System type: Self-pumped closed-loop antifreeze

Location: Washington, DC

Solar resource: 4.6 average daily peak sun-hours

Production: 1,231 kBtu per month, average

Domestic hot water produced annually (estimated): 70%

Solar Equipment

Collector: Alternative Energy Technologies AE-40, 4 x 10 ft.

Collector installation: Roof-mounted, 45° tilt

Heat-transfer fluid: 45% propylene glycol & 55% water: rated to -22°F

Storage

Domestic hot water storage tank: Bradford White, 80 gal.; with electric backup

Performance Monitoring

Thermometer: Pasco, dial; maximum 240°F

Pressure gauge: Ashcroft, dial; range: 28 mm Hg (negative pressure) to 30 psi (positive pressure)

Pressure & temperature gauge: P&T dial gauge in brass well

A new Bradford White solar hot water storage tank also provides backup heating, saving space in an already-crowded basement.

A side view of the top of the tank showing the thermometer that measures the tank's output temperature (the nearest copper pipe riser). Above it is the Honeywell adjustable mixing valve. The pink electrical cable is the 240 VAC electricity for backup water heating. The two twisted pair wires in the background connect to unused sensors (for active, not passive, systems) in the Bradford White tank.

Determining Your Water Heater's Age

Water heater warranties range from three to 12 years and, typically, you get what you pay for. Longevity depends upon the tank lining, water quality, and other factors. Most people replace their water heater in a crisis, when they discover that its not producing hot water or is leaking. If your water heater is out of warranty, it is living on borrowed time.

How can you determine your tank's age? Check out its serial number, says *Home Energy* magazine. "If it begins A-83 or 0183, the tank was built in January 1983. B-83 or 0283 mean February 1983, and so on. If it begins 8301, the tank was built in the first week of 1983; 8352 would mean the last week of that year."

Sunnovations SHW systems are currently the only "self-pumped" systems certified by the industry-standard Solar Rating and Certification Corporation (SRCC). Sunnovations has obtained SRCC "OG-300" certifications for 41 system configurations, using combinations of five different collector brands, one- to three-collector arrays of varying-sized collectors, single and double storage tanks, and gas or electric backup heat.

The Sunnovations geyser pump depends upon a vacuum (negative pressure) to reduce the boiling point of the heat-transfer fluid to about 100°F. The "geyser pump," which relies on solar heat for its pumping action, is the heart of the system. It can be affixed to almost any collector. (The Copper Cricket was an all-in-one geyser pump and solar collector.) After an initial vacuum has been established, the pump circulates the HTF through the collectors. As the sun warms the geyser pump, pressure increases and the heated fluid flows.

Bright sun means higher operating temperatures and higher operating pressures. But even in full sun, the system operates at slightly below ambient (outside) atmospheric pressures. The maximum temperature the system may reach is 185°F, below the temperature at which the HTF breaks down. When the system pressure reaches the ambient pressure, a

Solar-heated HTF coming into the storage tank (top gauge). The system pressure at the collectors ranges from 28 mm of mercury (vacuum) to 0 (ambient pressure) and depends on the insolation, ambient temperature, and temperature of the fluid returning from the heat exchanger. The gauge at the tank shows a higher pressure, as it includes head pressure (0.43 psi per vertical foot).

relief valve vents steam to a reservoir where it condenses back to liquid, and the geyser pump continues to operate. When the storage tank is fully heated, the return fluid to the collector will exceed 140°F, causing the pressure to rise rapidly. The temperature-limiting mechanism, which vents excess steam, cannot keep up, so fluid is vented out of the collector into the reservoir, thereby preventing the fluid from overheating. After the system cools, all the fluid expelled to the reservoir is drawn back into the system, which revitalizes the vacuum.

As the geyser pump system simply will not operate in extremely high temperatures, oxygen-barrier cross-linked high-density polyethylene (PEX) tubing can be used, rather than more expensive (materials and labor) copper pipe to carry the transfer fluid between the collector and the storage tank. PEX is flexible, so fewer joints are necessary and the joints are easier to make. While PEX piping can be problematic in traditional high-pressure and high-temperature active pumping SHW systems, as the Sunnovation system is self-limiting of both temperature and pressure, PEX is quite suitable.

While heated fluid flows without additional energy from electric pumps, for the passive Sunnovation system, the solar collector and geyser pump must be 33 feet or less above the storage tank. The geyser pump loses some heat to the outside air, especially on cold days. The unit must be warmed by the sun to 100°F to pump, so an active system set to come on at 90°F can be more productive on cold winter mornings. The relatively low flow rate (about 1 gallon per minute for two 4- by 8-foot collectors) will also result in some loss of heat delivered to the storage tank.

Several Thoughts

My system uses an 80-gallon Bradford White solar storage tank with built-in heat exchanger and dual 4,500-watt heating elements. The thermostat for the bottom heating element is located at midlevel on the tank, higher than the bottom heating element. The bottom element thermostat can be set to a significantly lower temperature than the top element thermostat, allowing adequate amounts of warmed—but not hot—water to be quickly heated by the top element when necessary, while also allowing cold water at the bottom of the tank to capture solar heat when available.

A major decision was whether to use gas or electricity to heat the water when sunshine is inadequate. We have a new super-efficient gas furnace—so efficient that it exhausts through an ABS plastic vent directly through the wall. Since there was no longer waste heat from the furnace to add to the natural gas water heater exhaust, water vapor could condense in the chimney and cause deterioration—a $1,200 flu liner would be needed. Using an electric storage tank eliminated the need for any chimney, so I removed the portion above the roof, which also occasionally shaded part of my PV array. The chimney below the roof found new life as a chase for the SHW system's PEX tubing.

During the estimated 20-year design life of any SHW system, the backup water heater may need to be replaced at least once—and maybe twice. The National Association of Home Builders says the life expectancy of a water heater is 10 to 13 years for gas and 14 years for electric. This replacement cost should be factored in when determining a SHW system's actual cost (see "Determining the Age of Your Water Heater" sidebar). If you replace your existing hot water tank when you install a SHW system, the new tank and installation labor qualify for the federal tax credit and perhaps other incentives. If your water heater is now beyond its warranty, it is living on borrowed time. When doing your analysis, the $1,000 to $1,500 cost to replace a conventional water heater should be subtracted from the cost of a SHW system, as it is a cost you would occur whether you have a SHW system or not. I estimated that the existing gas water heater would have had to be replaced in about six years anyway, so to determine the system's actual cost I deducted $750 from the gross system cost of the SHW system for a net cost of $1,780.

The chimney was removed and capped at roof level so it would not shade the PV modules.

The old flue is now the chase for the foam-insulated PEX tubing going to and from the SHW collector.

Navigating the SRCC Website

The Solar Rating and Certification Corporation (SRCC) is a nonprofit organization that publishes solar heating certification information online (solar-rating.org). Independent test laboratories, accredited by the SRCC, conduct a specified series of tests on collectors and systems and pass the information to the SRCC. SRCC certification is a requirement for the 30% residential solar tax credit and is required by many state, local, and utility incentive programs.

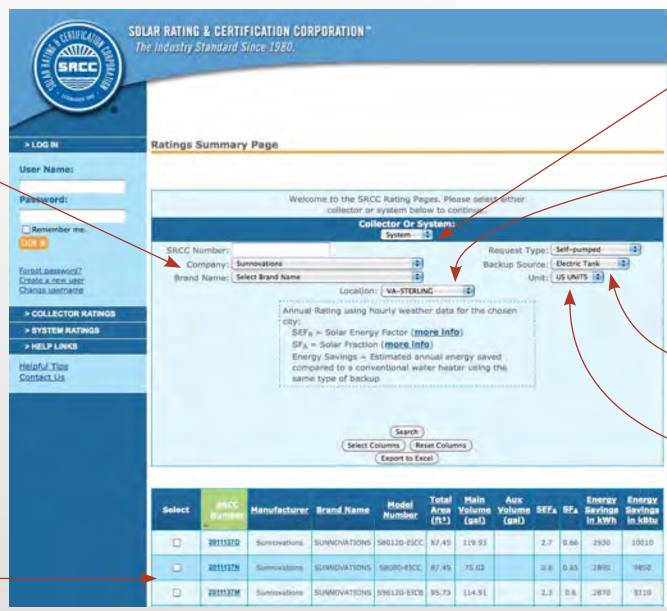
While the SRCC website has all the certification information, navigating it to find what you want can be intimidating. On the SRCC home page, pick Ratings from the left menu bar if you're looking for collector or system's certification status or estimated performance data. All of the other menu selections give information on certification rules, policies, and standards, and general information for manufacturers and interested users.

—Chuck Marken

If you would like to focus the selection for collectors, select the Company, Brand, Type, and/or Fluid. Leave blank and all of the collectors will be displayed.

Filling in the Company name and Brand will focus the search on only those systems; leaving it blank will display all systems.

The results of the search will appear below the search options as a summary. The energy savings shown (in kWh and kBtu) are exclusive for the Location that was chosen. Clicking on the SRCC system number will bring up the certification specifications and a system drawing in a two-page PDF file.



solar-rating.org

The default on the Ratings Summary Page is collectors—click on the box and select System for system ratings.

Selecting Systems will display new drop-down lists, including one labeled Location, which gives estimated performance that applies only to systems.

Note: Because they incorporate both collector and storage, ICS systems will only be listed in the system ratings.

If you would like to focus the selection, select the Type and Backup; if not, leave blank and all of the system types will be displayed.

Metric is the default units given; click and change to US UNITS if you want.

The system's cost was $8,500, against which we took a 30% federal income tax credit of $2,550; received a District of Columbia incentive of $1,700 (before taxes); and sold 10 years of future solar renewable energy credits (SRECs) for $1,780 (presently only DC and Maryland provide for SRECs from solar thermal systems).

This system has simple payback of eight years; a net present value of $2,220 for a 20-year investment horizon (the system should last at least that long); and a return on investment of 20%. If I had kept the natural gas backup heater rather than switching to electricity as a backup heat source, these results would be less attractive—that is, *if* gas prices continue record lows for the next two decades, which is not likely. If one also factors in the avoided cost of not having to spend $1,200 to line the flue to continue to use gas, my mostly solar-generated electricity looks as good financially when compared to buying gas.

An *Appraisal Journal* article found "an incremental home value of $10 to around $25 for every $1 reduction in annual fuel bills," so I estimate an increase in our home's value of between $2,600 and $6,500.

SHW System Comparison

System	Collector Area (Sq. Ft.)	Annual Energy Savings (kWh) Sterling, VA	Albuquerque, NM
Sunnovations geyser, Kioto (2 collectors)	43.7	2,030	2,880
Sunnovations geyser, AET (1 collector)	39.8	1,720	2,470
EagleSun, pumped, AET (1 collector)	39.8	2,120	3,130

The collector has quite a presence on the modest-sized townhouse's rooftop.

Performance

My system does not yet have an active monitoring system to be able to quantitatively track performance. However, I can share some observations. On sunny days, the HTF going into the storage tank is about 140°F. My summer gas consumption fell from an average of 6.6 therms per month to 0.6 therms (91% less), as it is now just used for cooking.

To get a quantitative sense of system efficiencies, it is useful to compare SRCC ratings for similar systems. The "SHW System Comparison" table (opposite page) depicts the best available approximations of three configurations: a Sunnovations geyser pump system with an AET collector; a geyser pump system with Kioto collectors; and a comparable active pump system with an AET collector.

While this SRCC OG-300 comparative analysis is interesting to technical types, it is not the most appropriate metric to evaluate SHW systems. Most interesting to the consumer is whole-system cost-effectiveness—measured in levelized dollars per kBtu—which is more appropriate, since it also factors in maintenance costs over the system's life. PEX rather than copper pipe means simpler and less expensive installation costs. No moving parts likely means fewer service calls. Lower—but hot enough—operation means no potential HTF overheating.

The Bottom Lines

I tend to have an early-adopter personality (not among the very first, but ahead of most everyone else), so it's no surprise that I chose to be one of the first to have a Sunnovations geyser pump when it came time to invest in an SHW system. Although its self-pumped system goes against the grain of current conventional SHW systems by operating at significantly lower temperatures and pressures, moving parts and electronics can fail, and I favor systems without them. I also don't like having to periodically change out "cooked" HTF.

I was willing to accept a lower total system performance for a passive, rather than active, system (see "Comparison" table). The production penalty (assuming we use every Btu of heat produced) for this particular system would be 19% less hot water than for a comparable active system. Given the significantly lower installation costs (PEX, etc.) and lower expected operating costs, the lower cost made the 19% production penalty worth it.

Now it turns out that the theoretical production penalty for using a Sunnovations passive system in my area (it varies based on the amount of annual insolation) need only be 4% for Washington, DC. Since our installation in December 2011, Kioto collectors are now available in North America. The Kioto collectors have a narrower riser diameter, which make them a more optimum fit with the Sunnovations geyser pump. They are also less expensive than AET collectors.

When one runs the numbers on these same three system configurations as if they were in Albuquerque, New Mexico (see table), it turns out the production penalty for my configuration over an the active system would be 21%. If the Sunnovation Kioto system were used, that penalty would be reduced to 8%.

Will the Sunnovation geyser pump go the distance? Did I make the right choice? I think I did, but only time, data, and experience will tell.

Access

Andy Kerr (andykerr@andykerr.net) is a frequent contributor to *Home Power* and a renewable energy and efficiency blogger (andykerr.net). He splits his time between Ashland, Oregon, and Washington, DC.

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TROUBLESHOOTING "Little Jake"

Courtesy Amiee Wetmore/MREA

Based on troubleshooting tests, Little Jake needed to come down for repair.

by Jenny Heinzen

Courtesy Doug Stingle/MREA

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One of the three wind turbines at the Midwest Renewable Energy Association (MREA) in Custer, Wisconsin, is a vintage machine that has its roots in the days before rural electrification. Made in 1946 by Jacobs Wind Electric, the 3.6 kW turbine was originally marketed to homes and farms that had no access to the electrical grid, and was used to charge batteries to run low-voltage DC lights and appliances.

In the 1980s, wind energy expert and MREA founding member Mick Sagrillo brought this turbine to his renewable energy shop in Wisconsin, where he remanufactured nearly every component. He donated the machine, top tower section, and controller to the MREA and led an installation workshop in July 2000 to erect and commission the system. Here at the MREA, it's affectionately called the "Little Jake," so we don't confuse it with the 20 kW Wind Turbine Industries Corp. (WTIC) wind turbine (also an original Jacobs design) on site, which was recently modified into a 17.5 kW machine.

Little Jake is a 600-pound, upwind machine (meaning that the blades face the wind ahead of the generator) with a 14-foot-rotor diameter and a swept area of 154 square feet. The three blades are made of robust Sitka spruce, and finished with high-quality automotive paint and leading-edge tape, used on helicopter blades for durability. In a 24 mph wind, the rotor rpm is 325, and the system produces 3,600 watts. Little Jake will cut in at 6 mph and start to govern at 27 mph. In high winds, the pitch-control governing system automatically allows the blades to twist from their optimum aerodynamic orientation, "shedding" wind to protect the machine. For user/technician shutdown, the manual furling mechanism folds the tail, which pulls the blades parallel to the wind. It is activated at ground level via a chain that runs from the tail, down the tower, through a pulley, and to a hand crank.

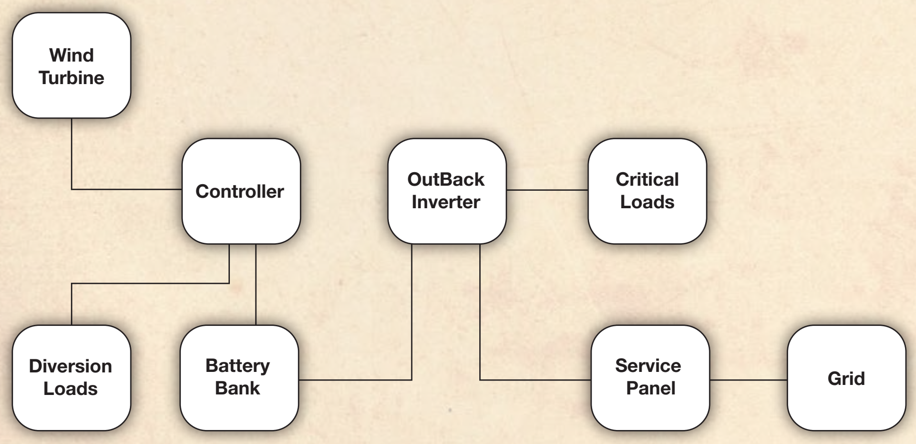
This Jake is a DC generator, quite unlike a modern three-phase permanent-magnet alternator. The field poles and windings contain a residual magnetic field within their iron cores. When the turbine blades are driven by the wind and the armature rotates within the magnetic field, current is induced into the armature, and brushes that ride on the commutator deliver that power through a slip-ring assembly (so the turbine can freely yaw without twisting wires) and down the tower to the balance of system components. This machine is battery-based, so the controller delivers the DC voltage from the generator to a battery bank and diversion loads. If the batteries are full, the power is routed to a load center and to the electrical grid through an OutBack inverter to provide utility-intertied and backup energy for the MREA.

Courtesy Jenny Heinzen

Little Jake's tail was manually furled out of the wind so tower wiring could be checked.

After almost 11 years in service, MREA staff noticed that although Little Jake was spinning, no voltage or current was displayed on the controller—the system wasn't delivering power. Initial investigations showed no signs of open or shorted wires, failed diodes, blown fuses, nor tripped breakers. Little Jake needed a more thorough inspection and, fortunately, the organization's July wind turbine maintenance and repair course was only a few weeks away. MREA small wind instructor Cris Folk and I were excited to have the opportunity to teach troubleshooting techniques on an installed machine with a real-world problem.

Little Jake System



Troubleshooting Little Jake

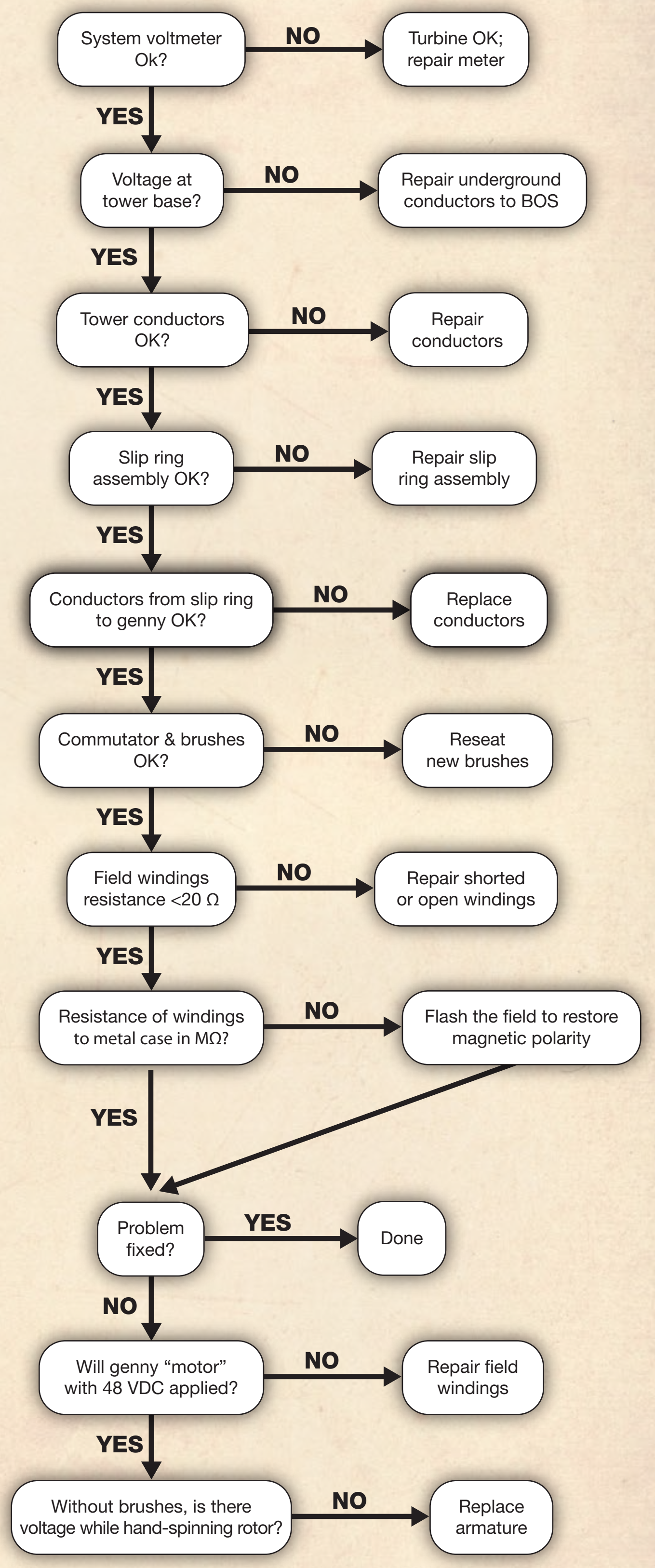
The key to successful troubleshooting is to isolate and test individual system components and understand the order in which they operate. Cris and I would rely on this rather than "swaptronics"—the replacing of components until the system eventually worked again. Swaptronics is a sorry excuse for troubleshooting—plus we didn't have spare parts to swap. We would have shared with the students the manual and/or schematics for the system—if we had any such documentation. But other than Mick's drawings and descriptions, we had nothing.

Courtesy Jenny Heinzen

The controller box was tested and diagnosed.

Testing Procedure

Problem: Low/No Voltage at Little Jake's BOS Meter



Any component or portion of the system tested and deemed "good" would be scratched off our list of possible causes. This process of elimination would point us toward the problem and its solution. We broke the system down into three areas:

Balance of System (BOS)
- Controller voltage checks
- Inverter voltage checks
- Battery bank voltage checks
- Verify correct setpoints in the inverter and diversion loads

Wiring (from the BOS to the tower and up to the turbine)
- Conductor continuity, short-circuit, and ground-fault (resistance) tests
- Splices & terminations

Generator, slip rings & brushes
- Voltage tests
- Continuity, short-circuit, and ground-fault (resistance) tests

BOS Checks

Voltage Tests. With the power on, safety gear donned, and all systems enabled, we checked for proper voltage with a multimeter on the battery bank (48 VDC) at the OutBack power center that's interconnected with two PV systems and the grid (240 VAC), and both the DC and AC sides of the OutBack inverter. We also scrolled through the parameters programmed in the inverter to verify that they matched what was recorded in the MREA operation logs and that nothing had been changed.

Resistance testing. We then furled the machine and turned off the power from both the grid and the battery bank, since resistance checks cannot—and should not—be done while a system is energized. Still armed with a digital multimeter, now set to ohms, we checked the components in the controller box: fuses, a diode, a circuit breaker, a voltmeter, and an ammeter. The fuses and circuit breakers had continuity, the diode (electrical check-valve) was showing one-way conductivity, and the needles on the analog meters were free to move. The BOS components were verified to be in good working order and not the cause of Little Jake's problems.

Diversion controller, dump loads, and DC panel.

The RE systems' balance of system (BOS) components, including the charge controller, battery bank, inverters, and DC and AC load power centers.

Courtesy Jenny Heinzen (2)

Wiring Checks

Conductor continuity & insulation testing. Next, we tested the underground wiring from the BOS to the junction box at the tower base. We disconnected both ends of the two wires (DC positive and negative) for continuity and insulation tests, using the multimeter to verify low resistance in the copper conductors and a megaohmeter or "megger" to test the THWN conductor insulation. Our megger was very old, with a hand crank and an analog display, but still accurate. Meggers are simple: The operator applies 500 or 1,000 volts to the conductors (in our case, with a hand crank), and the needle should display infinite resistance. Anything else signals insulation breakdown and/or a high-resistance fault. Our conductors passed both the continuity and insulation tests.

It was time to send a crew up the tower to test the wires from the junction box at the tower base to the slip-ring assembly near the tower top. (These were the same tests we just conducted from the BOS to the tower base.) We measured low resistance in the copper wires with a multimeter and saw infinite resistance with the megger. We also checked for short-circuits and insulation breakdown by connecting one test lead of the meter to the metal tower and the other test lead to each of the two power output conductors, one at a time. We were looking for infinite resistance from each conductor to the grounded tower on both the multimeter and the megger, and our tests confirmed that the wiring was good from the BOS to the top of the tower. This meant that our primary suspect was now the wind turbine itself.

Testing the Generator

Little Jake is a 48-volt generator. Generators have two windings—the field and the armature. Direct current (DC) is produced by spinning the armature within a stationary DC field. The induced current travels from the copper commutator, at the end of the rotating armature, through conductive graphite brushes, and then down to the slip-ring assembly. A second set of brushes contacting the slip-ring assembly allows the machine to yaw (pivot) freely with the wind, without twisting the wires that run down the tower and into the junction box at ground level.

We inspected all four brushes that ride on the generator commutator for excessive or irregular wear patterns, looked for evidence of overheating and pitting on the commutator, and examined the inside of the cover for signs of spattering solder—which would have shown us that the armature windings had been overheated. Everything appeared in good

A megaohmeter (megger) was used to test the THWN conductor insulation.

Courtesy Lakeshore Technical College

Right: Yaw slip-ring brushes.

Far right: Yaw slip rings.

Courtesy MREA (2)

working order; the brushes were evenly worn, had plenty of remaining life, and were set with a good amount of tension against the commutator. (Each of the four brushes slides into a spring-loaded retaining clip with five notches for increasing tension. All four brushes should ride around the commutator with equal amounts of tension.)

We also inspected the conductors between the slip-ring assembly and the generator terminals for the field and armature windings. We used a multimeter for continuity checks and the megger for evidence of insulation breakdown, just like we did when checking wires from the junction box to the top of the tower. We also isolated and performed resistance checks on the lightning arrestor by using a multimeter to test each lead to ground and from lead to lead. They all showed no continuity, and infinite resistance, which is appropriate.

We measured the resistance of the field, and it was an acceptable 16 Ω. Field windings are essentially giant coils of thin wire, so resistance should be low—the same as if the coils were unwound and just very long conductors. We checked for shorts within the generator by using the megger to measure resistance from the commutator to the metal input shaft (23 MΩ), and from the field to the metal case (3.5 MΩ). We didn't know exactly what kind of numbers we should see, but we knew that anything in the MΩ range was acceptable, since it shows high resistance with respect to ground.

None of these tests yielded suspicious results, and we were getting frustrated. We had tested every component and wire within the system, from the BOS to the top of the tower, and we still hadn't found anything wrong—not even a tiny clue as to why Little Jake wasn't delivering power.

Additional Tests & Final Diagnosis

We had no written documentation on the machine, so we called Mick. He validated what we had measured so far, and gave us advice about what to do next.

- "Flash" the field;
- "Motor" the generator;
- Check output voltage with an analog meter.

"Flashing the field" means re-teaching the machine which field poles are positive and which are negative. Without a residual magnetic field in the field windings, no current can be induced when the turbine begins spinning. To verify that our field windings had a polarized magnetic field, we lifted the brushes off the commutator and connected MREA's Sun Chaser (a portable solar power trailer) to the wires in the junction box going up the tower. After a full 15 seconds of delivering 48 volts of battery power up to the field windings, we were certain that the field poles contained magnetism with the correct polarity, but the Jake still yielded no output. (Machines with field windings using residual magnetism need to be "flashed" upon installation and after a high-transient event like a lightning strike.)

Next, with the generator brushes reseated, we used the Sun Chaser battery bank to run Little Jake's generator like a motor. With controller power still disabled and the tail furled, we back-fed 48 volts to the wind turbine from the junction box at the tower base. Indeed, the machine began to spin and "motor" with ease. This was both promising and unsettling—if it worked as a motor, why wasn't it delivering power as a generator?

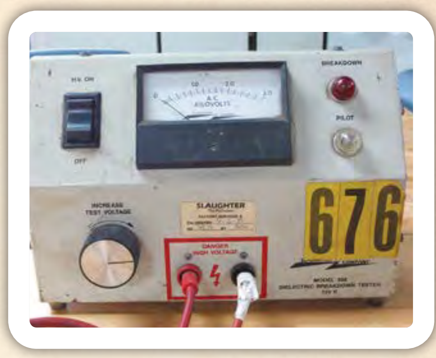
The final test was a simple voltage test, but had to be done with an analog voltmeter instead of a digital multimeter. I recruited friend and fellow windsmith Dave Kiedrowski to come to the MREA the following week to do this test with me. The idea was to watch the needle of the voltmeter (connected to positive and negative terminals on the generator) as we spun the rotor slowly at first, and then gradually up to a "significant" rpm, but not so out of control that we were in danger of being hit by a spinning rotor while strapped to the top of the machine in our climbing gear. According to Mick, we should have seen the voltage gradually rise, and the needle should have steadily climbed, with no spikes, jumps, or drops. But we never saw more than 2 volts register on the meter. The armature was simply not delivering voltage and, for the first time, we were pretty certain that the problem was within the armature windings.

It was too windy to unfurl the tail and work safely while we were on the tower, so we repeated this voltage test at the base of the tower, with the leads of the analog voltmeter connected to the conductors in the junction box. We manually unfurled the tail. At high wind speeds with a swiftly moving rotor, we were still only seeing a couple of volts. I relayed our results to Mick, and he confirmed that it was time to call a crane operator and take down Little Jake for repair. He agreed that the problem was in the armature.

Just to be sure the maintenance class hadn't missed anything, Dave and I repeated the continuity checks and high-resistance megger tests from the BOS to the generator. This time, we used a digital megger with batteries instead of a hand-crank, but the results were identical.

We also checked for shorts from the conductors to the metal tower using a high potential (hipot) tester I borrowed from fellow Jacobs enthusiast Jeff Nichols. Hipot or dielectric-withstanding voltage tests look for insulation breakdown and short circuits, and are often used to check electrical appliances for faults before they leave the assembly plant. Our hipot tests showed no ground faults or shorts to the tower. This was very similar to our tests with the meggers, but was just another tool to use and verify our original findings.

MREA regional training officer Clay Sterling and I worked with a crew and a crane operator to take down Little Jake in September 2011.



Courtesy Lakeshore Technical College

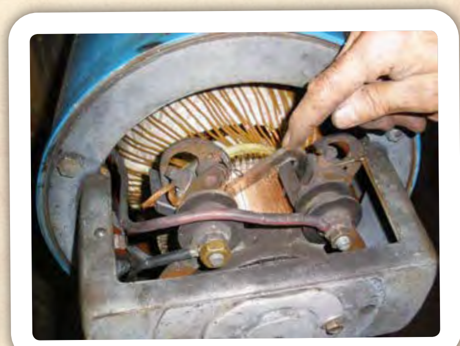
Testing for shorts from the conductors to the metal tower was accomplished with a high-potential (hipot) tester.

Bench Tests & Repairs

Once Little Jake was safely on the ground, MREA site manager Mike White disassembled the machine and packed up the generator for a trip to Mick's wind turbine repair shop, just a few hours away. On a frigid December day, the three of us cracked open Little Jake and hoisted the armature onto the test bench, a factory original 1940s Jacobs wind generator testing system. A variable-speed DC motor arced and sparked as it drove the shaft of the armature from a slow crawl up to full output, and the needles on the hand-drawn calligraphic meter scales showed us voltage, current, and rpm.

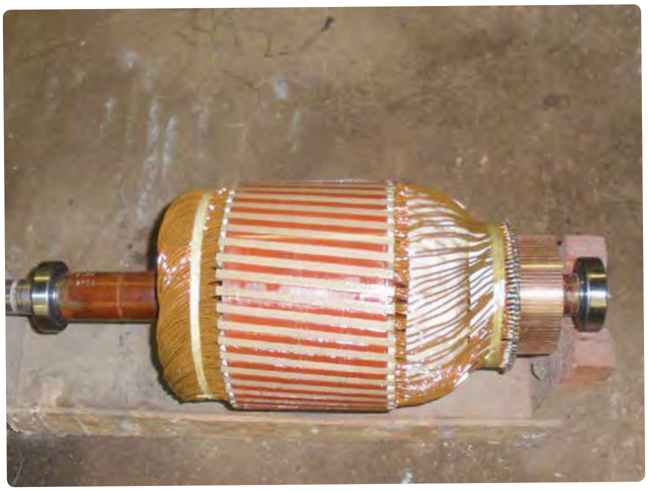
With the generator on the test bench, the problem became quickly obvious. The voltage needle on the analog voltmeter was volatile—but only at an extremely low rpm; it spiked and collapsed with each slow rotation, indicating that there was indeed a short somewhere in the armature windings, likely due to insulation breakdown. Over time, wire insulation can break down with heat, movement, or extreme environmental conditions—three things that are unavoidable in any generator. The Jake is a 1946 machine, and the insulation was 64 years old, having seen some 50 years of service.

Testing in the shop revealed an internal short—a short from wire to wire—in the armature windings.



Courtesy Jenny Heinzen (2)

The front end of the generator. The blades would be attached to the long shaft.



The rewound armature.

Courtesy Jenny Heinzen (2)

So we packed it back up and sent it to a motor rewind shop, where the insulation was burned off in a kiln at high temperature. Then, the technician diagrammed the geometry of the wire connections of the various coils in the wire slots in the armature. This Jake has 47 wire slots in the armature and 94 bars on the commutator that the wire coils are soldered to. The coils were formed with flexible insulated copper "motor" wire and replaced in the slots in the armature, with the coil ends soldered to the commutator in their original geometry. Once rewound, the armature was baked again, but at a lower temperature, which drives off any moisture. The warm armature was dipped in motor-insulating "varnish," then re-baked to set the varnish. Excess varnish was cleaned off the armature and commutator. The varnish also had to be cleaned out of the slots between the 94 bars in the commutator so that the varnish doesn't gum up the commutator brushes. Once this was done, the armature was reassembled in the generator and the whole thing was bench-tested again to confirm that it worked as it should. Rewinding is fairly complicated—to say nothing of being tedious—and it's best left to patient technicians who know what they're doing. The average rewind shop would likely charge between $1,000 and $2,000—the labor is intensive and insulated copper wire is expensive.

By January, we had a freshly rewound, slightly modified armature. With one extra winding turn and 11 AWG wire instead of 10 AWG, the machine would from then on produce higher voltage at a lower rpm, but have a slightly lower current-carrying capacity. We tested the armature on the bench in Mick's shop, then reassembled the machine and brought it back to the MREA.

Little Jake Lives On!

Thanks to an unusually warm spring, we were able to get a crane to the MREA in early March 2012 and reinstall the machine. Mike had repainted the turbine a sparkly royal blue normally reserved for muscle cars. Not only did it look better than ever—but it worked, too!

Little Jake still requires maintenance from time to time, as all wind turbines do (being exposed to the vagaries of wind and weather is tough on mechanical equipment), but we keep it in perspective. You wouldn't drive your car for months and months without so much as an oil change or a brake check, would you? (If you answered yes, then wind turbines aren't for you!)

There's really nothing we could have done to prevent an armature failure. Motion in a generator is unavoidable (if the turbine is actually turning). Heat can be dissipated in various ways, but this is taken care of in the generator design. The best thing an owner can do is to make sure that, in the case of a generator, the commutator brushes are in good shape and seated properly so they don't arc, since this creates heat. But the environment wreaks havoc on insulated wire, just as it does for electrical wiring in an unheated garage or a chicken coop—so there's not much you can do, unless you leave your wind turbine parked in your living room.

The other thing that can "prevent it from happening again" is to find a quality rewind shop that uses quality insulated wire and varnish. Cheaping out on these with cheap materials invariably means that you're going to be at it again until you figure out that this is not the place to cut corners.

Today, Little Jake is nestled behind the Renew the Earth Institute at the MREA on its 100-foot lattice tower, delivering electricity to the premises. We know that it will still require some tender loving care from time to time, but if this armature lasts as long as the original, we won't have to worry about another project of this caliber until about 2080.

Access

Jenny Heinzen is the curriculum and training coordinator for the MREA. She is a licensed master electrician and electrical inspector in Wisconsin. She works with organizations like NABCEP and RENEW Wisconsin to promote professional installations and supportive renewable energy policies, but her favorite days are those spent on a tower.

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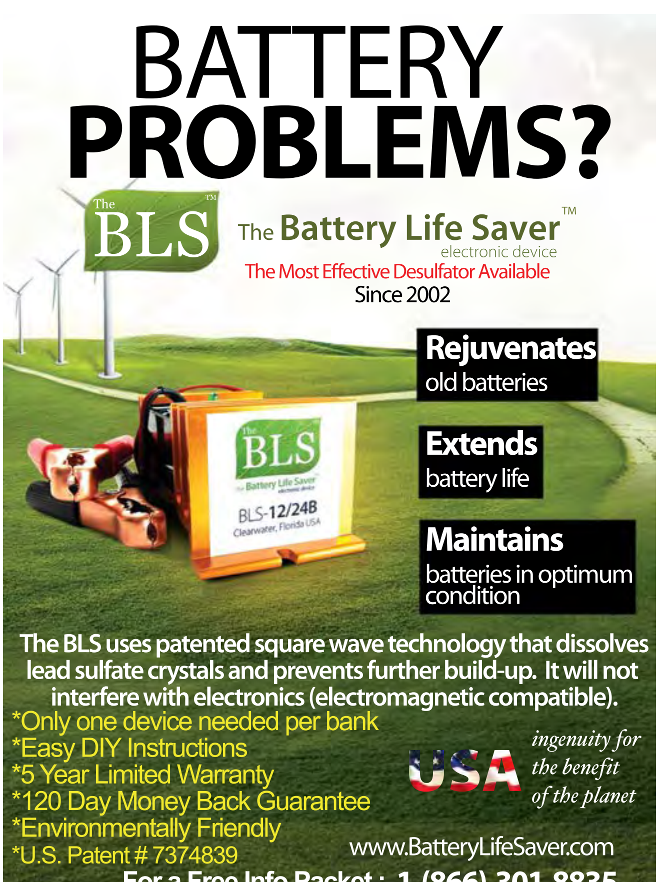
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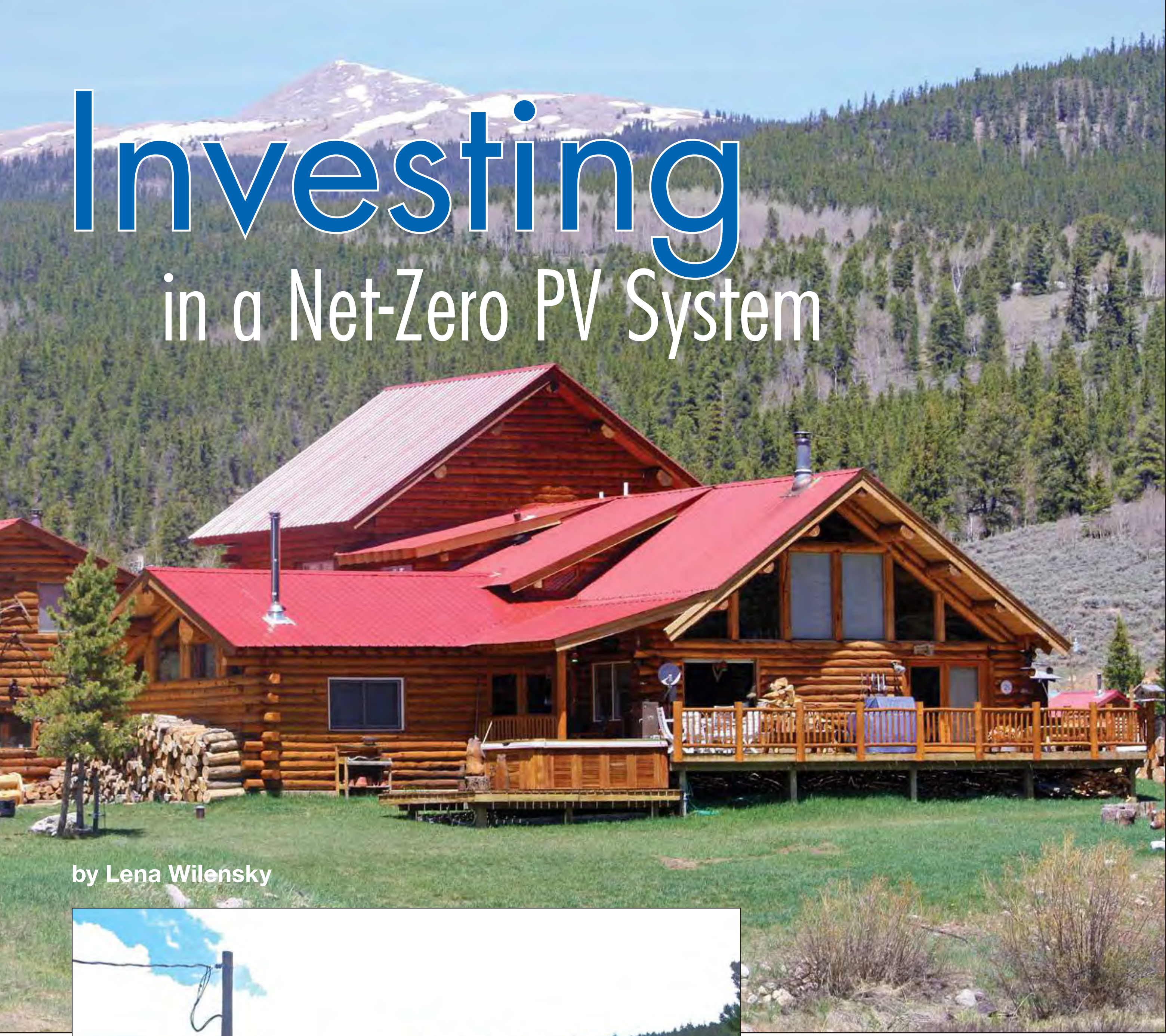
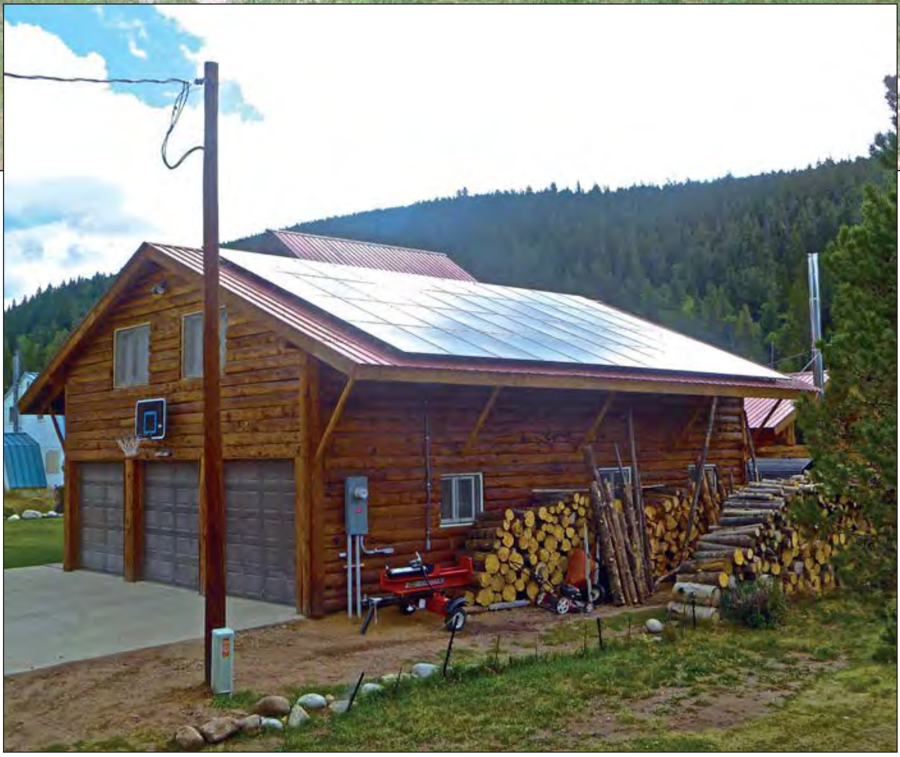
Investing in a Net-Zero PV System

by Lena Wilensky



Courtesy Helmut Metzler

The Metzlers' log home sits in a high mountain valley surrounded by beautiful views and lots of Colorado sunshine.



Nunatak Alternative Energy Solutions

Compared to most of the continental United States, Germany doesn't get a lot of sun—about 3 average daily peak sun-hours, while the U.S. averages about 4.5 to 5—but they still have a lot of PV systems. Despite having a solar resource that's similar to Alaska, by the end of 2012 Germany had installed more than 32 gigawatts of solar capacity. The United States was only at about 7.7 gigawatts. In 1991, the German government enacted the Electricity Feed Law, a renewable energy feed-in tariff that was established to reduce Germany's dependence on imported energy and fuel. While wind power expanded during this period in the mid-1990s, it wasn't until 1998—when the feed-in tariff for PV was raised—that solar electricity saw a boom. Now, more than 1 million German rooftops have PV modules, with about 4% of the country's electricity coming from the sun.

When Helmut Metzler and his wife Suzy moved to a small town in the Colorado mountains, they wanted to use PV modules to meet their electricity needs. Helmut was familiar with solar electricity—most of his family in Germany have PV arrays on their homes. Not using the abundant Colorado sunshine would have felt wasteful to him. But in the early 2000s, when the couple first investigated the cost of installing a PV system to offset 100% of their household's electricity, the resulting payback numbers were too low. As much as the Metzlers wanted to produce their own clean energy, Helmut felt he had to be able to justify the investment financially.

Then, in 2010, Helmut learned of the solar federal tax credit and Recharge Colorado's rebate program, as well as the lower cost of PV modules. This new information made the financial analysis favorable. Although the incentives were far below what his German relatives received for their systems, the return on investment was more than 5%—enough, he thought, to justify the project.

The Financial Case

To calculate even a simple rate of return on a PV system investment, some assumptions need to be made. Perhaps the most difficult, and most important, is predicting increases in retail electricity rates, which directly affect how quickly a grid-tied PV system can pay for itself. The best data available is historical averages.

Helmut used his home's previous billing data and averaged the electricity rates over 10 years. He found that the rates increased about 6% annually, which is below the state's 9% average increase over the past 10 years, but close to the 5.5% annual increase that is projected for the next 20 years.

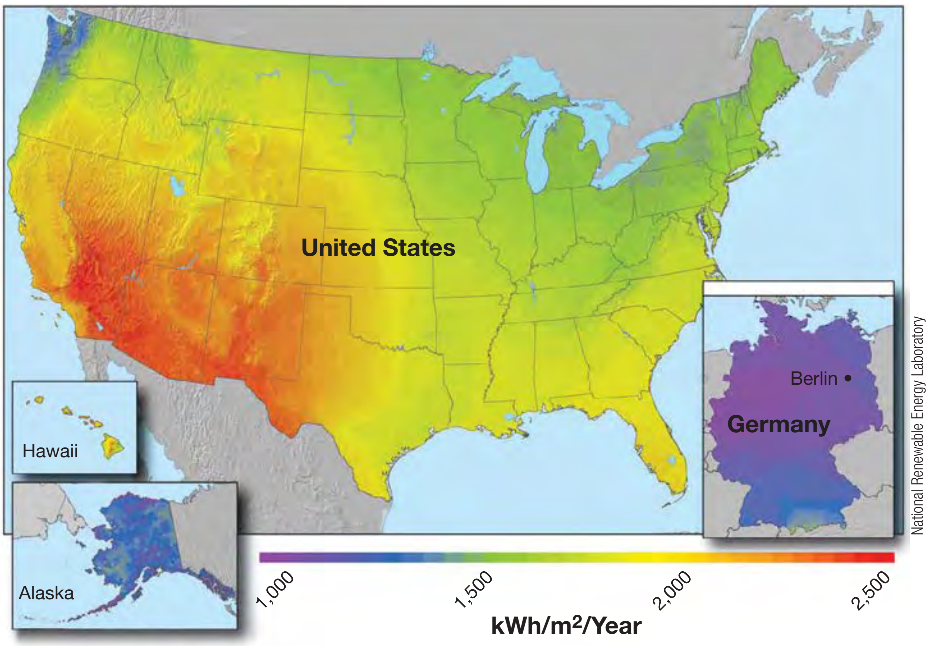
Accounting for Temperature

ASHRAE vs. Record Lows

Low temperatures create high PV voltages, and PV system design needs to account for these temperatures to ensure the array is compatible with the inverter. But how do we predict what the low temperatures will be for the next 30 years?

PV industry standard practice was to use an area's record low temperature for maximum voltage calculations, but designers are now turning to data published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), as recommended by the 2011 *National Electrical Code (NEC)*. The ASHRAE data is based on complex formulas of average and historical temperatures, and tends to be much less conservative than the record low temperature. For example, the record low for Pitkin, Colorado, is -60°F, while the ASHRAE extreme annual mean minimum design dry bulb temperature for a nearby area is -24°F. For the Metzlers' system, this 36°F difference would have made a big impact in system design, and using the record low temperature would have limited our options for string sizing. As suggested by the *NEC*, and knowing there is already some wiggle room built into the system design to begin with, we felt confident using the ASHRAE data for this project.

Solar Resource: United States & Germany



Annual average solar resource data is for a solar collector oriented south at a tilt equal to the local latitude.

Modules were mounted on the garage to take best advantage of unshaded roof space.

The Metzlers live in a 3,500-square-foot log home high in the mountains. While Helmut and Suzy are the only permanent residents of their home, visiting family and friends increase the energy impact to the equivalent of at least three full-time people.

Before installing the PV system, an audit identified the need for several energy-efficiency upgrades. They sealed some problem spots for air leaks, including exterior doors, some of the log beams, and crawl space entrances; and reduced their use of refrigerators. Far from the grocery store but with frequent guests, the Metzlers use several refrigerators and freezers. Now they shuffle food from one or more and unplug the empty ones when it's just the two of them.

While most of their home runs on electricity, a wood-fired boiler is used for space and water heating in the winter. Wood is locally available and inexpensive in this mountain town. Electric baseboard heaters take over when the Metzlers are out of town and can't keep the boiler going. Two electric tank-style water heaters are used in the summer and when they are not using the wood-fired boiler.

To determine a simple internal rate of return (IRR), he examined the cash flow for a 10 kW PV system, which would produce about 13,780 kWh per year and come close to covering the home's electricity usage. He accounted for inverter replacement after 10 years and initial upgrades to the AC service panel.

At the time, Recharge Colorado's rebate program paid $1.50 per DC watt for systems that met certain solar access criteria, with a cap at 3 kW, or $4,500. The Metzler system qualified for the full rebate. They were also able to take advantage of the 30% federal tax credit on the remaining cost.

Using the 6% average annual electric rate increase, Helmut figured an IRR of 5.4%— much better than the 1% to 2% IRR he had calculated for the past PV system investigation. Even a smaller electricity rate increase (4%) resulted in an IRR of 3.8%.

While these numbers weren't spectacular from an investment portfolio perspective, they were good enough to justify the PV project. Helmut also says that he feels that the PV system is a good bet against future inflation. If the United States suffers increased inflation sometime in the next 20 years, which some analysts say is likely, the IRR numbers will look even better. While utility rates would rise along with the price of all other goods and services, the Metzlers' electricity would be covered by their PV system, which was already paid for in pre-inflation dollars. The utility rates might increase dramatically, but their home's net usage will stay close to zero, with only the monthly access charges to pay.

This analysis makes a good case for a PV system even where local incentives are small or only the federal tax credit is available, since only about one-third of the Metzlers' system qualified for and received a rebate. As electricity prices rise, and if PV equipment costs continue to fall, the financial case will continue to improve.

The wood-fired boiler provides space and water heating for the home.

Courtesy Helmut Metzler (2)

The two-story log home has access to plenty of natural light, helping decrease the reliance on artificial lighting during the day and reducing the Metzlers' lighting loads.

The extremely low ambient temperature of this region (down to -24°F, per ASHRAE data) makes choosing an inverter difficult, as it must have a wide voltage window to accommodate high PV voltages as well as module degradation, which will lower an array's operating voltage over time. Because of these voltage concerns, and a small amount of shading during the winter months on one corner of the array, a Power One Aurora inverter was selected. These inverters have a wide input voltage window—200 to 530 V—and also have two separate inputs, so shading on one series string will not affect the other. The inverters were mounted on an inside garage wall to avoid getting buried by snow, and to keep them above their minimum rated operating temperature of -13°F.

The low roof pitch was a concern for winter production loss, as the roof will not shed snow easily. In this area, a 10:12 pitch (about 40°) would have been much better. Helmut was willing to manually clear the snow after big storms to ensure the array kept producing.

continued on page 97

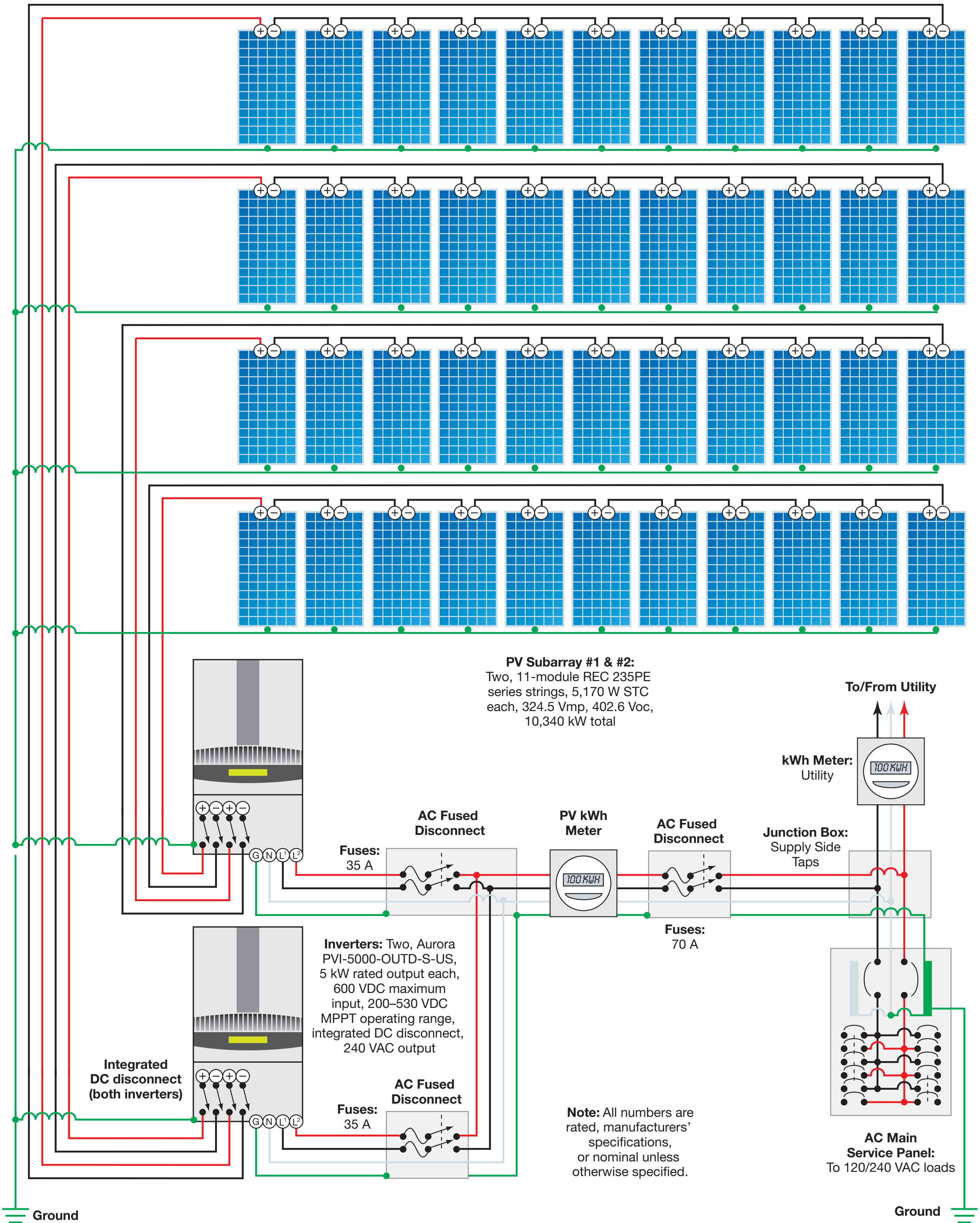
The PV System

Based on an average annual electricity use of about 16,800 kWh (before the efficiency improvements) and the available garage roof space, a 10 kW PV system would hit the mark, offsetting almost all of their utility electricity use. Since the utility only pays the avoided cost (the lowest wholesale price of electricity, often only $0.01 or $0.02 per kWh) for excess energy generated each year, there was no financial incentive to make the system any bigger.

The garage roof faces southwest, and although its 22° pitch was lower than optimal for shedding snow, it was the best place on the property for a PV system. After matching PV modules to the roof space and inverter input voltage windows, the final design was 10.34 kW, or forty-four 235 W modules. The National Renewable Energy Laboratories PVWatts version 2 calculator estimates annual production from this PV array to be 14,246 kWh.

The Metzlers' 10 kW system uses two transformerless string inverters as well as typical balance of system equipment, including AC disconnects and a PV production meter.

Metzler Batteryless Grid-Tied PV System



Tech Specs

Overview

Project name: Metzler residence

System type: Batteryless, grid-tied solar-electric

Installer: Nunatak Alternative Energy Solutions

Date Commissioned: September 2011

Location: Pitkin, Colorado

Latitude: 38.6°

Solar resource: 5.1 average daily peak sun-hours

Lowest expected ambient temperature: -23.8°F

Average high temperature: 82.4°F

Average monthly production: 1,298 AC kWh

Utility electricity offset annually: 100%

PV System Components

Modules: 44 REC 235PE, 235 W STC, 29.5 Vmp, 8.06 Imp, 36.6 Voc, 8.66 Isc

Array: Two subarrays of two, 11-module series strings, 5,170 W STC each (10,340 W total), 324.5 Vmp, 16.12 Imp, 402.6 Voc, 17.32 Isc

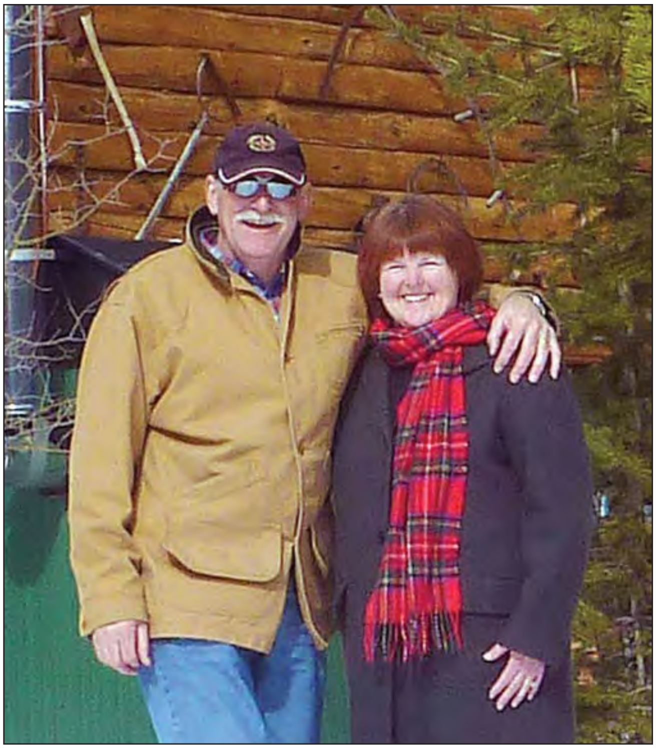
Array installation: DPW mounts on 220°-facing roof, 22° tilt

Inverter: Two PVI-5000-OUTD-S-US, 5 kW rated output, 600 VDC maximum input, 200 – 530 VDC MPPT operating range, 240 VAC output

System performance metering: Itron Centron digital meter, type C1S, 240 V

System Costs

Item	Cost
44 REC PV modules, 235 W	$21,445
Labor, travel & design	9,989
2 Power-One Aurora Inverters, 5 kW	5,854
AC service upgrade	4,549
DPW Power Rail mounts	3,857
Miscellaneous electrical	3,597
Shipping	1,024
Taxes	558
Permits & licensing	500
kWh meter & base	102
Miscellaneous hardware	25
Total	$51,500
Colorado Rebate	-4,500
Federal Tax Credit	-14,100
Grand Total	$32,900



Courtesy Helmut Metzler

The Metzlers reap rewards from the abundant Colorado sunshine and their rooftop renewable energy power plant.

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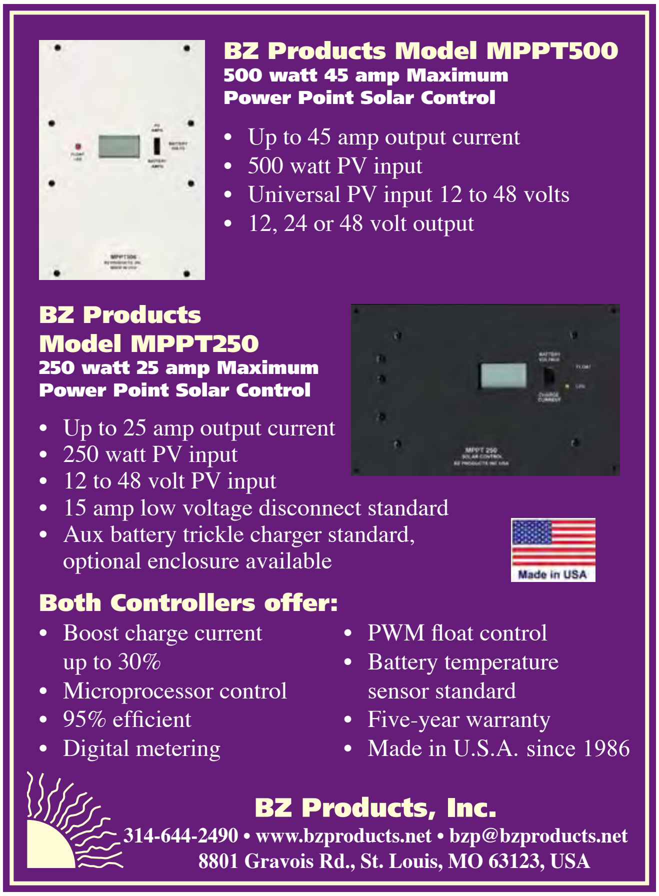
PV Performance

To accurately measure production, a revenue-grade kWh meter was installed on the combined AC inverter outputs. The grid interconnection was done with a supply-side connection in the AC meter main panel. While many net-metered residential PV systems are connected to the utility grid through a back-fed circuit breaker in the home's main service panel (a load-side connection), there are limitations to how much power can be connected in this way. In a supply-side connection, the inverter output is wired to the utility grid between the main service panel and the utility's meter, without the limitations imposed on load-side connections. Because of the large PV system and the location of the utility meter and main service panel, a supply-side connection made the most sense.

After a year of production, Helmut reports that the PVWatts estimates were a little low. Last year was sunnier than average, and his system produced 15,576 kWh—a 9.3% increase over the PVWatts estimate of 14,246 kWh. The system produced as much energy as the Metzlers consumed that year, saving them an estimated $1,744 and putting them well on their way to achieving their 5.4% rate of return.

Access

Lena Wilensky (lena@nunatakenergy.com) co-owns Nunatak Alternative Energy Solutions, a small Colorado RE company. She is a Solar Energy International instructor and a NABCEP-certified PV installer, and is certified by ISPQ as a PV Affiliated Master Trainer. She is also the proud mother of a future solar sister.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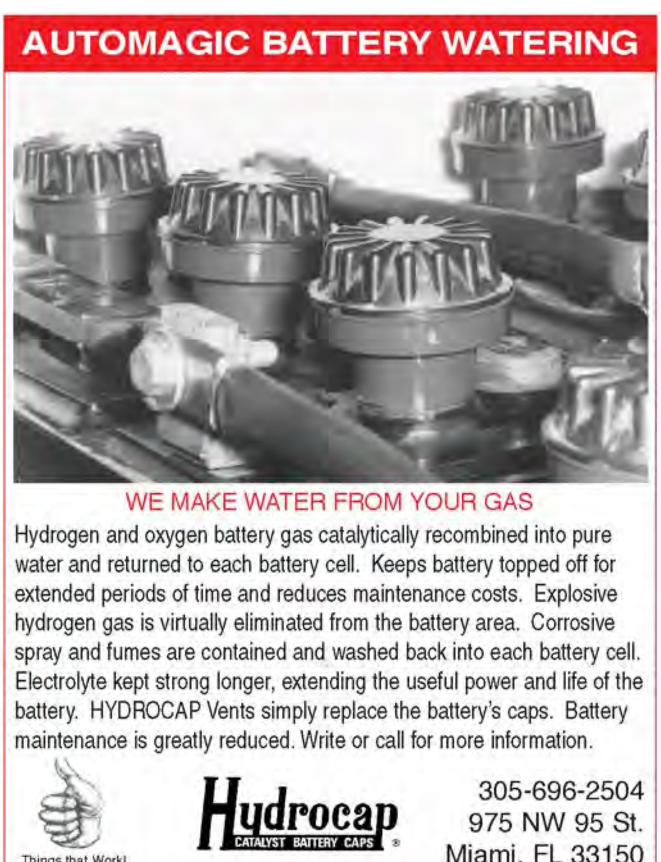
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More on System Grounding

by Ryan Mayfield

In *HP153*, "Code Corner" focused on the *National Electrical Code (NEC)* requirements associated with equipment grounding conductors (EGCs). This "Code Corner" will further explore system grounding requirements and methods.

System Grounding Requirements

NEC Section 690.41, System Grounding, helps set the basic grounding requirements for PV systems. The term "grounding" is used to reference the connection made to earth. In electrical systems, grounding occurs by connecting to a grounding electrode—for example, a long copper rod driven into the earth. Bonding refers to establishing electrical continuity by connecting components together.

Section 690.41 of the *NEC* requires that one current-carrying conductor (the positive or the negative) be solidly grounded in PV systems greater than 50 volts to limit imposed voltages from outside sources and stabilize the voltage to earth during normal operation. This grounded conductor is similar to AC systems in which, typically, the neutral conductor is bonded to ground in the main distribution panel. This section includes an exception for ungrounded PV systems that comply with Section 690.35. (Ungrounded systems are rising in popularity and will be covered in future "Code Corners.")

Section 690.42 establishes where in the circuit the system grounding should be. This *NEC* section simply states that "the DC circuit grounding connection shall be made at any single point on the photovoltaic output circuit," to eliminate multiple paths to ground in the circuit. But the informational note in the 2011 *NEC* and the exception should not be neglected, since they direct placing this grounding connection as close to the PV source as possible to protect from lightning surges. While this may be helpful to limit voltage surges associated with lightning, the equipment connected in the circuit must be considered before establishing a grounding connection at the array.

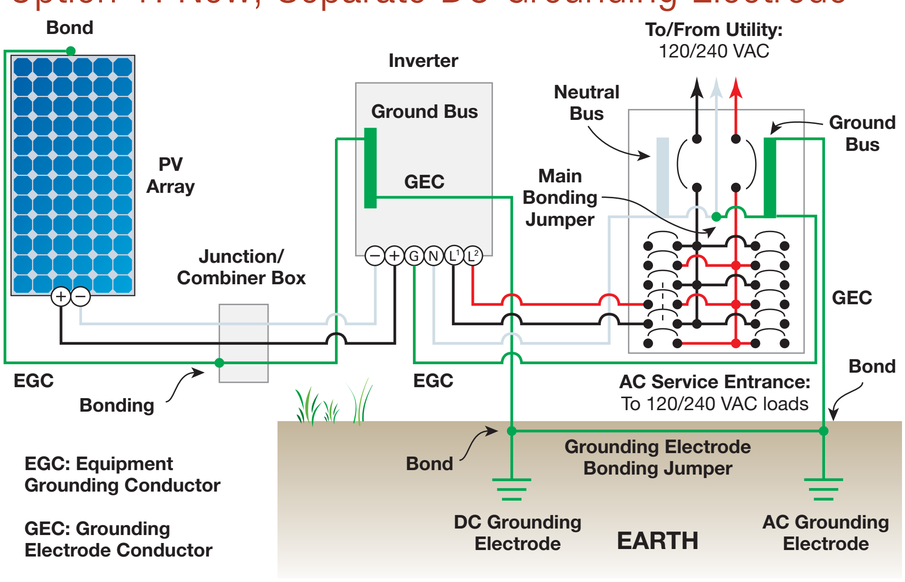
In a system with ground-fault protection (GFP), that device provides the current-carrying conductor to ground bond. For grid-tied PV systems, the GFP device is located in the inverter; and thus the required grounding connection is already established. When installing battery-based equipment, a GFP device may be included with the equipment or may be added on. When there is a GFP device, the current-carrying conductor to ground bond shall not be duplicated outside of that device. If you were to follow the informational note's advice and make a second grounding connection in addition to the GFP connection, you would introduce a second path to ground and, inevitably, a ground fault.

Making the Connection to Ground

Section 690.47 details the requirements for establishing the PV system grounding connection to earth via a DC grounding electrode system. Three installation methods are acceptable for the DC grounding electrode system. The first, 690.47(C)(1), allows the installation of a new, separate DC grounding electrode that is, in turn, bonded to the existing AC grounding electrode. This results in a grounding electrode conductor (GEC) running from the marked location in the inverter to a grounding electrode installed specifically for the inverter. The bonding jumper between the two grounding electrodes is sized to be the larger of either the existing AC GEC or the size of GEC as specified for DC systems in 250.166.

The second option is given in 690.47(C)(2) and includes a new dedicated GEC that is run from the inverter and is bonded to the existing AC grounding electrode system. For this option, there is no dedicated DC grounding electrode—the installation only has the AC grounding electrode. The size of the new DC GEC that is bonded to the existing AC grounding electrode is based on 250.166, which

Option 1: New, Separate DC Grounding Electrode



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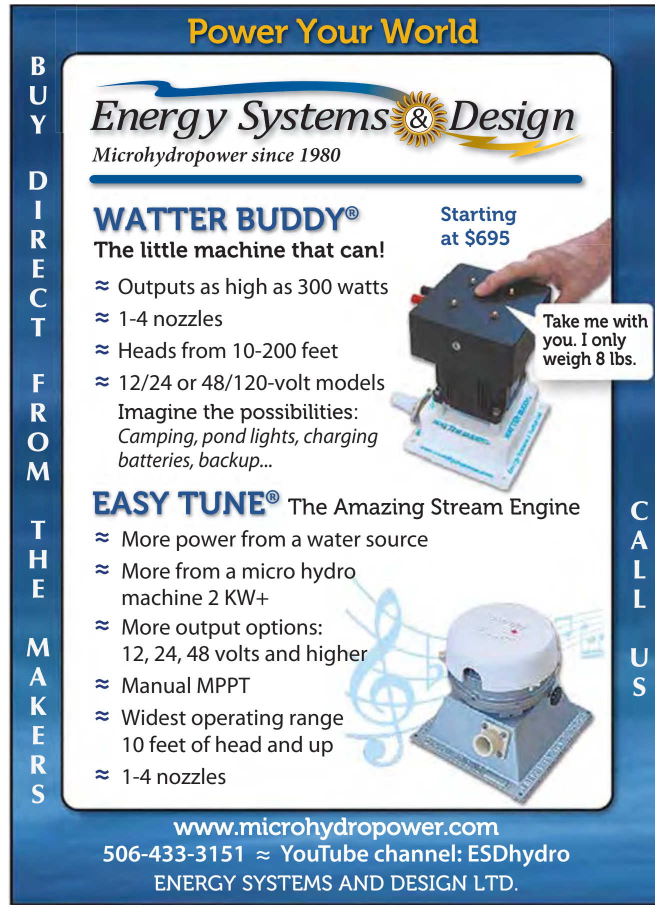

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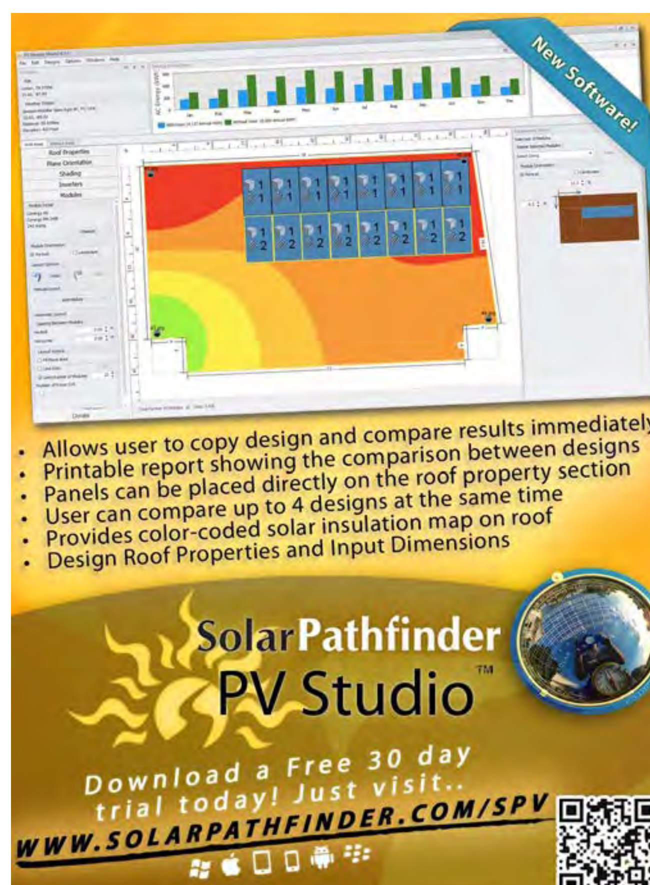

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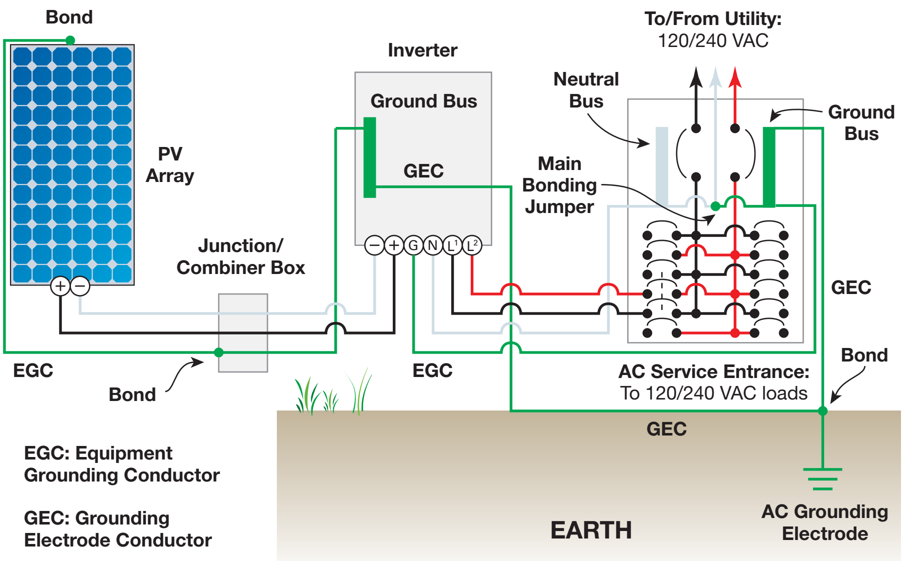
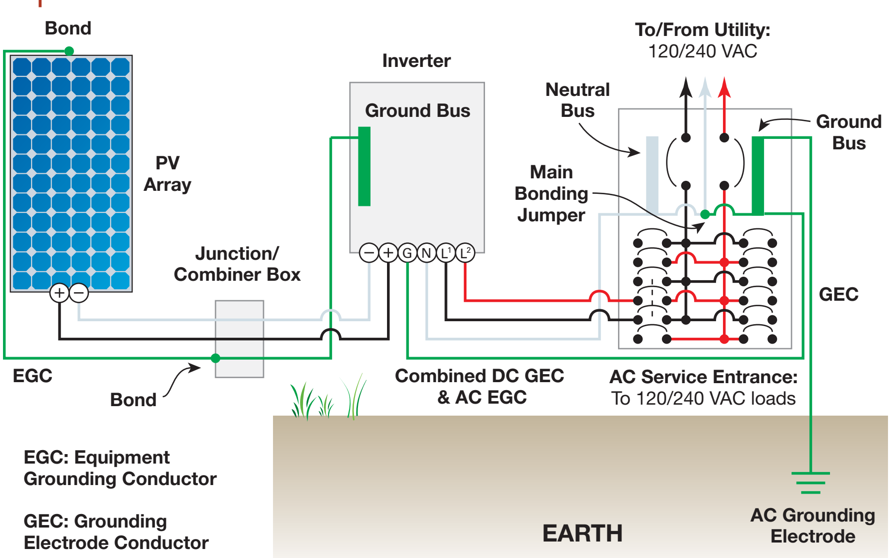
Option 2: New GEC from Inverter



Option 3: Combined DC GEC & AC EGC



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permits the DC GEC to be bonded to the AC GEC but only if the AC grounding electrode is not accessible. In both 690.47(C)(1) and (2), the new DC GEC does not replace the required AC EGC that bonds the metallic equipment together.

For options one and two, the DC GEC is sized as specified in 250.166(A) and (B), except as allowed per (C) through (E). Section 250.166(B) establishes that the GEC shall not be smaller than the largest conductor supplied by the system and not smaller than 8 AWG copper. For the "largest conductor supplied by the system," you should consider the conductors within the PV system—you do not need to consider the existing AC service conductors to determine the new GEC size. This section is focused on the DC system and the size of the conductors used to wire the array to the inverter. Sections (C) though (E) list the types of grounding electrodes that can be connected to the new GEC and indicate the maximum size of the DC GEC: 6 AWG for connections to rod, pipe, or plate electrodes; 4 AWG for connections to concrete-encased electrodes. For a connection to a ground ring, the DC GEC shall not be required to be larger than the conductor used to make the ground ring.

The third option and the most used method for establishing the DC GEC—a combined DC GEC and AC EGC—is covered in Section 690.47(C)(3). It allows a single conductor to serve the function of both conductors, as long as this one conductor is sized to meet the more stringent requirement, i.e. that conductor must be the larger of either the DC GEC, as described in 250.166, or the AC EGC, as specified in 250.122. Once this size has been established, the conductor must be unspliced or irreversibly spliced and run from the inverter's marked grounding location to the grounding busbar in the associated AC equipment. This means running an 8 AWG (minimum) copper conductor with the AC conductors from the inverter and though any additional equipment, such as meters and disconnects, into the utility point of connection. This method is popular due to the relative ease of running the conductors, although the requirement for an unspliced or irreversibly spliced conductor can complicate the installation.

Meeting the requirements for DC system grounding and the grounding electrode system can be difficult and time-consuming, not only during installation but during the system design. This is likely the most commonly discussed subject for installers and inspectors alike. Take time to clearly document your system with electrical drawings that methodically reference the various *NEC* articles one by one. Of course, if you have any questions, consult your local authority having jurisdiction. They will undoubtedly have some important opinions on the matter.

Access

Ryan Mayfield (ryan@renewableassociates.com) is the principal at a renewable energy design, consulting, and educational firm in Corvallis, Oregon. He trains PV installers and code officials and always finds the grounding and bonding portions of class the most entertaining and educational.

Surprise, Surprise, Surprise

by Kathleen Jarschke-Schultze

Life is full of surprises and adventures. My UPS driver calls every weekday to see if I have anything to ship out and is usually surprised when I don't have some story to relay. I certainly don't go looking for adventure in my daily life, but it has a way of finding me.

Myth or Fact?

In *H&H153*, I wrote about harvesting our phenomenal acorn crop this past fall. I was determined to note if an abundant acorn year correlated to a very cold or long winter. This had been the coldest January in 15 or so years. Our creek froze all the way across. And even the heat tape on the pipes could not keep them from freezing.

When the microhydro turbine's nozzles clogged with debris from the heavy snowfall, the turbine froze. In a cascade effect, with no working hydro—and little sun or wind—our battery bank became depleted.

It was our good luck—or not—to be on vacation during this time. Our house-sitter and our business apprentice were heroic in their work to get our home system up and running again, with no lingering problems.

Black & White

The night we got back from vacation, I put the chickens in their coop but apparently forgot to close the coop door. In the morning, I was surprised to see some of the hens were already out pecking around in the run attached to the coop. Chagrined, I went to the coop to make sure their feed and water were full and to give them a sprinkle of hen scratch. The feed and water were fine; everything looked good. But as I was leaving, I lifted the lid on the nest boxes to check for eggs. That's when a sleepy skunk rubbed its eyes, blinking up at me. I think I said something clever, close to "Oh, shoot!" and quickly, but quietly, shut the lid.

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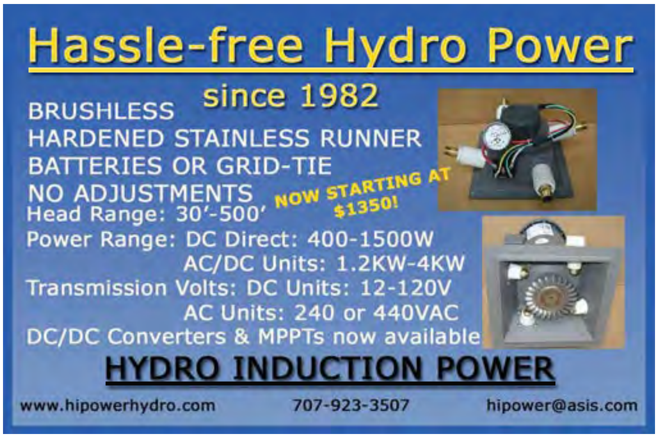
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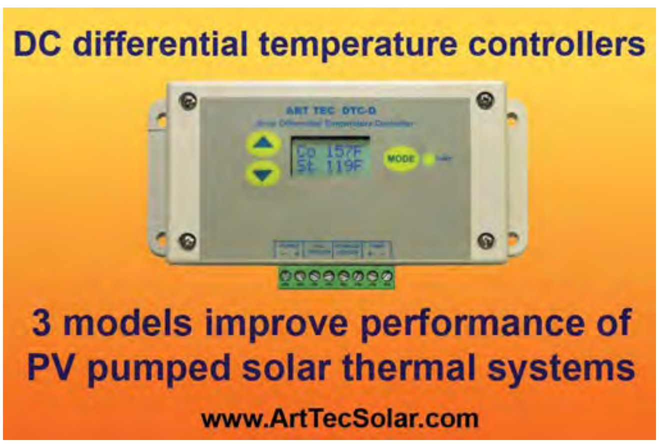
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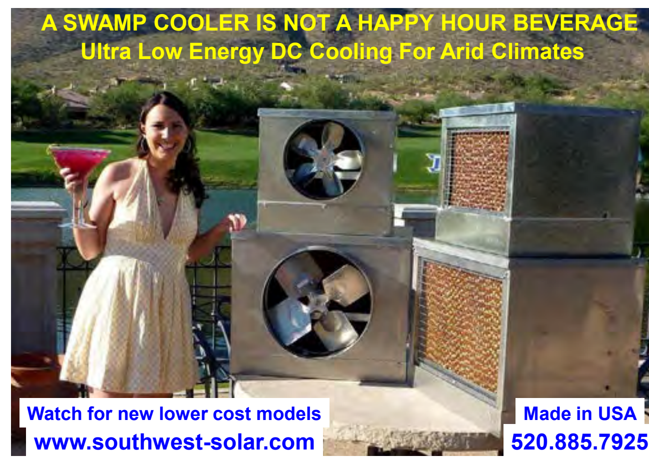
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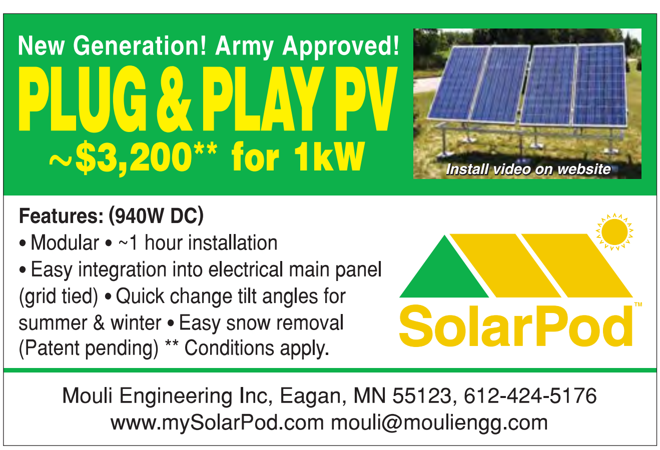
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I got one of my live traps and baited it by wiring one of our storage apples inside, beyond the trip pad. Then I bagged it in two garbage bags, leaving only the trap door end uncovered. A little package tape secured the bags to the trap. A small slit in the top allowed the trap handle to come through.

The trap was set in the chicken run, facing the coop door, which I left open. I was really hoping that the skunk, being a nocturnal animal, would just leave. No such luck—by morning, I had trapped it! And now I had to do something with it! I sneaked up on the trap and carefully pulled another garbage bag over the front end of the trap, standing behind it the whole time. So far, so good. Ever so gently, I put the trap in the back of my husband Bob-O's truck, securing it with a bungee. We drove it up to Jenny Creek, about six miles away, for reassignment.

I attached a 12-foot length of parachute cord to the trap release, since I wanted to be as far from the trap as possible when I released the skunk. After setting down the trap, I carefully removed the bag over the door. I backed away and, reaching the end of the cord, tugged on it firmly. The door swung open, but the skunk would not leave the trap. Bob-O picked up the trap and shook it, open end down, until the skunk dropped out, tail up and aimed at us. We ran, and it wandered off into the woods. Whew, not phew!

Pipe Scream

One sunny cold day, Bob-O happened to glance at the meter on our dining room wall that displays our battery's state of charge. On a sunny winter day, with the PV array and microhydro system working to capacity, the batteries should have been at 100%. Looking at the system meters, he discovered that the microhydro turbine was not contributing a single watt to our energy system. So he donned his ditch boots, called the dog, and began the hike to the hydro intake to make sure it wasn't clogged. Since a lack of power from a clogged intake is rare, he stayed along the creek bank as he walked the pipeline. Not too far up, he saw a 5-foot section of pipe shattered into large ugly shards, which were lying in the cold water. Some large rocks had worked their way out of the steep bank and tumbled right onto our penstock.

Bob-O returned to the house, retrieved some black plastic garbage bags and made his way to the intake, inspecting pipe as he went. Once at the head, he covered the intake with plastic to slow the flow of water entering the pipe. Knowing that draining the pipeline would take a couple of hours, he doubled up on his chores and took our trailer to get a load of horse manure for our garden.

By the time he got back, the water had mostly emptied and was just a trickle from the pipe. Bob-O got a section of scrap 6-inch pipe and two couplers from the boneyard. Then he put a coupler on both open ends of pipeline. In winter and with water in the pipe, using glue was not an option. Instead, he drilled three holes though each coupler and into the pipe and used screws to secure the couplers.

After cutting the scrap pipe to replace the missing section, we both climbed into the creek. He attached the repair section to the downstream coupler with screws. My job was to lift the empty downstream section so Bob-O, who was lifting the upcreek section, could slip the coupler over my end of the pipe. The theory was that lifting them would separate them enough to slip the coupler on the penstock, and then when we set the pipe down, the weight would push the new section tight into the coupler. Right…

We ended up using a tractor, ropes, chains, and a come-along to finally get that darn pipe together. We did it though, before dark, and it wasn't raining. Some days are just lucky days.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is making vegan cheese at her off-grid home in northernmost California.

Solar Array Orientation & Tilt

Array tilt and orientation affect PV system output, so they need to be considered when choosing a mounting method. Two terms—azimuth and altitude—relate to array orientation and tilt and are used to describe the sun's position in the sky.

Azimuth is the horizontal angle from a reference direction that the sun makes throughout the day. This angle is commonly referenced from north (0°)—east is 90°, south is 180°, west is 270°.

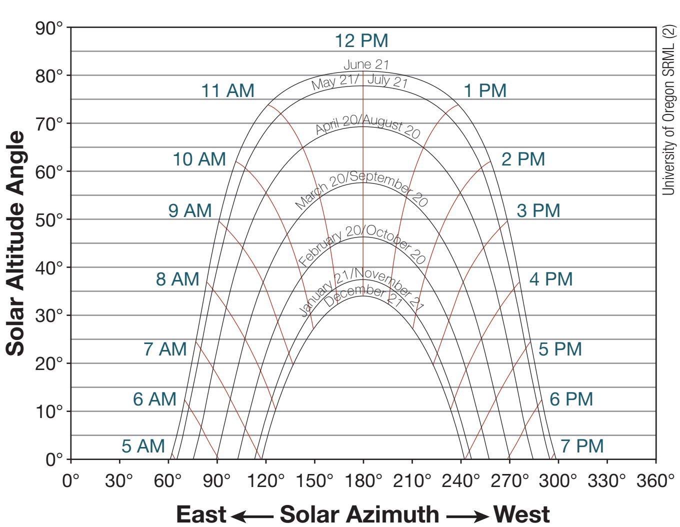
Altitude is the vertical angle the sun makes relative to the horizon. At dawn, when the sun is on the horizon, the altitude is 0°. As the sun makes its arc across the sky, its altitude progresses to be the highest at solar noon. The altitude changes throughout the day and also varies throughout the year, reaching its highest point on the summer solstice at noon.

The sun's azimuth and altitude depend not only on time of day and season, but also on location (i.e., latitude). The sun charts illustrate the difference in altitude angles for San Diego, California (latitude = 32.6°) and Bismarck, North Dakota (latitude = 46.8°). Notice that the sun's altitude is lower for locations with higher latitudes. For example, at 9 a.m. in Bismarck on December 21, the altitude is less than 10°. In San Diego, at the same time on the same date, it is almost 20°. At noon on the same date, the sun in Bismarck will only get 20° off the horizon; in San Diego, it will reach about 35°. (Note: A sun-path chart for any location can be made with the this online program from the University of Oregon Solar Radiation Laboratory: http://solardat.uoregon.edu/SunChartProgram.html.)

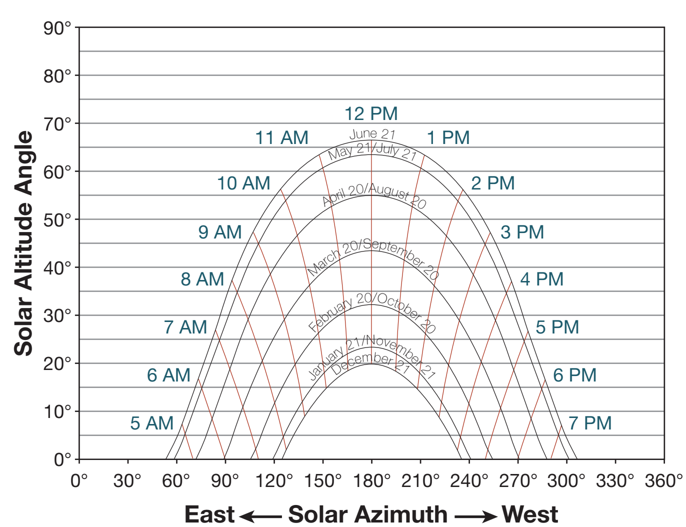
So how do solar azimuth and altitude angles relate to a PV array's placement? A PV array's tilt is the vertical angle between the back of the modules and level. The array's orientation is its horizontal angle relative to north (i.e., an array with a "south-facing" orientation is 180° from north). Ideally, we want our array's tilt and orientation to take advantage of the sun's altitude and azimuth angles as much as possible. While dual-axis tracking arrays can follow both of these sun angles, fixed arrays cannot. System designers rely on solar radiation data provided for a location and examine the predicted system output for various array tilts and orientations to find the combination that yields the highest production (see "Methods" in this issue).

—Justine Sanchez

Sun Path
San Diego, California
Latitude 32.6° N



Sun Path
Bismarck, North Dakota
Latitude 46.8° N



Times are shown in solar time and will vary slightly, depending upon the position within the local time zone and daylight savings time.

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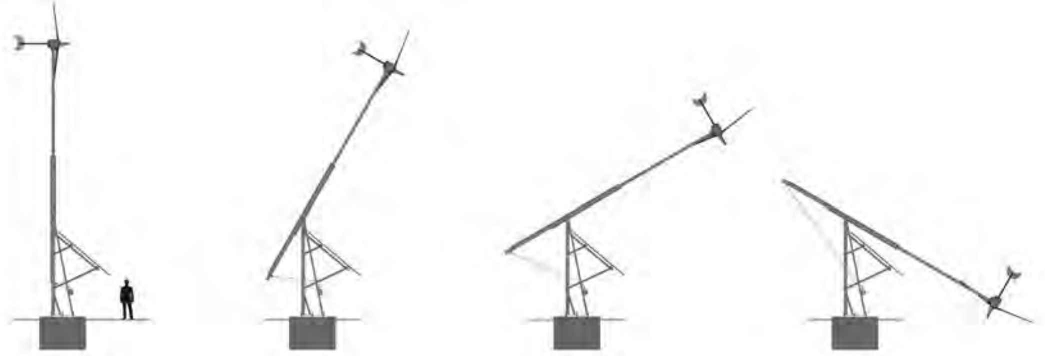

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