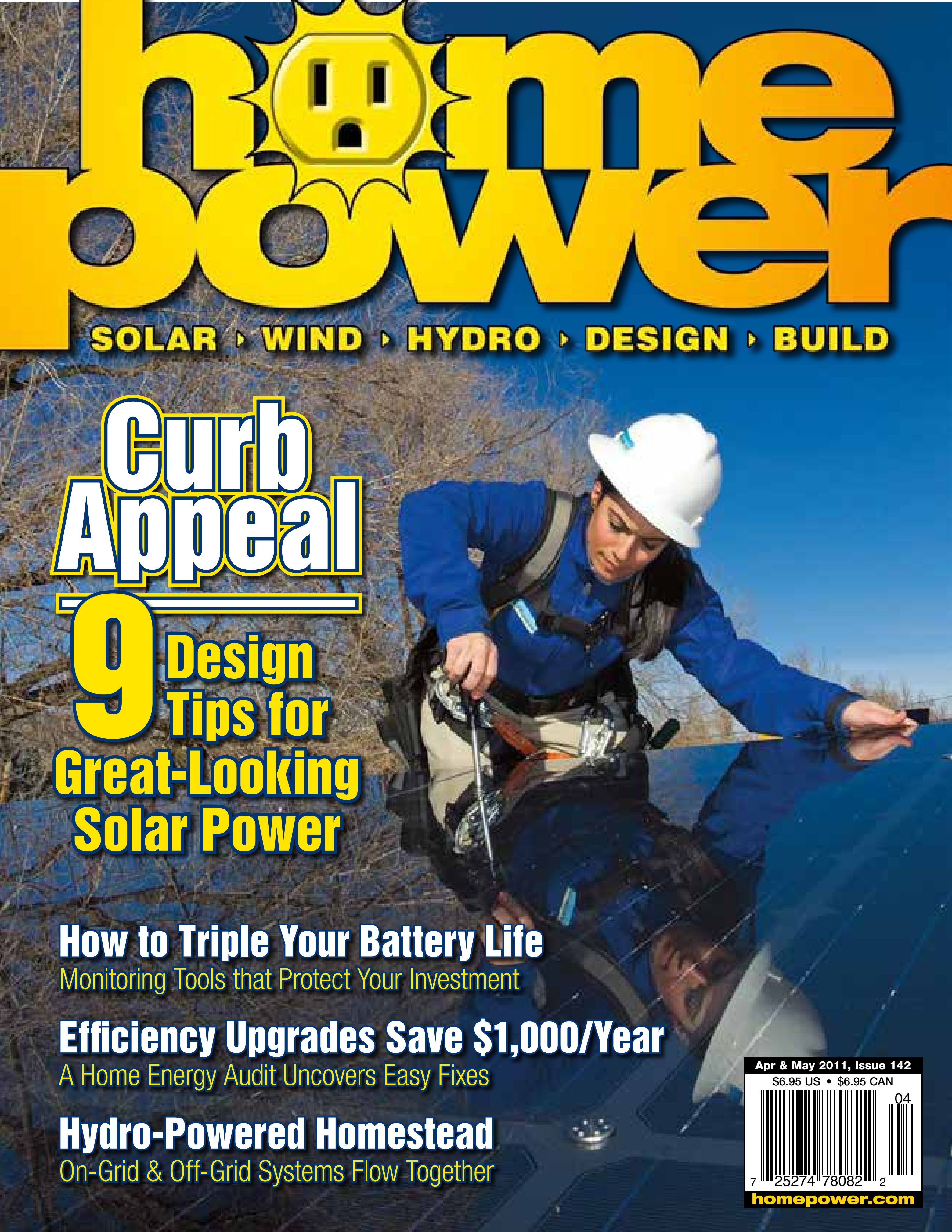
SINCE 1987

STEP-BY-STEP: PERFECT ROOFTOP SOLAR RACKING INSTALLATION

home power

SOLAR ▸ WIND ▸ HYDRO ▸ DESIGN ▸ BUILD



Curb Appeal

9 Design Tips for Great-Looking Solar Power

How to Triple Your Battery Life
Monitoring Tools that Protect Your Investment

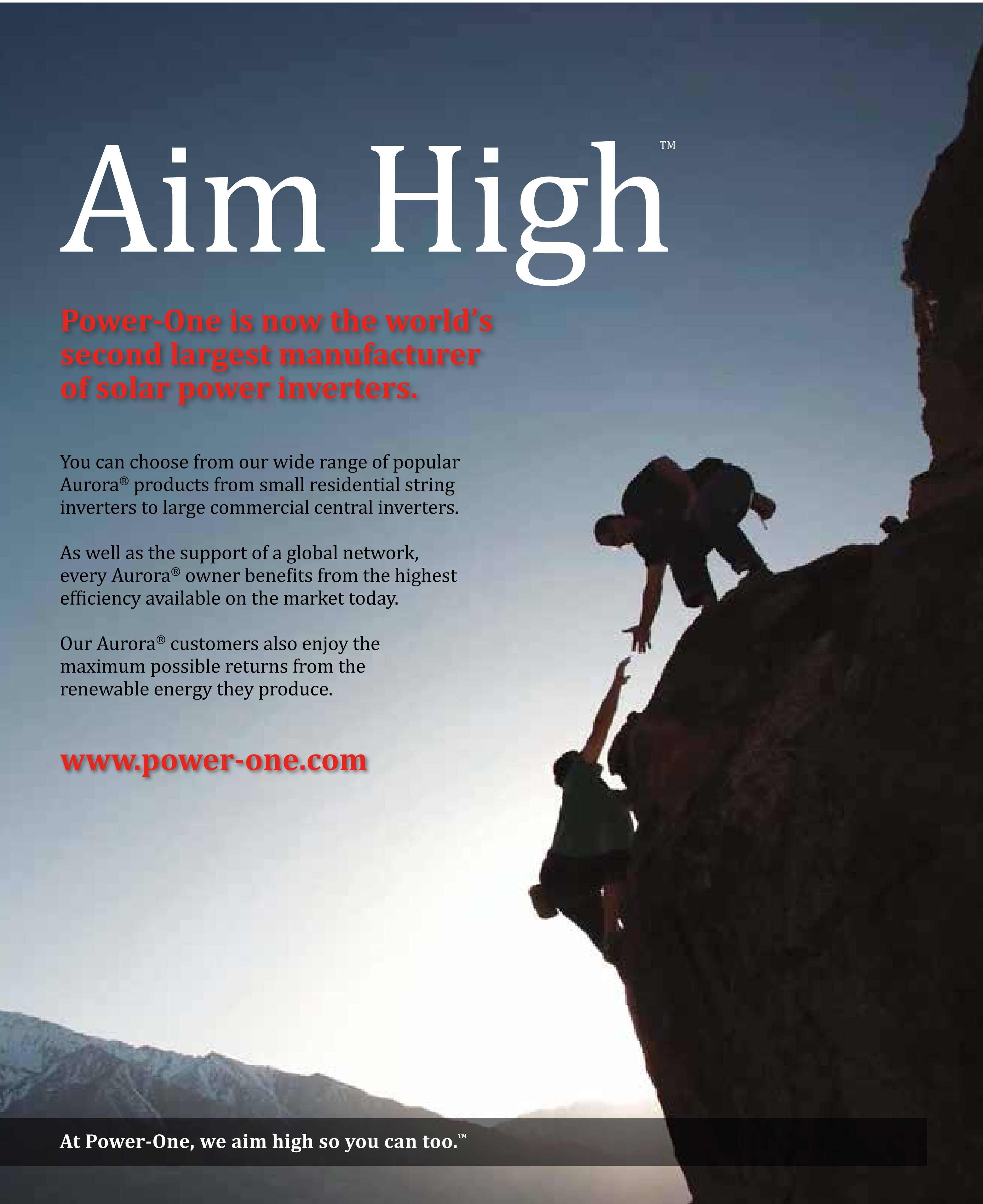
Efficiency Upgrades Save $1,000/Year
A Home Energy Audit Uncovers Easy Fixes

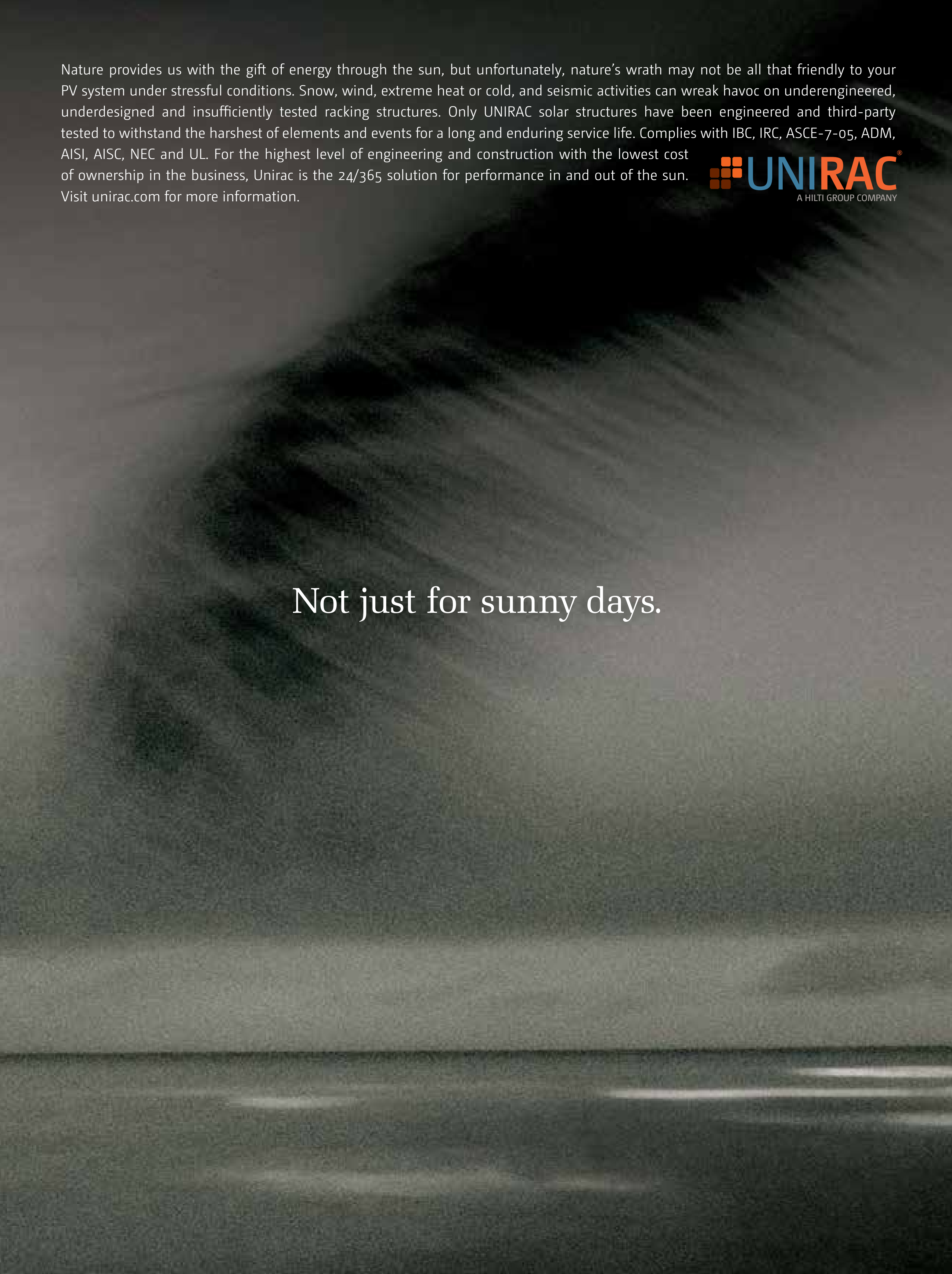
Hydro-Powered Homestead
On-Grid & Off-Grid Systems Flow Together

Apr & May 2011, Issue 142
$6.95 US • $6.95 CAN
04
7 25274 78082 2
homepower.com

power-one® Renewable Energy Solutions

AURORA®




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.
UNIRAC®
A HILTI GROUP COMPANY
Not just for sunny days.

AEE Solar

Plug into 30 Years of Solar Experience

Get all that AEE Solar has to offer:

- ✔ 3 decades of solar expertise
- ✔ Industry-leading tech support
- ✔ Broadest selection of the products you need
- ✔ Best-in-class training and dealer services
- ✔ A partner fully dedicated to your solar success

"AEE has been there for us since the beginning, helping us grow our company. From the terrific service your sales team gives us to great advice from your engineers, doing business with AEE Solar is always a pleasure."

JOHN ROGERS
Pacific Blue Solar, Inc.

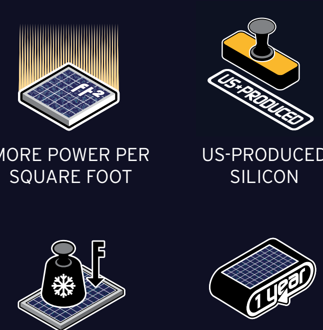
"AEE Solar consistently offers us sales and product support on demand. You go above and beyond to make sure we have the products we need and the ability to deliver them in a timely manner. Having a supplier like AEE definitely gives us a competitive advantage."

TERRY HUFFT
Top Hat Energy

REC

PEAK ENERGY MODULE

Get REC's New High-Efficiency Peak Energy Module from AEE Solar!



MORE POWER PER SQUARE FOOT

US-PRODUCED SILICON

ROBUST AND DURABLE DESIGN

ENERGY PAYBACK TIME OF ONE YEAR

AEE Solar

800-777-6609

www.aeesolar.com

sales@aeesolar.com

THE ONLY WHOLESALE DISTRIBUTOR YOU'LL EVER NEED

I am pleased to announce on February 1, 2011, DC Power Systems and Solar Depot, two strong, trusted names in renewable energy, completed the first step in our consolidation. The boards of both companies, along with ITOCHU, our ultimate parent company, agreed to begin our journey toward full integration by placing both companies under common ownership and management. Our combined companies will be the largest, most diverse renewable energy distributor in the Americas, carrying more products, more technologies and offering more services than any other renewable energy distributor operating in this hemisphere.

Throughout the upcoming months, you'll gradually see changes as we integrate our operations. Until then, it's business as usual for you. In some ways we will continue to operate as two separate distributors under one holding company. You will continue to receive quotes and place your orders as you always have, speaking to the same sales and customer service people you have always relied upon. Simultaneously, we'll be working hard behind the scenes to integrate our policies and practices to create best-in-class warehousing, shipping and back-office operations.

Integrating two established distribution companies will take time. As we complete the process, we will stay true to the values that have shaped both DC Power and Solar Depot: focusing on the basics of great customer service, quality products, fair prices, abundant value-added services and a corporate culture built on working together. On behalf of all of my coworkers, thanks for choosing us today.

Kevin Shimokobe
CEO
DC Power Systems and Solar Depot LLC

sales@dcpower-systems.com
1-800-967-6917
www.dcpower-systems.com

infodepot@solardepot.com
1-800-822-4041
www.solardepot.com

TWO SOLAR POWERHOUSES
BECOMING ONE.

contents

Main Features

44 **pretty** PV

Michael Welch

Architectural PV options can create more aesthetically pleasing solar installations.

54 **grid-tied** system

Kyra Moore

Powerful women designed and installed this 6.75 kW grid-tied system at the Moore household.

62 **battery** monitoring

Dan Fink

A battery monitoring method can help you keep your batteries working optimally and protect your investment.

80 **PV** racking

Greg McPheeters & Tim Vaughn

Learn from the pros, and choose the right rack to make your rooftop PV array picture-perfect.

88 **overheating** solutions

Chuck Marken

Prevent your SHW system from summertime overheating.

On the Web

Facebook Special!

$10 Subscription & Renewal

When *Home Power* hits 2,000 Facebook "Likes," we'll drop our one-year U.S. subscription price to $10 ($20, non-U.S.) for 48 hours. That's 60% off our regular price! Help us get there: "Like" and suggest us to your Facebook friends, then watch your news feed for the milestone announcement: **facebook.com/homepower**

Follow us on Twitter!

Watch for bite-size article teasers, renewable energy event information, sneak peeks at upcoming coverage, subscription specials, and topical retweets: **twitter.com/homepowermag**

Share us everywhere!

Share an inspiring *Home Power* article on Facebook, Twitter, Digg, StumbleUpon, and many other services: **homepower.com/articles**

Events Calendar

Search, browse, or post RE events: **www.homepower.com/events**

Article Database

Search and browse more than 1,900 articles in PDF: **www.homepower.com/articles**

Back Issues

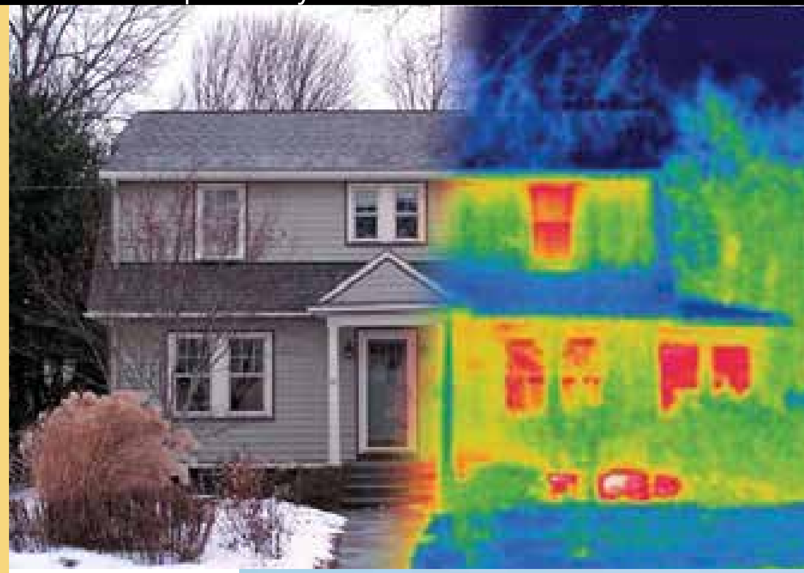
Subscribers and HomePower.com members can access and download three years of back issues (18) in PDF: **www.homepower.com/backissues**

On the Cover

A technician from Lighthouse Solar installs frameless Lumos PV modules in Boulder, Colorado.

Photo: Topher Donahue

These pages, clockwise from bottom: Courtesy Solar World; Bogart Engineering; courtesy REC Solar; Eric Youngren; courtesy Infrared Diagnostics; Carol Weis



70

104

Up Front

8 **from** the **crew**
Home Power **crew**
Shrinking our footprint

12 **news** & **notes**
Kelly Davidson
Solar incentives & Congress

16 **gear**
Tyco Electronics combiner box; Enphase Energy dashboard

20 **returns**
Kelly Davidson
Education in Delaware

24 **solutions**
Martin Beggs
Net-zero neighborhood

26 **methods**
Justine Sanchez
Wire sizing for PV

30 **mailbox**
Home Power **readers**
Feedback & forum

34 **ask** the **experts**
RE industry professionals
Renewable energy Q & A

94

More Features

70 **energy** retrofits
Tom Harrison
Small changes can add up to big savings. Learn how homeowner Tom Harrison invested in energy retrofits, reaping the rewards of a more efficient and comfortable dwelling.

94 **microhydro** 2x
Eric Youngren
Two distinct microhydro systems provide power to this island homestead and business.

104 **solar** healthcare
Carol Weis & Walt Ratterman
An off-grid PV array at a hospital in a remote Haitian town helps keep critical equipment running.

In Back

114 **code corner**
John Wiles
Changes in the 2011 *NEC*

118 **home** & **heart**
Kathleen Jarschke-Schultze
Seedy beginnings

123 **advertisers index**

124 **back page basics**
Justine Sanchez
Edge-of-cloud effect

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

Size 32 Shoe

We all have heard that Americans have a disproportionately large impact on Earth. We're 5% of the world's population, yet consume 24% of its energy resources. But statistics can be difficult to act on unless you can apply them to your everyday life.

So, the other day, one of our crew (who has not yet installed renewable energy systems at her home) took an online quiz that estimates the size of a household's personal "footprint" on Earth (www.myfootprint.org). The results were shocking—her lifestyle was such that if everyone on the planet lived similarly, we would need 2.19 Earths.

But her family is atypical in that they have a relatively high consciousness when it comes to energy use, water use, eating habits, transportation, recycling, and consumption. If you think 2.19 Earths is staggering, consider this: The typical American has a footprint that is 3.5 times greater than her family's!

Numbers aside, there are real actions we can all take to make life here on Earth better for us now, and for future generations. One significant way to decrease our footprint is to use renewable energy. Adding in 100% renewable energy to the calculator improved her family's household footprint by 15%, to 1.86 Earths needed.

The footprint website gives lots of ways to do this after taking their quiz, including details in these areas.

Add energy-saving features to your home. Install CFLs, weatherproofing, and use energy-saving appliances.

Adopt energy-saving habits. Keep the thermostat relatively low in winter and ease up on the air conditioning in summer, unplug electronics when not in use, and use clotheslines.

Use cleaner transportation. Drive less, bike more, and take buses and trains on local trips and vacations.

Reduce your housing footprint. Choose sustainable building materials, furnishings, and cleaning products.

Adopt water-saving habits. Take shorter, less-frequent showers, install low-flush toilets, compost instead of disposing, wash your car infrequently, and fix leaks right away.

You've already taken one step in learning to reduce your footprint by reading *Home Power*. And one step at a time, we'll reach the ultimate goal of sustainable footprints.

—Michael Welch, for the *Home Power* crew

Think About It...

Our personal consumer choices have ecological, social, and spiritual consequences. It is time to re-examine some of our deeply held notions that underlie our lifestyles.

—David Suzuki, scientist

MMP Installation is Simple As

Mount the Backplate
Mount the BP-MMP backplate to the wall on 16 inch centers. The back plate is 16 ga. powder-coated steel and features ¼-20 pemnuts for fast installation of the inverter and MMP enclosure.

Install the MMP Enclosure
Start four of the supplied ¼-20 bolts into the pemnuts to mount the MMP enclosure. Four mounting keyholes allow you to simply place the enclosure over the bolts and tighten them without having to support the enclosure during installation.

Install the Inverter
Place the inverter/charger on top of the enclosure and secure with supplied bolts. The enclosure supports the weight of the inverter/charger, allowing one person to install a 60 lb inverter/charger without help. The DC positive and negative buss bars are preinstalled, connecting the DC once the inverter is in place. Connect the AC input and output wiring, battery cables, and optional DC breakers.

Attach the optional ME-RC or ME-ARC remote control to the front cover, install the front cover, and you're done.

MAGNUM
ENERGY

To learn more about the MMP and other Magnum products visit www.magnumenergy.com

contact us

Home Power—independently published since 1987

Publishers	**Richard & Karen Perez**
Executive Editor & CEO	**Joe Schwartz**
Managing Editor	**Claire Anderson**
Art Director	**Ben Root**
Senior Editors	**Michael Welch, Ian Woofenden**
Technical Editors	**Justine Sanchez**
	Erika Weliczko
Associate Editor	**Kelly Davidson**
Graphic Artist	**Dave Emrich**
Building Technology Editor	**Rachel Connor**
Solar Thermal Editor	**Chuck Marken**
Transportation Editor	**Bradley Berman**
Columnists	**Kathleen Jarschke-Schultze**
	John Wiles
Advertising Manager	**Connie Said**
Advertising Director	**Kim Bowker**
Chief Information Officer	**Rick Germany**
Operations Director	**Scott Russell**
Data Manager	**Doug Puffer**
Customer Service & Fulfillment	**Jacie Gray, Shannon Ryan**

Home Power magazine
PO Box 520 • Ashland, Oregon 97520 • USA

homepower.com

facebook.com/homepower

twitter.com/homepowermag

Subscriptions

To subscribe, renew, change, or inquire about a subscription:

800-707-6585 or **541-512-0201**

subscription@homepower.com

www.homepower.com/subscribe

Back Issues

Many of our back issues are available in print and/ or online in Adobe PDF. Our first 131 issues are also compiled on DVD-ROM. More information at:

www.homepower.com

Order online or by phone:

800-707-6585 or **541-512-0201**

Submissions

For inquiries and information related to editorial submissions, write to us at:

submissions@homepower.com

www.homepower.com/writing

Website

www.homepower.com

Send your comments regarding the site to:

web@homepower.com

Ask the Experts

To have your technical questions considered for publication, send them to:

asktheexperts@homepower.com

Letters to the Editor

E-mail your comments and suggestions to us at:

mailbox@homepower.com

or write to the address above.

Marketing

Promotional opportunities and offers:

marketing@homepower.com

Advertising

For inquiries and information related to advertising in *Home Power* or on www.homepower.com:

Western States:
connie.said@homepower.com
541-326-5773

Eastern States:
kim.bowker@homepower.com
541-858-1791

www.homepower.com/advertising

Interior paper is made from 85%–100% recycled material, including 20%–30% postconsumer waste.

So Far, So Good

Solar incentives continue despite divided Congress

With conservatives in control of the House, capturing more seats in the Senate, and vowing to deliver deep cuts in federal programs, competition for funding may be fiercer than ever in the coming years for energy projects and programs.

"We have had a fair amount of bipartisan support in the past, and we're hoping it will continue moving forward," says Dan Adamson, vice president of government affairs for the Solar Energy Industries Association (SEIA). "But there are a lot of new players, and there is definitely some uncertainty."

If history is any indicator, then solar may survive the ensuing partisan power struggles. The investment tax credit—hailed as the single most important piece of legislation for residential and commercial solar—was originally passed in 2005 with a Republican-controlled Congress and has survived two presidencies.

Adamson says that it is too early to tell what impact—good or bad—the shift to a more conservative legislature will have. "We're not making assumptions about anyone. We're just doing what we can to educate all members of Congress about the benefits of solar. Job creation is one thing that all the parties seem to want, and growth of the U.S. solar market offers that," he says.


©iStockphoto.com/uschools

The solar industry scored an eleventh-hour victory during the lame-duck Congress in December. The Section 1603 Treasury Grant Program (TGP), which was set to expire at midnight on December 31, 2010, narrowly escaped demise. The program, also known as the "Payments-in-Lieu-Of-Tax-Credits" program, received a one-year extension as part of a bipartisan compromise over new tax legislation.

"The makeup of the new Congress may make our task more difficult, but the need for investments in renewable technology and infrastructure has never been greater," says Senator Kirsten Gillibrand of New York, who helped push for the TGP extension. "This is no time to back down from our efforts."

The TGP serves a critical function for the solar industry, providing commercial and nonprofit installations with a cash grant in lieu of the long-standing 30% solar ITC. Since the onset of the economic downturn, securing third-party tax equity to take advantage of the ITC and cover up-front costs for solar projects has been challenging, according to John Lushetsky, program manager of the U.S. Department of Energy Solar Energy Technologies Program.

The TGP was created as part of the American Recovery and Reinvestment Act (ARRA) to address this problem, essentially shifting the incentive from a back-end subsidy to an up-front cash grant.

"The investment tax credit is the cornerstone of federal solar policy, but it can only do so much in the current economy, where tax equity financing is scarce," Lushetsky says. "The ITC is on the books until 2016, but without the treasury grant program and other key incentives in place, we are not going to see the same level of market development and job creation that we have seen over the past few years."

As of early January, the TGP leveraged roughly $5.8 billion in federal funds to attract nearly $18 billion of outside investment for solar, wind, and other renewable energy projects. The majority of that funding—roughly $4.9 billion—went toward 223 grants for wind energy installations, with $472 million doled out for 1,430 PV and solar thermal installations in 43 states. New Jersey received the second-largest chunk for solar projects, after California.

The TGP extension marked the end of a banner year for solar. In 2010, the United States installed 830 megawatts of PV—almost more than double that installed in 2009, according to senior analysts at GTM Research in Cambridge, Massachusetts. An additional 78 MW of concentrating solar and roughly 700 MW of solar thermal drove the total solar installations well above 1 gigawatt for the first time.

Alongside support from state and federal policies, nationwide growth is being propelled across residential, commercial, and utility-scale market segments by the continued decline of average system costs—which are below $6 per watt.

In addition to extending the grant program, Congress also approved an incentive that allows companies to write off the full depreciation on solar equipment in the first year after installation rather than over five years.

Industry leaders will be pushing to reinstate the advanced energy manufacturing credit. The $2.3 billion for the ARRA tax incentive—$1.1 billion of which was dedicated to solar projects—is now fully exhausted. Despite efforts by solar champions in Congress, the program did not receive additional funding as part of the 2010 year-end package.

Legislation introduced last year by former Congressman Phil Hare (D-Illinois) and current Senator Sherrod Brown (D-Ohio) aimed to revive the 30% manufacturing credit with an additional $5 billion in funding for new facilities and a cash-grant option similar to the TGP. At this time, the legislation has not been reintroduced.

Among those programs that may experience changes are the 1703 and 1705 loan guarantee programs through the DOE, in which the federal government shares some of the financial risks of nuclear, fossil, and renewable energy projects. Collectively, the two programs have more than $18.5 billion in funding authority for renewables. However, the $2.4 billion in appropriated funds to pay for credit subsidy costs for eligible 1705 projects—made possible through the ARRA to support an estimated $20 to $30 billion in loan guarantees—is due to expire on September 30, 2011. As of February, the programs had committed $4.7 billion in loan guarantees, and finalized loan guarantee in support of five major solar generation and manufacturing projects. Of the five projects, three have closed.

"We hope that the members of Congress realize that the tremendous impact that these programs have had, and how important it is for United States to continue to grow its solar industry," Lushetsky says. "When you look at the amount being invested in China and other countries, these are still relatively small efforts."

According to data compiled by SEIA, the United States accounted for more than 40% of global PV cell production as recently as a decade ago. Yet in 2009, Europe and Asia led global production, with the United States producing only 7% of the world's PV modules. Looking at the entire solar energy supply chain, the United States remains a significant net exporter with total net exports of $723 million in 2009.

SEIA is hoping the power of bipartisanship will advance an industry-wide target of installing 10 gigawatts of solar each year until 2015. To realize that goal, the group is lobbying lawmakers to put in place a series of policies, including longer contract terms for federal power purchase agreements. Current law limits the length to 10 years, versus the 20-year power purchase agreement (PPA) model used in the private sector, which has been shown to make solar investment more cost-effective.

Also on the agenda are uniform national net-metering standards and stronger solar access laws that prohibit or limit private restrictions on solar, such as those imposed by a homeowners' association. There are no bills or major efforts afoot on feed-in tariff legislation, although SEIA has a working group examining the issue.

What's happening at the federal level may not touch homeowners directly, but all the efforts benefit the industry in a broader sense, Adamson says.

"These programs are creating jobs and encouraging domestic manufacturing that is helping to lower the cost of solar and allowing the solar industry to compete against the heavily subsidized fossil-fuel industry," he says. "Ultimately, those savings trickle down to ratepayers and homeowners in the form of lower rates for utility-scale solar electricity and lower installed costs for residential systems."

—Kelly Davidson

SunShot Initiative

In February 2011, the U.S. Department of Energy (DOE) announced funding for the previously announced SunShot Initiative—an effort to decrease the cost of electricity from solar energy and help restore the nation's dominance in the global PV market, which has eroded significantly. In 1995, the United States supplied 43% of the PV market, but today that has dropped to about 6%.

SunShot derives its name from the 1960s all-out "moon shot" initiative, which restored the United States' lead in the space race by being the first country to send a person to the moon. The moon shot was called the Apollo Project, which not coincidentally, is the name of a later-day Congressional effort to sever the ties to Mideast oil, while creating jobs and addressing human-caused climate change.

SunShot's goal is to reduce the cost of PV-made electricity by about 75% by the end of the decade, without additional subsidies. If solar's installed costs drop to $1 per watt—equivalent to a levelized cost of 5 to 6 cents per kWh—it would be competitive with the wholesale electricity rates of electricity nearly everywhere in the United States.

In addition to the traditional investments in PV technology, a new tack intends to reduce system installation and permitting costs. With this, the initiative hopes to increase the demand for PV technologies, ultimately enabling new domestic PV manufacturing.

The February announcement focused on $27 million allocated to nine different projects to advance solar development and manufacturing. The lion's share will go to five projects intended to improve the U.S. supply chain for PV materials, and manufacturing machinery and technologies. The rest of the funding, $7 million, is allocated to the PV Incubator program, which helps shorten the commercialization time for emerging solar technologies.

New Report Addresses Permitting Costs for PV Installations

While solar equipment prices are falling, the total installed cost of residential solar systems is falling more slowly because of inconsistent local permitting and inspection processes, according to a report compiled by San Francisco-based PV integration company SunRun.

The report found that wide variations in permitting processes and practices add $0.50 per watt, or $2,516 per 5 kW installation—the equivalent of a $1 billion "hidden" cost of solar over the next five years.

"Every city and town has its own set of regulations and requirements for solar installations. Our research identifies inconsistencies in local permitting as one of the most critical roadblocks to a sustainable, subsidy-free solar industry," says SunRun CEO and cofounder Edward Fenster.

SunRun interviewed operations professionals at 15 PV installation companies nationwide, and consulted with key stakeholders to develop recommendations.

According to the report, solar installers identify local permitting as the most stubborn cost they face: Variations in local permitting and inspection practices force installers to spend time and money customizing plans for each jurisdiction.

Courtesy Namaste Solar

The report builds on key findings from the Solar America Board for Codes and Standards (Solar ABC), an organization funded by the U.S. Department of Energy (DOE) to address issues with solar codes and standards issues. A recent Solar ABC study—"Expedited Permit Process for PV Systems: A Standardized Process for the Review of Small-Scale PV Systems"—concluded that residential-sized PV systems share many similarities that would allow for a nationally standardized, expedited permit process. The SunRun report proposes that the DOE launch a "Residential Solar Permitting Initiative" that implements the "expedited permit process" developed by the Solar ABC and targets 200 high-volume cities that impact more than 50% of the solar market.

In addition to an online common application, specific recommendations include a contest to reward jurisdictions for improving permitting in key solar states—modeled after the U.S. Department of Education's "Race to the Top."

Cities like Portland, San Jose, and Philadelphia have adopted streamlined measures with much success, according to the report. San Jose, for example, partnered with surrounding municipalities to standardize their permitting processes, even sharing inspectors across jurisdictions. As a result, area installers are consistently able to price installed PV systems below $6 per watt for larger systems.

"We've instituted multiple improvements to help the solar industry, without compromising safety or requiring additional city staff time, including reduced permitting fees and a streamlined process for projects less than 10 kW," says Kristin Sullivan, program director of the Philadelphia Solar City Partnership Program.

The report also notes that Germany and Japan have eliminated permitting for residential solar. By comparison, solar installation costs in Germany are 40% lower than in the United States.

"Local permitting red tape keeps solar off millions of American homes and businesses and seriously jeopardizes our ability to be competitive with entrenched fossil fuels," says Rhone Resch, president and CEO of the Solar Energy Industries Association.

"The [DOE] is continuing to review the data from the recent study, which brings valuable real-world data to the discussion. Installers and system integrators have the best knowledge of permitting process variations and cost implications, so their outlook will help inform the Department's efforts moving forward," according to a DOE spokesperson.

The report is currently under review by the DOE and available at www.sunrunhome.com/permitting.


All The Power You Need
Under One Umbrella
QUALITY SYSTEM CERTIFIED TO
ISO 9001
ISO/TS 16949
ISO 14001
Whatever your application,
you can depend on Deka Solar.
Deka Solar Gel/AGM or Flooded batteries are the proven choice for all your renewable energy applications. Deka Solar Batteries, sold worldwide through major photovoltaic equipment manufacturers and distributors, exceed the high standards of the solar industry with superior quality and environmentally conscious battery solutions. Available from MK Battery Distribution centers across North America, Europe and the Asia Pacific region.
PROVEN PRODUCTS IN DEMANDING PHOTOVOLTAIC APPLICATIONS • U.L. RECOGNIZED COMPONENTS • COMPETITIVE WARRANTY • MADE IN THE U.S.A.
Deka
SOLAR
PHOTOVOLTAIC BATTERIES
MK
POWERED
MK Battery • www.mkbattery.com
A subsidiary of East Penn Manufacturing Co., Inc.

Courtesy Tyco Electronics

Tyco Electronics

Solarlok Combiner Box

In January, Tyco Electronics (www.tycoelectronics.com) released its five-string input, plug-and-play combiner box for residential PV systems.

The Solarlok pares combiner box installation to four steps: mounting the box, connecting output conduit, pulling and landing the output wiring (positive, negative, and ground), and then plugging in the array input strings (and landing the array ground) to the outside of the box.

Positive and negative PV input string connectors plug into Solarlok connectors on the outside of the box. Internally, the combiner box is pre-wired so that each input string can be fused (up to 15 A) and combined in parallel to a single output. Four 3/4-inch knockouts allow output conduit to exit in any direction. Each input string can handle a PV short-circuit current up to 9.6 A.

A transparent cover, under the hinged metal outer cover, prevents access to the live circuits when open. A Solarlok ground bolt on the outside of the box (which is bonded to the internal ground terminal) accepts the array grounding conductor. The maximum ambient temperature rating is 122°F, which is a consideration for rooftop installations where temperatures can often exceed this rating.


Courtesy Enphase Energy

Enphase Energy
Installer Dashboard

Enphase Energy's Installer Dashboard is a software tool now offered within the Enphase Enlighten website (www.enphaseenergy.com). The dashboard allows installers to view a map and the status of all of their Enphase installations on one screen. The dashboard can be customized, adding or altering widgets that display various informational screens on the dashboard page. Current widget options include power and energy pages, system installation progress, maintenance alerts, general solar industry news, and Enphase installer community discussion boards. The dashboard can also be accessed via a web-enabled smart phone.

Pushing PV

A bright idea brings hands-on solar education to a school in Delaware.

At the nonprofit Newark Center for Creative Learning (NCCL) in Delaware, conservation and sustainability have always played a fundamental role in the school's curricula. The 40-year-old organization, which serves 90 children from kindergarten through the eighth grade, has always provided examples of environmental caretaking to its students.

NCCL's 19 kW photovoltaic system is its latest endeavor. The school applied for a grant through the Longwood Foundation, an organization that supports community charitable organizations, securing $50,000 toward the system's installation. The system alone—90 210-watt modules on the school's south-facing roof—is impressive, but the real wow factor is how the school has integrated renewable energy into the curriculum.

With a portion of the grant, the school commissioned a team of graduate students from the University of Delaware—Cory Budischak, Erik Koepf, Keith Douglass, and Sarah Mastroianni—to develop educational tools about solar energy.

"We wanted the PV system to be more than just something that would lower the school's electricity bills. We wanted our students to understand the principles involved [in generating renewable electricity], and feel a sense of pride and ownership," says Sean Kerrane, a teacher at NCCL.

The starting point for a hands-on system was four unused, 15-year-old modules that were donated by Steve Hegedus, director of the Institute for Energy Conservation at the University of Delaware. Hegedus has strong ties to NCCL—both his son and daughter attended, and his wife taught at the school for nearly 20 years.

It was at Hegedus' urging that NCCL reached out to the students working with the solar hydrogen IGERT outreach program, a group supported by the National Science Foundation. The resulting collaboration gave way to the development of a solar learning lab and curriculum.

"The real challenge was to build a system with all the standard components that would be safe for kids to experiment with," says Koepf.

The final product—a mobile solar demonstration system—is a PV system on wheels. The self-contained unit, which in a collapsed state still clears a standard 80-inch door frame, features two charge controllers, six batteries, and two inverters, along with four PV modules that can be tilted at different angles.

The set of lesson plans developed by the team combines in-class lectures with outdoor experiments that allow students to wire the components together to power lights and fans and even recharge a remote-controlled toy car. Lessons blend science and math with the basics of solar energy capture, storage, conversion, and conservation.

"The experiments allow students to see for themselves how array output varies with the tilt and orientation of the array or how the charging current of the batteries varies with temperature and voltage," says Budischak, who is pursuing his doctorate in electrical engineering. "You can just tell that it all clicks when they can see all the components for themselves."

The cart made its debut at NCCL last spring, when the team trained teachers on how to conduct experiments and troubleshoot potential problems.

"I've used the array on our roof as a springboard to talk about solar energy and costs, but talk only gets you so far," says Ray Magnani, who teaches math and science to seventh and eighth graders at NCCL. "The cart's design allows the kids to follow all the wires and understand how everything works. It has sparked the students' interest in a way that a normal lecture-based lesson never could."

Based on those initial reactions, NCCL plans to integrate the solar learning lab into the curriculum for grades 5 to 8. The team intends to evolve the design and develop lessons that will appeal to a range of grade levels, from preschool up to university levels. Future enhancements include a small-scale wind turbine and data-logging multimeters that will enable students to analyze information about the system. Also underway is the design of a solar water pumping system that will include a series of fountains, where the distance the water travels through or out of the fountain will depend on output from the PV modules.

—Kelly Davidson

Solar Cart Components

PV modules: Four Arco M55, 12 V, 55 W each

Batteries: Six Lifeline GPL31, 12 V; two 9.5 Ah; two 36 Ah; and two 95 Ah. Batteries of each capacity allow students to experiment with the different charging mechanisms (e.g., modules at different tilts) and different loads (e.g., incandescent vs. LED bulb) on the same capacity.

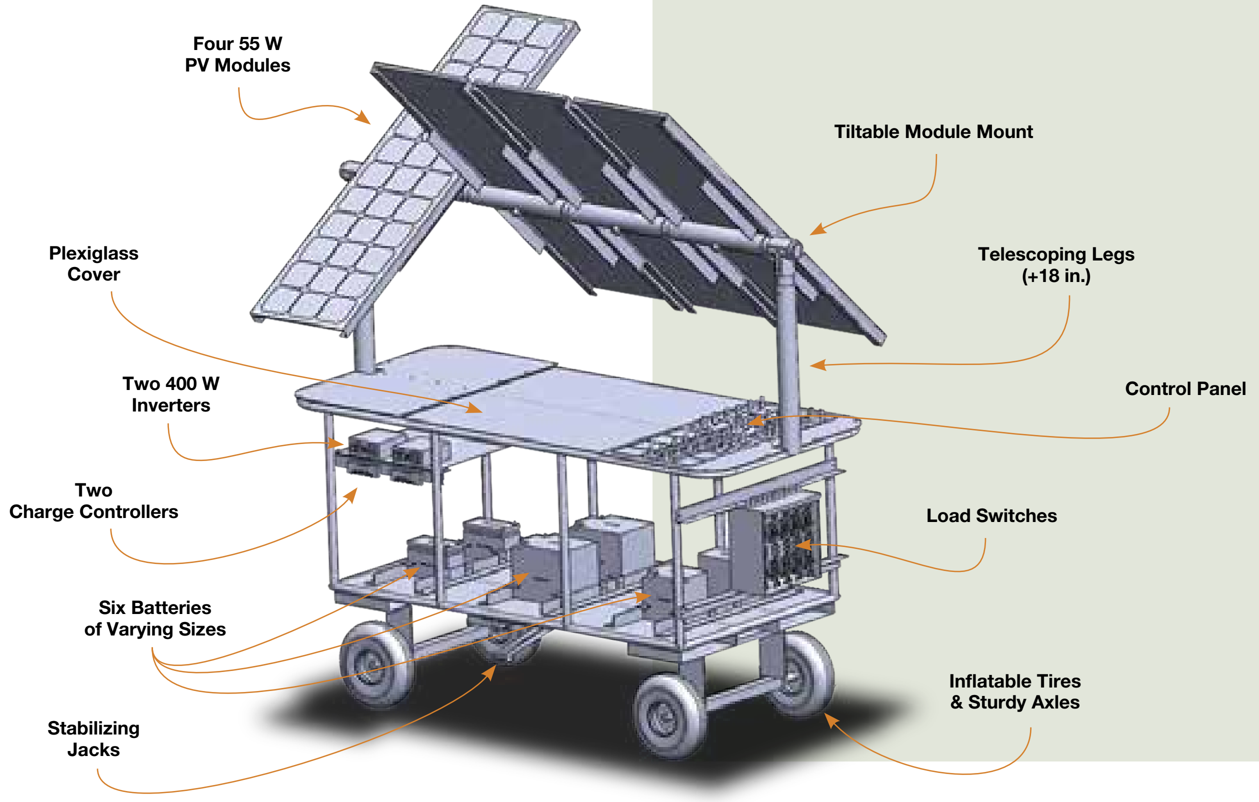
Switch box: 10 switches wired in a modified breaker box with connections on the top and bottom. The six batteries and four PV modules are connected to the switches such that components of the system can be connected and disconnected easily. A locked cover prevents unintended access.

Charge controllers: Two Morningstar SS-20L-12, 12 V charge controllers allow experiments to run simultaneously with as many as four modules.

Inverters: Two 400 W (one sine wave and one modified-square wave) Vec024B and AIMS Power PWRI30012S inverters, with standard AC receptacles. This allows students to run experiments simultaneously, comparing the differences between the two inverters.

Control panel: A color-coded panel equipped with plug-in terminals and insulated connections hard-wired to the PV modules, inverters, charge controllers, and batteries.

Array installation: Custom-fabricated mounts installed horizontally above the cart between two telescoping legs that allow the modules to be raised an additional 18 inches. Modules can also rotate 180°.



Net-Zero Neighborhood


Namaste Solar

Going green was the focus of the development at Spring Leaf, a 12-unit, net zero-energy neighborhood infill project in Boulder, Colorado. For architect George Watt, Silver Lining Builders, and developer Cunningham Farms Development, that meant coordinating all of the details to create integrated design for the houses and neighborhood, from the efficient use of materials to handling stormwater runoff in an eco-friendlier manner.

The first house in the development, at 3979 Spring Leaf Lane, is on a trajectory to exceed the U.S. Green Building Council's LEED Platinum certification. Predicted to be a net energy producer, the well-insulated house has high-performance windows, rigorous air-sealing, Energy Star appliances, and LED and compact pin fluorescent lighting throughout. A 9.9 kW batteryless grid-tied PV system generates enough electricity to serve all of the home's loads, and then some.

In keeping with the modern, streamlined design of the house, the concept for the PV system was to install an array that would be visually integrated into the roof. In the planning stages, the architect and PV integrator worked together to make sure that roof assembly would accommodate 44 SunPower 225-watt modules in an edge-to-edge array. A unique, low-profile racking system facilitated the appearance of a roof-integrated array.

The challenge with this particular PV installation was creating the edge-to-edge array with standard racking equipment. Because the Quick Mount PV flashed roof attachments cannot be located at the utmost top and bottom of the roofline, the module racking required that the top and bottom Unirac SunFrame rails be cantilevered over the top and bottom horizontal rows of the PV roof attachments. To accomplish this, the installers built a Unistrut substructure, with Unistrut lengths running north/south, effectively spanning vertical columns of roof attachments.

An eGauge monitor provides both PV production information and a real-time load profile for the home, which soon proved itself invaluable last winter, when the architect and builder observed that the load profile wasn't consistent with expectations. Further investigation revealed that the geothermal system was not operating at its peak efficiency. Without the monitor, this issue could have gone undetected.

—Martin Beggs

Project Specs

Project name: Spring Leaf Lane

System type: Batteryless grid-tied PV

Installer: Namaste Solar

Date commissioned: September 16, 2009

Location: Boulder, Colorado

Latitude: 40.02°N

Resource: Solar

System capacity: 9.9 kW STC

Average annual production: 14,440 AC kWh

Average annual utility bill offset: 100%

Equipment Specs

Number of modules: 44

Manufacturer & model: SunPower SPR-225-BLK

Module rating: 225 W STC

Inverters: Two SunPower/SMA America Sunny Boy 5000US

Inverter rated output: 5,000 W each

Array installation: Roof-mounted

Roofing material: Composition shingle

Array azimuth: 180 degrees

Tilt angle: 40°

Installers worldwide know SMA inverters are the key to a successful solar project.

An inverter transforms the DC power produced by solar panels into utility-compliant AC power, allowing it to be fed into the utility grid. During the transformation process, it is very important that energy loss be minimized. SMA inverters reduce loss and maximize your solar system's performance. SMA is the world's largest manufacturer of solar inverters and builds the most efficient, technologically advanced inverters available. When considering an inverter for your solar power system, SMA is the only logical choice.

SMA Inverters: Ask for them by name.

The Future of Solar Technology

SMA

Wire Sizing

for a Batteryless Grid-Tied PV System

In *Code Corner 141*, John Wiles discussed some of the 2011 *NEC* requirements that are used in conductor sizing. Here is an example of how to size the DC and AC conductors for a batteryless grid-tied PV system. (Note: This same procedure has always been required, except for the temperature correction factors, which was first included in the 2008 *NEC* for conduits on roofs.)

Our example system is located in Denver, Colorado, and consists of two 10-module series-connected PV strings. The modules are roof-mounted, and the positive and negative of each series string transitions on the roof in a junction box (using 90°C rated terminals) from USE-2 from the subarrays to THWN-2 (90°C rated) in conduit. No DC fuses are required for two strings of modules, and all four conductors are run within the same conduit to the inverter (with each conductor landing on 90°C rated inverter terminals). The conduit is secured 1 inch off the roof surface, and the one-way circuit length to the furthest module to the inverter is 100 feet (40 ft. of module array length + 15-ft. rooftop conduit run + 45 ft. from the roof to the inverter). The inverter is mounted near the main service panel, which is on an external wall, out of direct sunlight.

Example Specifications

PV Module

STC power: 245 W

Voc: 37.7 V

Isc: 8.25 A

Vmp: 30.8 V

Imp: 7.96 A

Inverter Specifications

Output power: 4,800 W

Maximum DC input voltage: 500 V

DC voltage operating range: 200 to 450 V

AC nominal output voltage: 240 V

AC rated output current: 20.5 A

Step 1: Determine the continuous currents in each circuit.

Calculate the continuous DC array-to-inverter current by multiplying the string short-circuit current by the *NEC* safety factor.

Isc × 1.25
8.25 A × 1.25 = 10.31 A

The inverter AC continuous current output to the main AC service panel is simply given in the inverter specifications. In this case, it's 20.5 A.

Step 2: Calculate the rating of the overcurrent device, where required.

In this case, we have only two module strings and thus have no DC fuses required.

The inverter's AC output will be wired to a backfed circuit breaker in the main service panel, which will be sized at 30 A to handle no more than 80% of the inverter's rated output current:

20.5 A rated inverter output ÷ 0.80 = 25.63 A, next larger available size is 30 A

Step 3: Size the conductor.

Size the conductor, which must meet both the ampacity requirement and the 125% requirement. Choose the larger of the two (A or B below):

A. Ampacity Requirement. Conditions of use, including temperature and conduit-fill correction factors, are considered:

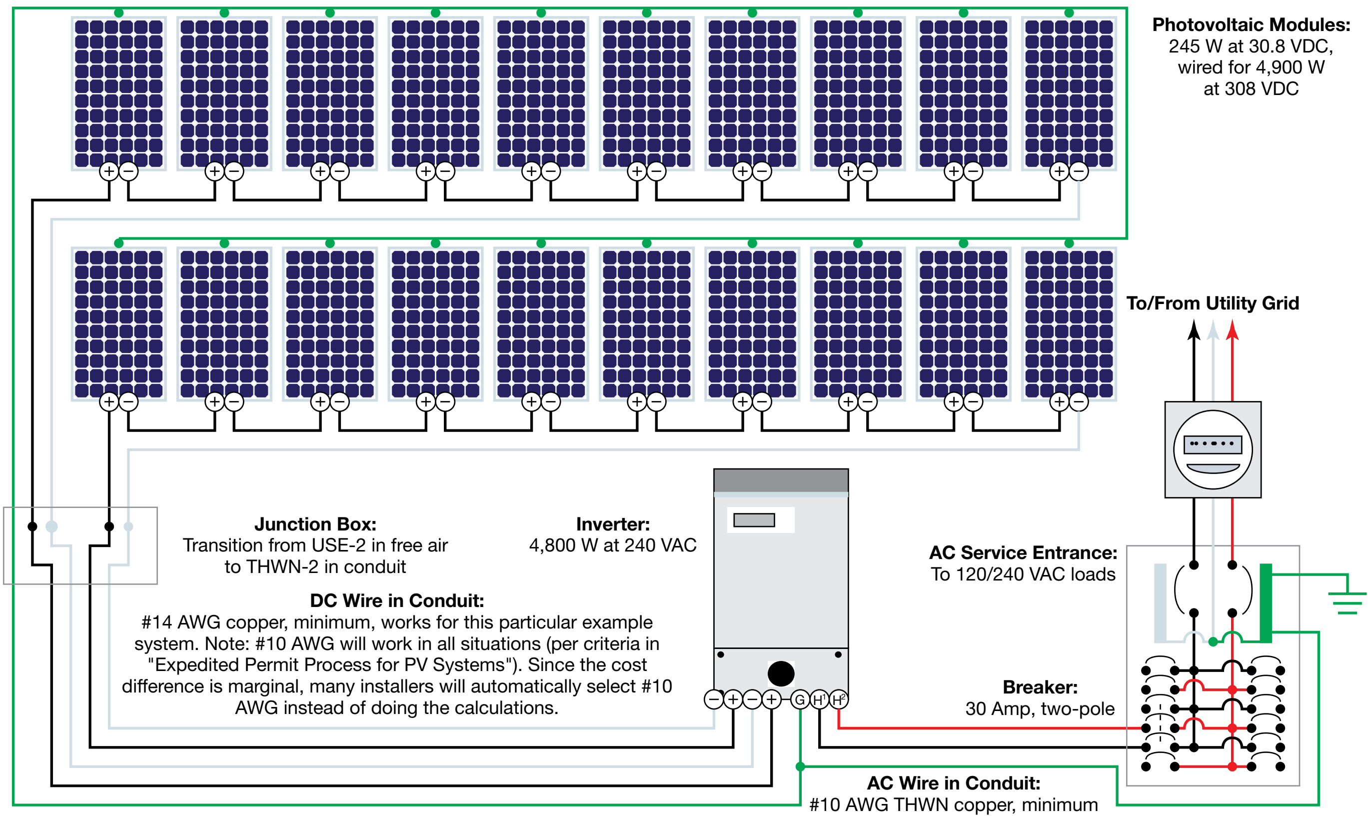
For the PV DC circuit, which is on the roof in conduit, we use the temperatures these wires may experience. First, we find the ASHRAE 2% design temperature data for Denver: 34°C (www.copper.org has the data; search for "temperature derating table").

Then, use Table 310.15(B)(3)(c) in the 2011 *NEC* to find the temperature adjustment value. For conduit that is secured 1 inch off the rooftop surface, the adjustment factor is 22°C.

The resulting temperature is 56°C (34°C + 22°C). Then use this with *NEC* Table 310.15(B)(2)(a) to find the temperature correction factor: 0.71 for our 90°C rated wire.

Because we have four current-carrying conductors in this conduit, per *NEC* Table 310.15(B)(3)(a), a 0.80 conduit-fill correction factor must be included:

Continuous current ÷ temperature correction ÷ conduit fill
10.31 A ÷ 0.71 ÷ 0.80 = 18.15 A



The 90°C column in *NEC* Table 310.15(B)(16) tells us that a #14 conductor is required.

B. 125% Requirement. Calculate 125% of the continuous current:
10.31 A × 1.25 = 12.89 A

Again, use the 90°C column in *NEC* Table 310.15(B)(16), which calls for a #18 AWG cable.

The larger of the two requirements is #14 AWG for our DC PV array-to-inverter wire run.

Now for the inverter *output:*

A. Ampacity rule. Because the AC inverter output circuit is not on the rooftop, we can use 75°C rated wire, and simply use 34°C as our ambient temperature stated (not on rooftop). This yields a 0.94 temperature correction factor from NEC Table 310.15(B)(2)(a). Since the AC output has less than four current-carrying conductors (2 hots, and no neutral is required for this inverter), the conduit-fill correction is 1.0.

20.5 A ÷ 0.94 ÷ 1.0 = 21.81 A

According to the 75°C column in *NEC* Table 310.15(B)(16), a #12 AWG conductor is required.

B. 125% Requirement. Calculate 125% of our continuous current:

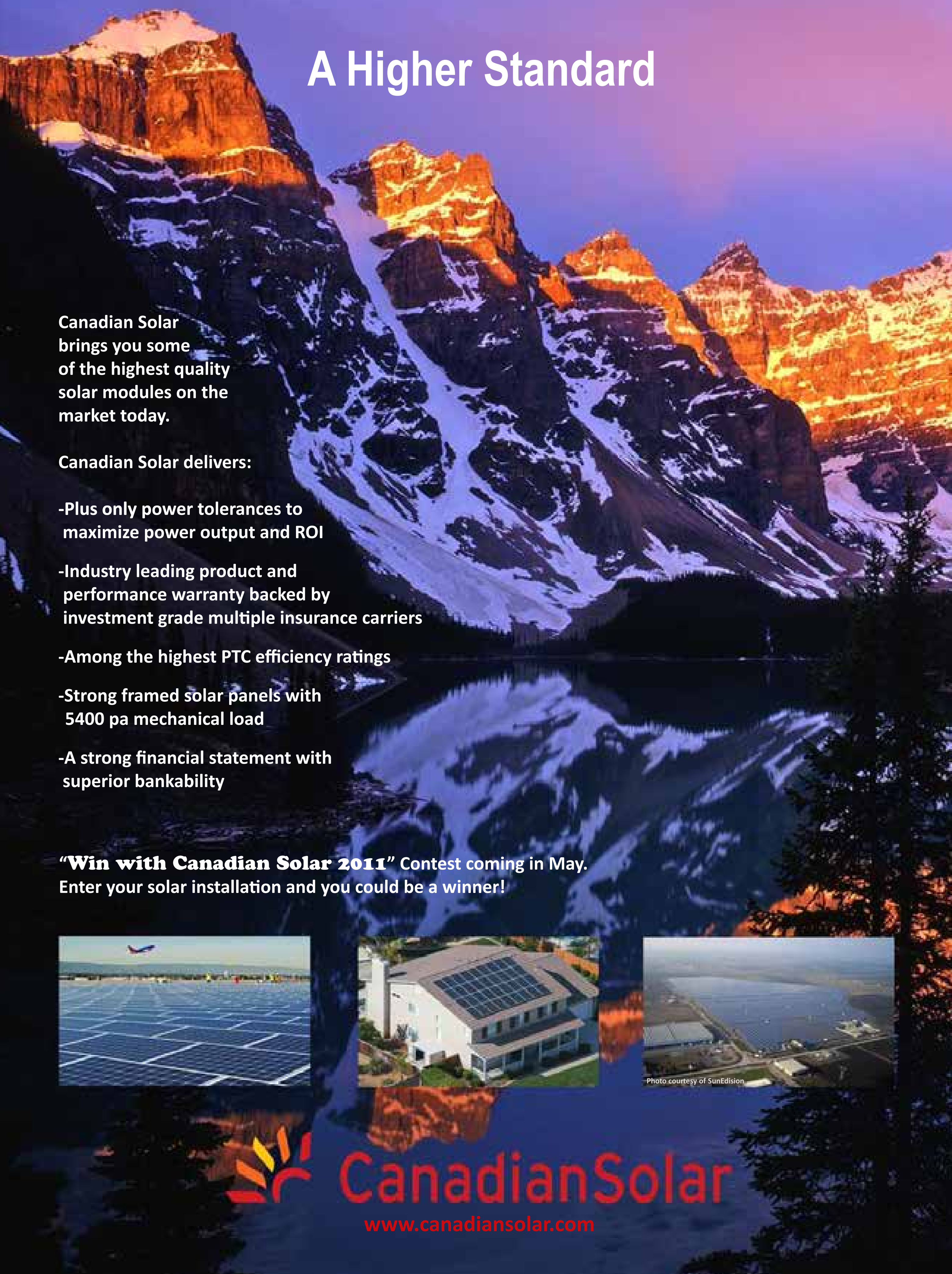
20.5 A × 1.25 = 25.63 A

Again, use the 75°C column in *NEC* Table 310.15(B)(16), which calls for a #10 AWG cable.

Choose the larger of the two requirements, which is #10 AWG, for our AC-to-main service panel wire run.

Another approach for sizing the DC PV wire is covered in "Expedited Permit Process for PV Systems" (www.solarabcs.org/permitting). Using #10 AWG conductors for this circuit is suggested, considering the highest PV module ampacity currently available and the hottest climate in the United States (Palm Springs, California). This method assumes the conduit to be at least 0.5 inches above the roof surface, and having no more than nine current-carrying conductors. Additionally, this method assumes that each module series string is run individually (i.e., no strings are paralleled in a combiner box). While using #10 AWG conductors for this circuit will be overkill for many situations, it can save you from going through the multitude of wire-sizing steps required and the possibility of making mistakes.

—Justine Sanchez


A Higher Standard
Canadian Solar brings you some of the highest quality solar modules on the market today.
Canadian Solar delivers:
-Plus only power tolerances to maximize power output and ROI
-Industry leading product and performance warranty backed by investment grade multiple insurance carriers
-Among the highest PTC efficiency ratings
-Strong framed solar panels with 5400 pa mechanical load
-A strong financial statement with superior bankability
“Win with Canadian Solar 2011” Contest coming in May.
Enter your solar installation and you could be a winner!
Photo courtesy of SunEdision
CanadianSolar
www.canadiansolar.com

Propane Practicalities

I always turn to Ms. Jarschke-Schultze's column ("Home & Heart") first when I receive my copy of *Home Power*, and never fail to find it entertaining and informative—until *HP141*. The article on her purchase of a gas range seems particularly inappropriate for this magazine, not unlike, for example, a discussion of which model of Hummer is most environmentally friendly.

Propane and methane are not renewable resources, and a full life-cycle analysis suggests that these hydrocarbons may release as much carbon into the atmosphere as burning coal. In addition, many states are now faced with hydrocarbon gas extraction by hydraulic fracturing that has resulted in the industrialization of once-rural landscapes, as well as water, noise, and air contamination.

While Ms. Jarschke-Schultze has certainly been a pioneer in off-grid living and she does make some reasonable points about the unnecessary use of electricity in most gas ranges, *Home Power* should be very careful in advocating a solution for cooking that is environmentally and socially damaging.

Robert E. Oswald • Ithaca, New York

I agree, Robert, that propane is not renewable. While you say my article is like "a discussion of which model of Hummer is most environmentally friendly," I'd argue that it is closer to asking, "Do I drive my vehicle the 60 miles to town or do I walk?"

Practical choices are sometimes limited. Electric ranges are not an option for most off-gridders because of the high cost of the extra batteries and RE sources needed. There is no publicly marketed, hydrogen-fueled range. I do use my solar cookers in sunny weather and, when possible, I use my wood heater to cook. However, this does not cover all the cooking I do. It's not practical to do canning with solar cookers or on top of the wood heater, to give you two examples.

I'm open to suggestions for a viable off-grid alternative for cooking. While a portion of the grid electricity here in the Northwest is produced by hydropower, 80% of it is fueled by coal. Do we stop encouraging people to tie into the grid because of this? We can reduce our use of unclean fuel sources as much as practicality allows. We are a work in progress, with a higher goal.

Kathleen Jarschke-Schultze •
Home & Heart *columnist*

Monitoring Feedback

I appreciated Michael Brown's overview of monitoring options ("Keeping Tabs on Your PV system" in *HP139*). We evaluated a number of different options as part of the installation of a 4.2 kW grid-tied PV system this past summer. Had this article been available prior to our installation, we would have made a different choice.

We have an inverter-specific monitoring system and, presently, have no consumption monitoring. Although the power company (Duke Energy) installed a cell-enabled meter to keep hourly tabs on our consumption and generation, the company does not presently appear interested in sharing that data with us! My hope is that, within a few years, the companies making whole-house power meters and state utility regulators will help the utilities see the advantages of giving consumers more timely—and more detailed—usage information.

I would also recommend one important addendum to the article. Before you buy a monitoring system, understand both the up-front cost and recurring costs. Our PV installer selected the inverter manufacturer's product as the monitoring solution.

The manufacturer insists on a yearly fee to be able to download my data to my PC (where I want to integrate it with consumption data I'm capturing manually). We were dumbfounded by the cost, representing about 7% of our yearly savings with PV. This soured us on an otherwise positive impression of the manufacturer's monitoring solution. So, just as in other realms of business, "caveat emptor"—ask about recurring fees before you buy a monitoring solution. You may think it's *your* data, but your monitoring solution provider might have different ideas.

Bob Wray • Chapel Hill, North Carolina

Passing of a PV Pioneer

I am sad to announce the passing of friend and fellow RE conspirator Paul Wilkins on December 9, 2010, after a 13-year struggle with lung disease.

Paul was my loyal friend for 31 years, and one of the first pioneers of off-grid PV-powered living. Our association began in 1979. I was operating WindLight Workshop, my wind power business. There was no industry at the time, just a loose network of pioneers scattered around the country. In the face of many challenges, I needed a miracle from heaven. APaul (as his friends call him) showed up at my Santa Fe shop one day, visiting from California on a self-defined work-study. He spent a solid month helping me build lightweight towers and charge controllers.

Later in 1979, Arco Solar began the first mass-production of PV modules. They wouldn't sell to end users. APaul convinced them that he was of true pioneer stock. When that didn't work, he refused to leave their building until they sold him modules! He brought one to me. So, which was the miracle from heaven, APaul? Photovoltaics? I'll just say it was the start of a long love affair with RE. I declared that the best thing that ever happened to wind power was PV, and changed direction accordingly.

I produced a charge controller for wind and PV called "Charge-A-Stat." In 1982, I dove into solar water pumping and gave the controls production to APaul. He made them for about five years under the name "Solar Works!" There are still a bunch of them in use. Next, another PV home pioneer, Joel Davidson, was tiring of his creation, the *PV Network News.* Joel gave *that* to APaul, who continued to publish it for a few more years.

APaul kept PV in his home and heart until the end. He was a network node for anyone who would listen. No, he was not your typical... anything! He was a self-created beat poet, itinerant VW mechanic, professional radio tower painter, artist, PV pioneer, a devout eccentric, and generous friend to many. He is survived by his wonderful partner of 33 years, Francine. Light a candle for APaul. He's still leading the way.

Windy Dankoff

Paul also has a rich history with Home Power*, and a kinship with publishers Richard and Karen Perez, and early magazine crew members. His directory,* PVNN*, was a crucial asset to the growing RE industry, and used often by our staff and others. He could often be found at renewable energy events, video camera in hand. As an avid videographer, he became our first video editor, reviewing outside videos, and conceptualizing a series of off-grid videos that* Home Power *eventually published.*

A lover of peace and renewable energy, Paul provided this memorable "Think About It" quote during the first Gulf War: "Nobody has to die for solar energy."

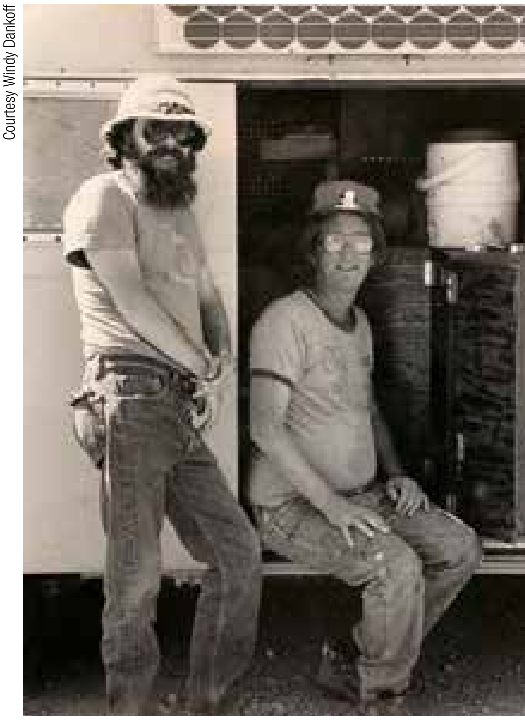
The Home Power *crew*

write to:

mailbox@homepower.com

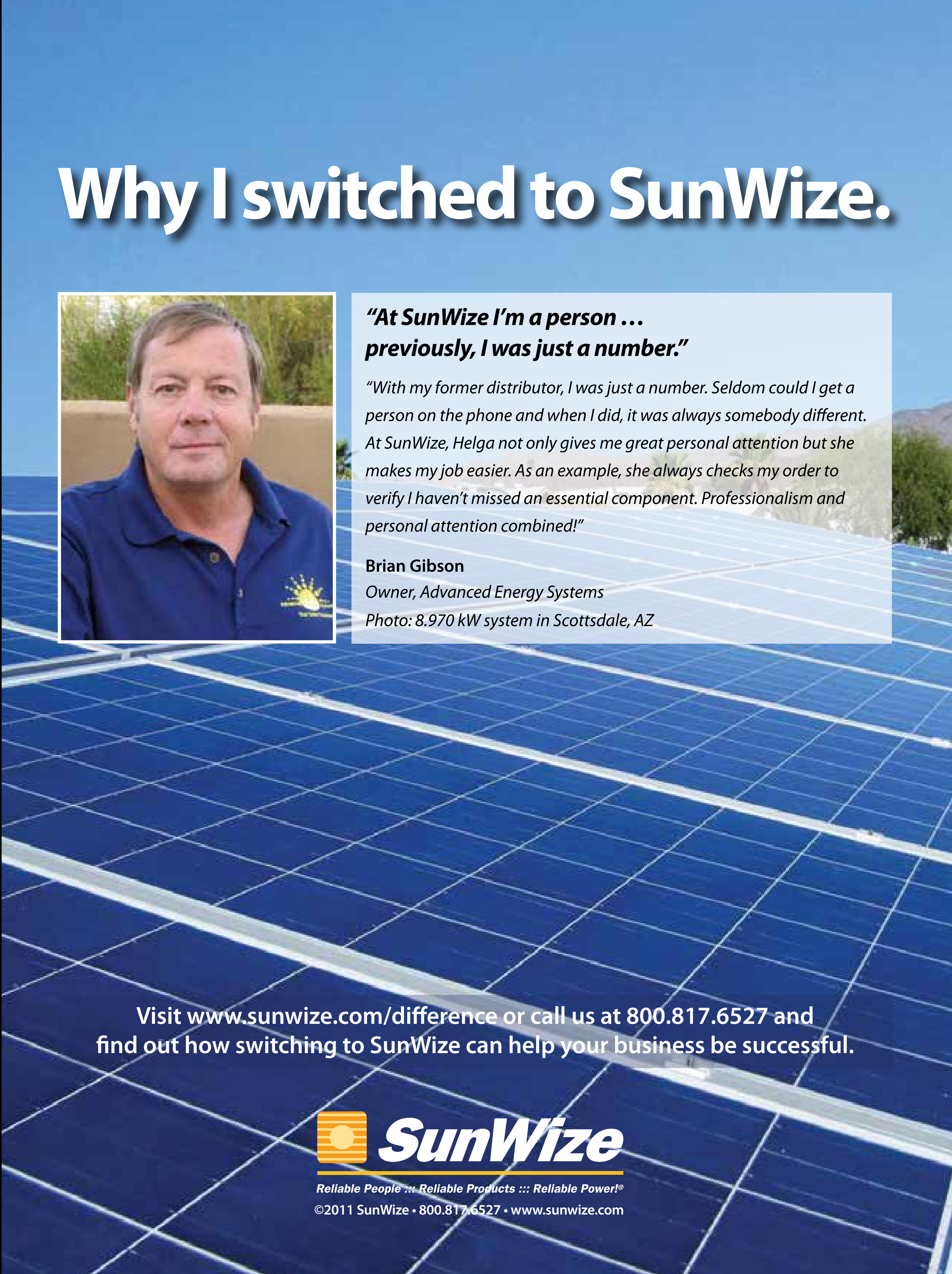
or Mailbox, c/o Home Power
PO Box 520, Ashland, OR 97520

Published letters are edited for content and length. Due to mail volume, we regret that unpublished letters may not receive a reply.



Courtesy Windy Dankoff

Paul Wilkins (right) with *Home Power's* Richard Perez, circa "back then."


Why I switched to SunWize.
"At SunWize I'm a person … previously, I was just a number."
"With my former distributor, I was just a number. Seldom could I get a person on the phone and when I did, it was always somebody different. At SunWize, Helga not only gives me great personal attention but she makes my job easier. As an example, she always checks my order to verify I haven't missed an essential component. Professionalism and personal attention combined!"
Brian Gibson
Owner, Advanced Energy Systems
Photo: 8.970 kW system in Scottsdale, AZ
Visit www.sunwize.com/difference or call us at 800.817.6527 and find out how switching to SunWize can help your business be successful.
SunWize
Reliable People ::: Reliable Products ::: Reliable Power!®
©2011 SunWize • 800.817.6527 • www.sunwize.com

Grid Backup Connection

Your recent issue had an article on battery backup for grid-tied systems. I am interested in this topic because I have a batteryless grid-tied system and experience periodic disruptions of grid power, for up to 8 hours per event.

SMA America's Sunny Island inverter would install with a new subpanel between the AC disconnect and my existing inverter. It switches automatically between the grid and a battery backup system—but only to serve circuits connected to the added subpanel, not the main service panel. That means all my house circuits would be down when the grid is down, and the only circuits with electricity would be ones separately wired to the new subpanel. I find this solution unsatisfactory.

What I want is a product that can be inserted between the grid input and the main service panel to disconnect the panel from the grid, and connect the service panel to the battery backup through an inverter, so *all* house circuits have power. Does such a product exist?

Tom Wicker • via e-mail

You need a transfer switch, a common electrical component frequently used to tie engine generators into existing electrical services. They are available to either automatically or manually select from two different sources to energize loads. We use them in cases much like yours when a customer desires to back up the whole house and has the budget to do so.

These switches must be sized to match the amperage of the service they are connected to—100 A, 200 A, etc., since all amperage needed by the home must pass through this switch. The transfer switch is needed only because the inverter's ability to pass AC current through to loads is limited by an internal relay. Even with several inverters in parallel, the pass-through capacity in most cases will fall short of the original electrical service rating needed to power all the residential loads. This bottleneck is avoided by installing a transfer switch. The grid powers the home at full amperage when available, and the transfer switch allows the battery backup system to power the home at its designed amperage until the grid returns.

The transfer switch is usually wired in between the grid output (from the meter base) and the main service panel, and also between the inverter output and main service panel. The tricky part is that only one of these sources can be used at once. In normal operation (with the grid present), the transfer switch directs power from the grid to the loads while the inverter is waiting in standby mode, ready for the grid to drop at any moment. With an automatic transfer switch, the grid presence holds the contacts closed, connecting the grid to the loads. Once the grid drops out, the contacts open, disengaging the grid and engaging the inverter output and powering the loads with the inverter and battery backup system.

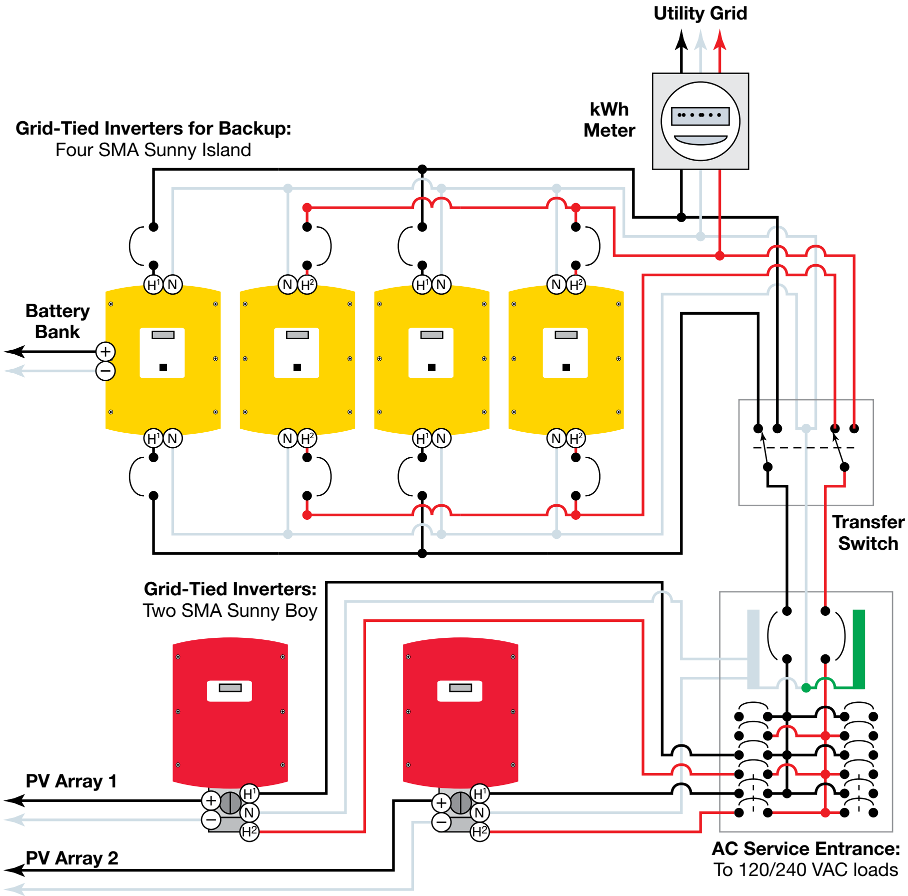
Once the grid returns, the automatic transfer switch will wait for approximately five minutes to make sure the grid has stabilized before reconnecting the loads to the grid. This type of switching is fairly quick, but not as quick as the internal relay switching found in battery backup inverters. Many loads, like computers, will be affected by the amount of time the transfer takes.

This setup takes care of the inverter output-side of our system, but we also usually need to have a grid connection to this inverter, when the grid is available, for battery charging. This connection must be made upstream of the transfer switch and can be done a few different ways. Some utilities will set a new meter base or change out the bottom lugs on the meter base to a double lug, which allows connection of four conductors into the bottom of the meter base. Two 120 VAC lines (L1 and L2) are for grid input to the transfer switch and two more can be used for the grid input to the battery-based inverter.

Another option would be to install a junction box after the meter base and splice each conductor—L1 and L2—into two sets of conductors. This is done with UL-listed, insulated splicing blocks, paying careful attention to conductor sizing. Be sure to check with your local inspector or authority having jurisdiction before implementing any of these methods—permits may be required.

The Sunny Island inverter allows you to continue using an existing batteryless grid-tied inverter(s) in conjunction with a battery backup system, and under this whole-house backup arrangement, the Sunny Boy inverters could simply backfeed breakers in the main service panel. When the grid is available, the Sunny Boys will backfeed the grid if PV production is greater than household consumption. And when the grid is down, and the transfer switch is connected to the Sunny Island system, any excess power from the PV array can be routed to the Sunny Island to charge batteries.

Whole-House Sunny Island Backup



This type of integration is commonly desired, but is very costly because of the increased equipment needs and costs involved in backing up a whole residence or commercial entity. Where one inverter may suffice to back up critical loads in a residence, it could take two, three, or more inverters paralleled together to approach the power needed for a whole-house backup system. And with more backup power comes the need for a larger battery bank—another costly proposition.

Even with large inverter banks, there are likely to be prohibitive loads like heat pumps with heat strips, electric water heaters, electric ranges/ovens, etc., that will consume huge amounts of energy from your battery bank reserve. A whole-house backup system will likely increase the system's cost by 50% or more, with most of this cost going to additional inverters and batteries. This is why most home backup systems have dedicated subpanels with only critical loads served by the super-fast internal transfer switch in the inverter. Generators are usually a more affordable solution for whole-house backup.

Systems like this are complex and should only be designed and installed by experienced industry professionals.

Flint Richter • www.rockygrove.com

Water-Heater Hydronic System

We're using a hybrid heating system (wood, passive solar, hydronic floor) to heat our new, 1,472-square-foot home. The passive solar system is working well when we have sunny days, and the efficient wood heater puts out a lot of heat, but we're still wrestling with the hydronic floor system.

Our hydronic system was designed to be open-loop and connected to our domestic hot water (DHW) tank. We've decided, however, that we'd like to isolate the space-heating and domestic water heating. (Eventually, we'll have an integrated SHW storage/water heater tank serving our DHW needs.)

An expensive electric boiler has been recommended. Since we're at the end of our budget, we're wondering if a simpler, less-expensive option would be to use a standard tank-style electric water heater. We're not concerned about our floor's "reaction time," since we don't expect it to act as a conventional furnace would. Instead, we view the floor system as more of a thermal battery. The wood heater can provide immediate heat, if needed.

We've established a well-insulated, airtight envelope. The house has high-performance windows and doors; R-30 in the walls; R-45 in the roof; and R-15 rigid foam under the slab and as perimeter insulation. Approximately half of this square footage gets some passive solar gain, which is absorbed by a 5-inch concrete slab.

We're wondering if you think the water-heater approach would work for the hydronic system. If so, how small of a tank could we get away with? Or maybe you have another idea entirely—like buying some wool slippers and sweaters—*much* cheaper options than either the boiler or water heater!

Martin & Suzie Stromm • Bend, Oregon

Many people have been heating radiant floors for years with water heaters. You are already aware of the recovery-time factor with an electric model and that is the only real drawback. In a space-heating job that uses water heaters, smaller can be an advantage when considering recovery time.

So while this is kind of a tough question, it has an easy answer—30 gallons. However, the volume of the water heater doesn't necessarily identify the heating element. Almost all residential water heaters, 30 gallons to 120 gallons, are equipped with two 240-volt, 4,500-watt elements or 4.5 kW—about half the output of the boiler your pro is recommending. The output will be 4,500 W *maximum* because water heaters have a sequencer that only allows one element (top or bottom) to be on at a time. Water heaters come smaller (6 to 20 gallons), but all except the 20-gallon units will have 120-volt elements that won't do the job. The 20-gallon ones could have either a 120- or 240-volt element like the larger models, so it may be possible that a 20-gallon model would suffice. You'd just need to check the element.

You could replace the 4.5 kW elements with 5.5 kW, which are available for some larger water heaters—a larger element would heat your home more quickly. But your home's insulation is impressive, so upgrading elements might be unnecessary. With elements readily available online at $8 to $10 each, though, it's an easy change-out later on. For either size of element, you will need a dedicated 30 A, 240 V circuit.

So, how about the water heater to serve a major part of the work—and wool slippers as backup?

Chuck Marken •
Home Power solar thermal editor

Energy Independence in the Suburbs?

Is it possible to achieve energy-independent living (off-grid) in the 'burbs? Would it be with geothermal and solar, since wind and hydro are out of the question? I'm new to this game, would like to achieve as much independence as possible, and would like an unbiased opinion.

Jason Williams • via e-mail

Certainly, energy independence is possible in the suburbs, depending on your renewable resources and your home's energy appetite. Start by paring your usage:

- Build or retrofit an energy-efficient, super-insulated home; and incorporate other strategies to minimize energy use for space heating and cooling.
- Use air-, ground-, or water-source heat pumps—excellent renewable energy devices—to supply whatever heating and cooling is needed.
- Choose very efficient appliances.
- Modify your lifestyle to maximize energy efficiency and minimize energy consumption.

Then tackle the energy-supply side with:

- Passive solar heating;
- Solar domestic hot water; and
- Solar electricity

With these energy-saving strategies, a typical home's roof can carry enough PV to power the home completely. If you ignore these strategies and run a typically energy-intensive American home, you'll be hard-pressed to make all the energy on site.

Consider the on-grid versus off-grid question separately. In most cases, being on-grid will make the most sense—economically and environmentally. It will be less costly to reach net-zero energy if you have the grid there to use for overnight and seasonal energy "storage." See "Off Or On Grid?" in *HP128* for more info.

Ian Woofenden • *Home Power* senior editor

Renewable Property

I would like to live a comfortable—but low-impact—lifestyle, and minimize my ongoing energy costs. I don't want to live in a mud hut or freeze in the dark, but I do want to reduce my environmental footprint. Would I be better off buying off-grid property or on-grid property, and what qualities I should look for in the properties I'm considering?

John Walters • Rolla, Missouri


Residential Inverter Solutions
1.8 to 7.5kW
SOLECTRIA RENEWABLES
Made in USA
Ontario FIT Content Compliant
Top Efficiency & Reliablility
96% CEC Efficiency every model
1.8 to 7.5kW inverters - 8 models available
Integrated panels available up to 15kW
50 various integrated panel combinations
Widest operating voltage window
Most web-based monitoring options
See us at Intersolar
San Francisco, CA
July 12-14, 2011
Booth 7534
www.solren.com/HP
SOLECTRIA
RENEWABLES

When you make your own energy, you can build your house anywhere—but some places are more challenging. The deep woods, for example, are apt to be shady and windless, but there might be a stream for hydro. Wind- and water-powered installations would need the most government approvals and may even require public hearings. Grid-tied photovoltaic systems have a modest amount of hurdle-jumping required by inspectors. Off-grid systems are the easiest, as far as getting permission goes. Your local renewable energy dealer will help you with a site survey.

Are you handy, or a "call a repairman when it breaks" person? If you're handy, you can select lower-priced land further back in the boonies, but you will have to devote more time to managing your off-grid energy systems. If not, you will be happier using grid-tied systems with no battery, closer to town.

Location is crucial to minimizing your energy footprint—seek a building site with good access that's not too far from where you regularly visit. Some people (relatives, plumbers) might want to visit you, too, and will appreciate easy access, so beware of bad roads.

Some off-grid land is bargain-priced because most buyers consider it too far from the nearest power lines. With renewable energy, you can ignore the power lines, but you might want to be within range of a cell phone tower, cable TV, or postal service.

If you need a mortgage, most bankers are not used to dealing with houses in the middle of nowhere. Likewise, their "ratios" might not account for putting twice the normal cash into insulation and top-grade windows.

On-grid or off, it's a major advantage to build a new, super-insulated, energy-efficient house from the ground up, compared to fixing up a charming but drafty old home. You will be able to make the foundation and floors interface with your solar heating system, and you can design the right roof angles for sun and shade in each season. Front-load your energy expenses—for example, invest in double the usual insulation now rather than higher heating costs later, and PV modules now, rather than a lifetime of electricity bills. To start to reduce your energy footprint, see the response to the previous letter. Most people can cut their present energy consumption in half with no loss of comfort.

My personal choice turned out to be the high desert Southwest. My wife and I wanted low property taxes, plenty of sunshine, clean well water, paved flat roads, relatively warm winters, and tolerable summers. We built with concrete for minimum maintenance and maximum thermal mass. No place or building style is perfect, so we made a thousand compromises. You'll find your own place based on your own values and compromises.

Every issue of *Home Power* features happy homeowners with one kind of energy system or another—whether for space or water heating, or electricity from sun, wind, or water—with or without grid-tie, and with or without battery backup. There's no right or wrong approach; just many different ways that people achieve their RE lifestyles.

Joel Chinkes • SolarGuy@PhotonHarvest.com

Radiant Retrofit

I made a big mistake when building my workshop and garage and didn't put in PEX tubing in the concrete floor for space heating. My idea is to lay PEX pipe on the shop's concrete slab and build a floating wood floor over the top, using 2 by 2s for joists and 3/4-inch plywood for flooring. I am assuming the concrete would absorb some of the heat, and heat would come through the floor. I also considered pouring

a 2-inch slab on top of PEX tubing, but wonder if the total of 6 inches of concrete would be too much mass.

I assume a couple of PV modules—like those used in domestic hot water systems—would provide enough energy to run the circulation pumps. I already have a 7.7 kW PV system for all my household electricity needs. What are your thoughts?

Ken Spence • via e-mail

Here's how to heat a small shop, based on the design process recommended by the Radiant Panel Association (RPA) and most radiant tubing manufacturers:

1. Perform a heat-loss calculation. Most radiant tubing manufacturers have this software available.

2. Determine your heating load—Btu per hour per square foot—on the available floor area. This is called your heat-flux number. Typically, a well-insulated garage or shop without a lot of glass or open garage doors falls within the range of 10 to 20 Btu per hr. per square foot on the average coldest day of the year.

3. Select a radiant floor system:

a. For your application, this could be as simple and affordable as 1/2-inch PEX tubing that's installed 8 to 9 inches on center between plywood sleepers. This is probably less expensive and easier than pouring a thin slab. Install at least 3/8-inch-thick foam insulation as a thermal break on top of the concrete. Do not use foil-bubble insulation, which conducts heat under compression.

b. A plywood-only approach may require a much higher water temperature than an aluminum plate or aluminum-coated board system (see "Water Temperature" table). With high heating loads, the water temperature differences are significant. If your heating loads are low, it may not make a big difference.

4. Choose your heating source. The simplest and least expensive method to supply your radiant heat system is a standard 4,500-watt electric water heater. Check with your local code enforcement to make sure this is allowed, and add a large label stating this water heater is for *space heating only.* A 4,500-watt element can produce about 15,000 Btu/hr. of hot water, which may be more than enough for your application—do the heat loss calculation to be sure.

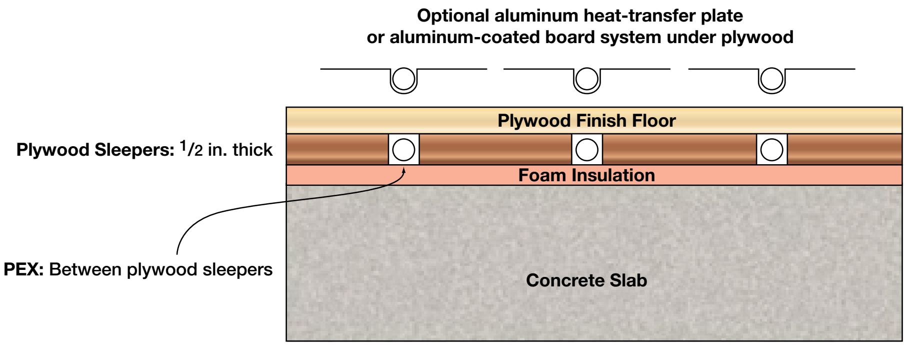
Other options, in order of least to most expensive: gas water heaters; tankless water heaters (if approved for heating);

Radiant Supply Water Temperature Required (°F)

	Btu Per Hr. Per Sq.Ft.					
Method	**10**	**15**	**20**	**25**	**30**	**35**
PEX, 9 in. on center between wood sleepers; 3/4 in. plywood above	108	122	136	150	164	178
Aluminum plate or board system; PEX, 9 in. on center; 3/4 in. plywood above	90	95	100	105	110	115

Approximate supply water temperature based on 70°F indoor temperature and 20°F drop between supply and return. Chart based on RPA Radiant II Design Manual.

Radiant Floor Retrofit Details



and electric, gas, or oil boilers. Check with local code enforcement, heating contractors, and suppliers for what may be best in your area.

5. If you decide to use a water heater, the piping is very simple. Don't forget to add a 30 PSI boiler relief valve to the system, and leave the factory-installed 150 PSI relief valve in place. In the schematic, you'll see an air scoop, expansion tank, circulation pump, water feeder with backflow preventer, and the two relief valves mentioned. Turn the power off to the water heater during the non-heating months to save energy.

If it is necessary to heat the garage side, an electric, ceiling-hung heater would be the least expensive option. Other possibilities are gas-fired, ceiling-hung garage heaters and wall-hung, direct-vent heaters. I personally do not like non-vented gas heaters since they leave the moisture of combustion in the room, which can be significant.

I hope this gives you a little more direction on your shop/garage heating project.

Bob Zima •
Certified RPA radiant heat instructor

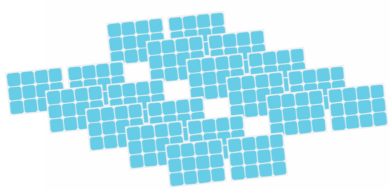
write to:

asktheexperts@homepower.com

Published letters are edited for content and length. Due to mail volume, we regret that unpublished letters may not receive a reply.

The first high voltage solar charge controller on the market!

> Introducing the Xantrex™ XW MPPT 80 600 high voltage charge controller.

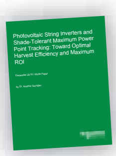


- > High input voltage up to 600V dramatically reduces wiring gauges and conduit sizes
- > Allows PV string arrays to be located far away from controller
- > Shade-tolerant Fast Sweep MPPT technology increases energy harvest
- > Can be used with positive, negative, and ungrounded arrays
- > Seamless integration with XW inverter/charger system

Schneider Electric Xantrex XW Inverter/Charger system

Schneider Electric Xantrex MPPT 80 600

Schneider Electric provides a complete range of inverters, breakers, disconnects and load centers for renewable energy solutions.



Download the FREE white paper

“String inverter shade tolerant MPPT technology”

Visit www.SEreply.com | Key Code z988w

Schneider Electric

SQUARE D by Schneider Electric

APC by Schneider Electric


SKYSTREAM 600™
by Southwest Windpower
NOT ALL PIONEERS HEAD WEST.
The pioneers of today are you and me. We possess the power to lead the way toward a new energy frontier, without ever leaving home. We're regular people. And with our personal wind turbines we're converting wind into free electricity, right from our own backyards. Wind. It's clean, renewable, and yours for the taking.
Discover the all-new, more efficient Skystream 600 wind turbine from Southwest Windpower, the global leader in personal wind energy since 1987. skystream600.com
©2011 Southwest Windpower. All rights reserved.

Architectural PV Design Considerations

Topher Donahue

by Michael Welch

Installation details and new module and racking options are making PV systems aesthetically appealing to a wider range of homeowners. Here are some options for creating great-looking systems.

Orientation

No PV array sticks out more than one that is akimbo to the roof lines. And facing an array due south when no roof surfaces point in that direction can really bring attention to the rooftop. These installations are at the root of what got PV and SHW systems banned in communities that have strict design standards.

If there are west- or east-facing roof slopes available, a PV array can be mounted there at a slightly lower cost compared to spending more money on the customized PV racks and extra labor needed for mounting a south-facing array on a roof facing another direction. The yearly energy losses of east- or west-mounting range from about 20% to 25% (assuming a tilt angle of about 45° or less)—not insignificant, but worth it to many. The losses from southeastern- or southwestern-facing arrays will only be about 10%. The savings in rack costs and labor, if used to buy a slightly larger PV array, would help mitigate the energy losses. (Note: To qualify for some incentive programs, PV systems may need to be oriented/tilted within a certain percentage of ideal, which may rule out extreme east- or west-facing orientations, but may still allow for southeastern or southwestern roof slopes.)

Michael Welch

Opposite: Frameless modules, such as these from Lumos Solar, can visually streamline PV installations.

Left: Off-camber array mounts may maximize PV production, but there are other costs, including the judgment of your neighbors.

Courtesy Namaste Solar

Right: Well-designed east- or west-facing PV arrays can make better use of roof space, with a minor reduction in production compared to south-facing arrays.

Tilt & Stand-Off

PV arrays produce more energy if their tilt is set to gather the most sunlight. For best annual energy production, that's *usually* at an angle about equal to the local latitude. (For instance, an array in Savannah, Georgia, would likely be tilted to 32°.) However, the optimum tilt for some areas is not equal to latitude—for instance, in Seattle (at 48°N), because of its cloudy winters, arrays produce more energy if their tilt is about latitude *minus* 15° (also about 32°). Because south-facing roofs are rarely sloped at the optimum angle, some arrays use mounts with longer legs at the back to place the modules at the ideal tilt for energy production. This also increases airflow to cool the PV cells. If adjustable legs are used, the experienced system owner willing to risk occasional roof-climbs can make seasonal adjustments to eke out even a few more kWh.

But arrays pitched differently than the roof pitch are subject to wind loading, and the rack and the roof that supports it have to be engineered to handle uplift forces from the wind, making the mounting system more costly. Plus, they draw attention compared to systems mounted parallel to the roof plane.

Because of these factors, most modern installations mount the array parallel to the roof, as a wide selection of racks are available. With this strategy, there is still the need for engineering calculations to determine the number of rail supports and how deep lag screws must penetrate the rafters, but the wind-loading on the building and those attachment points are significantly less. Standoffs keep the array away from the roof surface for good airflow—usually, 6 inches is adequate.

Most south-facing roofs have a slope that is at least in the ballpark of what the ideal tilt angle would be, so yearly energy output differences are marginal. For example, a roof having the common slope of 4:12 is about an 18° angle. If your home is in, say, Columbia, Missouri, the ideal tilt angle to maximize annual production would be 34°. The energy loss from mounting the array parallel to the roof plane (at 18°) versus at the ideal tilt (34°) is only about 3%.

Topher Donahue (2)

Above: Even on very low-angled roofs, PV arrays mounted parallel to the roof plane can produce a significant percentage of their potential, with a streamlined appearance.

Below: On all but the flattest roofs, tilt-up racks just add engineering complexity, installation cost, and visual obtrusiveness.

Courtesy Florian Solar

Left: This custom patio array by Florian Solar makes electricity, and provides rain and sun protection.

Below: Solar awnings serve a dual purpose—generating energy and shading windows.

Courtesy Lighthouse Solar

Awning or Patio Cover

Several array mounting methods avoid the home's rooftop altogether. The first—PV awnings—have the added advantage of providing shade. Many PV modules are about the same length as purpose-built window awnings, making them an attractive choice for shading windows on south-facing walls. Plus, using adjustable awning supports can make seasonal tilting easy—either to increase system output, or to decrease and increase shading as the season and solar gain needs dictate.

A PV awning system can be pricey, as the method may require custom engineering to match the mounts to the building attachment means, array weight, and local wind loads. Beefed-up hardware and attachment methods must handle all the cantilevered weight that tries to pull the array away from the building, and there is often increased labor involved in mounting custom systems. Assuming the awning is to be on the south side of the building, the energy produced should nearly match what a south-facing roof-mounted system would produce. The exception is when the sun's arc sweeps to the northeast or northwest, producing shade on the array by the building itself.

Another place where an array can serve two functions—producing energy while providing shade—is over a patio. Custom-designed PV patio structures are becoming more common, and some installation companies are specializing in their design. Whether this solution is practical depends upon where the patio is situated. Most patio shading structures do best if located facing south. But if on the other sides of the building, the tilt (negative on a north patio) and building shading will affect output significantly, and the array will likely be in the building's shade for significant portions of the day, especially in winter.

Solar carports can be another way to get more value out of your PV array investment. If the right spot is available, you can orient and tilt the structure for optimum solar gain and keep your cars out of the weather.

Bifacial modules, which produce power from both the back and front, can be an excellent fit for patio and carport applications. They allow some filtered light to pass through the array, providing soft lighting underneath. If a light-colored surface is used underneath, this can reflect light back to the underside of the array, helping to augment power production.

A purpose-built solar carport, optimized for both functions.

Courtesy Lighthouse Solar

On the Ground

Other alternatives to roof mounting are ground and pole mounts. These methods are usually selected when the roof is not available due to shading or orientation problems, but are a viable aesthetic choice.

These methods transfer the aesthetics issues to another area of the property, where they can be dealt with in other ways. If desired, shrubbery or decorative fencing can hide these arrays, as long as it is not close enough to cause shading problems on the modules. The *National Electrical Code* requires preventing access to the wiring of these arrays. Often, the solution is a fence—though such an access-prevention fence is likely to be too close to the array to hide it sufficiently.

With these mounts, ideal tilt and orientation are easy to set and, as long as there are no buildings or trees making shade, production can be maximized. Ground mounts and pole mounts are available in a wide range of configurations, ready to accept the modules of your choice. Some inverters can be mounted at or on the mounting structure, eliminating the need to find a spot at the home. Access to the arrays for installation, adjustment and maintenance is usually easier than on a roof—ground and pole mounts are ideal for the tinkerer who wants to adjust the array's tilt seasonally.

Trackers are also an option for properties with wide-open solar access (ideally from dusk to dawn). By keeping the array pointed at the sun all day—without human intervention—trackers help maximize energy output.

But for all of these options (ground, pole, and tracking) extra excavation and installation labor is usually required for poured and reinforced concrete footings, and for the conduit ditches to the home. And the cost of aesthetic fencing or landscaping must be considered, which will vary depending upon what is acceptable to the homeowner. So while potential energy output is equal to or even greater than a rooftop system, cost for the simplest mount and protective fencing will be more than a roof-mounted system.

Right: Pole mounts and trackers can be positioned to optimize solar exposure.

Courtesy Namaste Solar

Below: Ground mounts are unrestricted by roof size or shape.

Courtesy Lighthouse Solar

Joe Villacci

Putting a PV array on an outbuilding can preserve a home's architectural lines.

Outbuildings

Mounting a PV array on a shed, garage, or other outbuilding can keep the lines of a home aesthetically pleasing. As with ground and pole mounts, this can transfer the aesthetics issue to other areas of the property, which might be more visually isolated from the home's main viewshed. Depending upon the outbuilding site, array energy output and cost is about the same as for a roof-mounted system on the home with similar solar access, though trenching and conduit to the home might increase the system's cost. If the outbuilding is purpose-built, then the roof orientation and slope can be constructed for ideal solar access.

Rooftop Fitting

Assuming that the roof is the chosen site for an array to be mounted parallel to the roof plane, the array's size and placement can make a difference in its overall appearance. For example, centering an array on an area of unbroken roof surface looks more symmetrical than placing it to one side or the other, or segmenting it to avoid dormers, chimneys, or plumbing standpipes. If an array is significantly smaller than the roof surface, then some people feel that it looks better closer to the ridge than down by the eaves—but like all aesthetic considerations, there is a lot of personal opinion involved.

Often, homeowners want to maximize the amount of energy their systems produce, which means filling as much of the roof surface with as many PV modules as possible. Local fire codes dictate whether or not you can install modules to the roof edges, or must leave space for access around the array. Many codes require at least 3-foot setbacks at the top and to one side of the array, but these stipulations can vary. Aesthetically, hanging PV modules or rack rails over any of the edges of the roof surface can look sloppy. If there is not enough room on the roof for standard efficiency modules to produce the amount of energy desired, then one option is selecting modules with a higher conversion efficiency. Using the highest-efficiency modules can increase array cost by about 7 to 12%.

Modules come in many different sizes, but most are rectangular, with width-to-height ratios between 1:2 and $1^1/_2$:2. A variety of sizes makes it possible to more closely tailor an array to the roof space. For example, a 40- by 18-foot roof could accommodate three rows of 10 modules that each measure 39 inches wide and 59 inches tall, while allowing a 3-foot path to each side and 3 feet of access at the top. Choosing a 39- by 65-inch module (of the same wattage) means that only two 10-module rows would fit. Even if oriented in a landscape format, only 24 modules could be accommodated.

Joe Villacci

A well-designed, positioned and installed PV array can integrate well into a home's rooftop.

This overhanging array may have wind-loading problems, besides being unsightly.

Courtesy Miller Solar

Module Aesthetics

Courtesy Solar World

Black module frames, dark single-crystalline cells, and black backsheets can help a PV array blend into a dark-colored rooftop.

If you want to go all-out in attempting to match your array to the roof, there are a few options. Modules with black frames and black back-sheets meld visually with a dark-colored roofing surface. A handful of modules are available with bronze frames, which may be a good match for clay roof tiles or brown-colored shingles or metal. Verification of efficiency differences between white and black-colored components aren't available, but since black absorbs more of the sun's heat, expect a little loss in efficiency.

Another aesthetic choice is the dark, more matte-like cells found in single-crystalline modules versus the sparkly appearance of multicrystalline cells. When comparing standard single crystalline versus multicrystalline modules, the differences in energy output and cost between the two are negligible, although the efficiency gap will be between 3% and 5% when comparing multicrystalline or standard single crystalline to high-efficiency single-crystalline modules. A less common type of cell, amorphous, has its own dark, matte appearance. This type of PV technology is mostly used in building-integrated PV (BIPV) applications (see page 51), but is also available in framed and frameless modules. Amorphous modules are cheaper, but produce much less power per square foot, which means twice the surface area or more to accommodate an amorphous array as compared to a crystalline silicon array.

Topher Donahue

Frameless PV modules, like these Lumos LSX, offer a modern-looking installation.

Installation Quality

Your installer's experience, knowledge and attention to detail can make a significant difference in how a finished system looks. This includes neatly laid out or hidden conduit runs; no visible wiring; no rack rails protruding from the array edge; and making sure the array is centered in open areas and square with the roof. An experienced installer will not use unflashed L-brackets as feet, but will select the properly flashed standoffs to hold the array. A conscientious installer will also work with you through the various module choices, weighing the financial and energy costs versus benefits of all the different aesthetic approaches.

Michael Welch

Exposed wiring looks bad and is vulnerable to damage.

BIPV

Building-integrated PV is often touted as the holy grail of PV systems, as they can blend into the structure and, in some cases, replace roofing materials (such as shingles or tiles). The most commonly found BIPV products are amorphous silicon PV laminates, which fit between the ribs of standing-seam metal roofs, and PV shingles designed to replace some of the asphalt shingles on a standard roof. Another product that has gained popularity is crystalline silicon solar tiles, meant to replace flat cement tiles.

Courtesy Atlantis Solar

These products are finding acceptance in the solar housing tracts that are popping up around the country. These houses are being built to sell to the masses, and not the solar-savvy individual, so the feeling among builders is that the house must appear as "typical" as possible. For now, the products have higher cost and spotty availability—not as many are made (economy of scale) compared to standard PV modules. The products' labor costs can be higher as well, because they require additional product-specific installation training and the accompanying learning curve.

Most PV installations have plenty of airflow around the modules, which helps keep cells cooler and producing energy more efficiently. Because of restricted airflow, especially behind the cells, BIPV products tend to operate at higher temperatures, decreasing the cells' production. For example, solar tiles will produce 3% to 5% less energy than conventional roof-mounted arrays.

Courtesy BP Solar

PV roofing tiles and shingles integrate power production into the roofing material for improved aesthetics.

Amorphous silicon laminates that apply directly to standing-seam metal roofing blend in well, but require additional roofing space to achieve the same energy output as an array that uses standard crystalline modules.

Courtesy Actus Lend Lease

Some large architectural projects, like skyscrapers and other business buildings, are specifying PV technology integrated into glazing and other building features. Generally, the designer works with the manufacturer to obtain custom-produced modules—which are not available to homeowners. For more information on BIPV and other PV aesthetics, see "Residential Building-Integrated Photovoltaic Systems" in *HP130*.

Access

Michael Welch (michael.welch@homepower.com) is a senior editor for *Home Power*, and a long-time energy activist and off-gridder who is satisfied with the purely functional beauty of the solar-electric systems on his home and office.

Moore Power

by Kyra Moore

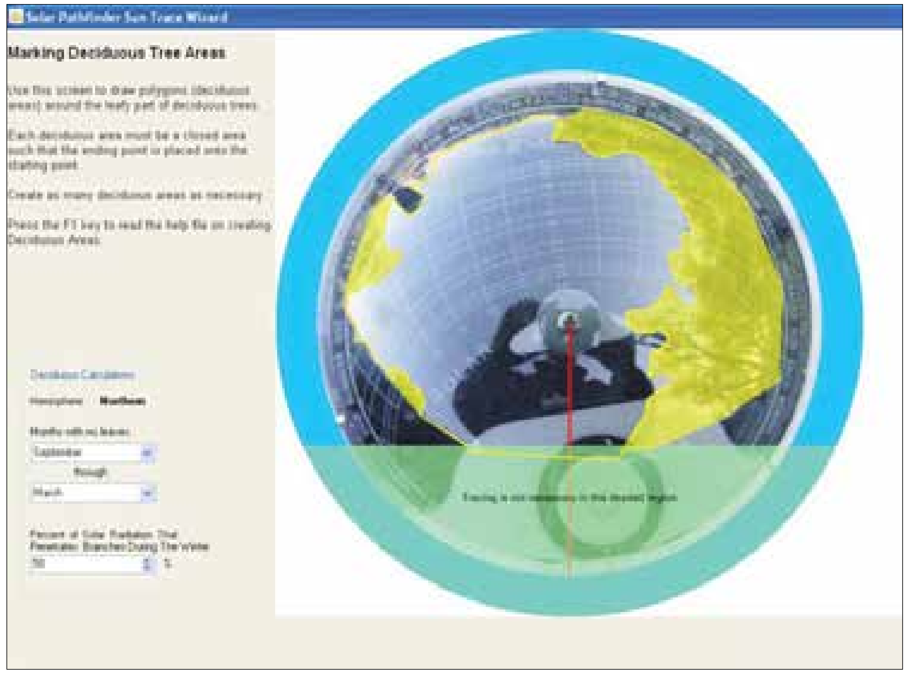
Decades before "going green" was hip, my dad, architect Jerry Moore, designed and built our house in Boulder, Colorado, using energy-efficiency principles. I didn't fully appreciate those energy-saving features until I became involved in promoting sustainability while living off-grid in Durham, North Carolina. Inspired by my experience, I attended Solar Energy International's Photovoltaic Design and Installation Course and later joined Southern Energy Management as a PV installer and designer.

I was excited when my dad called me to install a PV system on my childhood home. His decision was driven by available rebates and tax incentives, a needed roof replacement—and the discounted "family" rate for labor and materials. For the job, I gathered a powerful crew of women including two other SEI graduates and instructors: Rebekah Hren and Lauren Craig. It turned out to be an interesting installation with a few technical twists!

The completed 6.75 kW array.

Site Analysis & Interpretation

The home's 28- by 36-foot, south-facing roof was a great match for solar, with an azimuth of 15° west of south and a pitch of 33.7°. When the house was built in the 1980s, the roof had been designed for a future PV system. However, over the last 30 years, a large mountain willow on the southwest portion of the property had grown considerably. A Solar Pathfinder shade analysis revealed that the tree shaded part of the roof primarily after 3 p.m. throughout the year. We did a more sophisticated analysis by uploading photos into the Solar Pathfinder program, which allows you to precisely trace tree lines and even account for scattered sunlight through deciduous trees when the leaves have fallen. Based on the location, orientation, slope, and shading factors, the program calculated 81% of usable solar irradiation for the site.



The Solar Pathfinder software calculated the usable solar irradiation at the site. The translucent yellow shading on the photo depicts deciduous trees.

Design

Grid-tied PV system sizing is not always determined by household energy consumption. System sizes are usually limited by available roof space or budget constraints. My father's goal was to maximize generating capacity. With module efficiencies as high as 18%, SunPower's E18 series modules were a first choice, compared to others in the 13% to 15% range. Since SunPower modules are slightly shorter and slimmer than other modules of the same power rating, there was room to squeeze in an extra module per row.

With the southern roof facing the street, aesthetics were also a concern. With black cells and a black frame, the SPR 225s provided an attractive solution. In addition, the systems are offered in scalable packages, including modules, inverter, rails, and a monitoring kit. All the equipment was delivered in a convenient portable storage unit, which served as on-site material and tool storage. However, the increased performance, style, and

Lauren Craig and Kyra Moore install the PV modules.

convenience does come at a premium—$0.50 to $1.00 more per watt.

The rooftop could accommodate 30 modules, resulting in a total system size of 6.75 kW. Our rack choices were either Unirac's SolarMount or SunFrame. The SolarMount does not require as much precision, since the rails are underneath the modules. SolarMount also allows the use of grounding clips, which ground the modules to each other and to the rails, offering easier installation than using ground lugs on each module and stringing bare copper #6 wire throughout the entire array. We chose the SolarMount option for these reasons and because the flashed standoffs for the L-feet and rails could be installed by the roofing contractor. Using Unirac's installation manual and local wind and snow loads, I calculated the maximum distance to be spanned by the L-feet. With that and row placements, my dad provided the roofers with a precise layout of the standoff locations.

I chose SMA America's Sunny Boy 6000-US inverter because of the company's reputation, performance, and reliability. Inverters can be loaded from 100% to 115% of their AC rating. Due to system inefficiencies and performance under real weather conditions, the 6.75 kW array infrequently produces more than the inverter's 6,000 W AC power rating.

This Sunny Boy 6000-US inverter (bottom) has an integrated DC disconnect and integrated series string combiner. The box above the inverter is the SunPower remote monitor that's linked wirelessly to a receiver plugged into the home network router.

PV Breaker Calculations

The sum of the rated current for the solar breaker and main breaker cannot exceed 120% of the bus bar's rating (*National Electrical Code* Section 690.64):

Solar breaker + main breaker ≤ 120% bus bar rating

Note: The main breaker rating and the bus bar rating will not always be the same. Sometimes, there could be a smaller main breaker on a larger panel, which would provide more capacity.

For example, what is the maximum solar breaker allowed in a 125 A main service panel with 125 A bus bar?

Solar breaker + 125 A ≤ 1.2 × 125 A

Solar breaker ≤ 150 A - 125 A

Solar breaker ≤ 25 A

When there is not enough room for a solar breaker, there are several options:

- Replace the existing main service panel with a larger panel and main breaker, which can be expensive.
- Bypass the main panel and provide a supply-side connection into the electrical service, between the service panel and the utility meter. This requires coordination with the utility and a licensed electrician to make the connection.
- Downsize the main breaker to make room for the solar breaker. This requires a thorough load analysis of the home's circuitry to ensure that main breaker will be large enough.

See *Code Corner* in *HP135* for more information on inverter supply-side connections.

The last part of the design was the connection to the grid. The inverter specification for maximum AC output current dictates the size of the breaker needed to backfeed into the main service panel. The Sunny Boy 6000-US has a maximum continuous output current of 25 A at 240 V. For *NEC* requirements, a safety factor of 1.25 resulted in a 35 A breaker (25 A × 1.25 = 31.25 A, rounded up). However, our mains panel only had enough capacity left for 25 A (see "PV Breaker Calculations" sidebar), so instead we used a supply-side connection as the easiest and most cost-effective solution.

Installation

The home's triangular roof had a skewed edge, so instead of a ladder we used a scissor lift for worker access. (See the "Roof Safety" sidebar for other challenges and solutions.)

Attaching the feet and rails to the standoffs installed by the roofers was straightforward due to our design work. With the SolarMount system, the first module's placement is crucial. If the first module is even slightly askew, the

Roof Safety

If you can fall 6 feet or more, fall protection is required by the Occupational Safety and Health Administration (OSHA).

A personal fall-arrest system includes the anchor, rope, harness, rope grab, and lanyard. Our roofers installed three permanent anchors across the roof peak. The anchors will be handy for future system maintenance. The rope diameter must match the rope grab and be long enough to hang below the eave of the roof. Find a harness that fits comfortably. Make sure the lanyard between the harness and the rope grab is short enough so that when weight is on the rope, you can still reach the rope grab to make adjustments.

Safety Tips

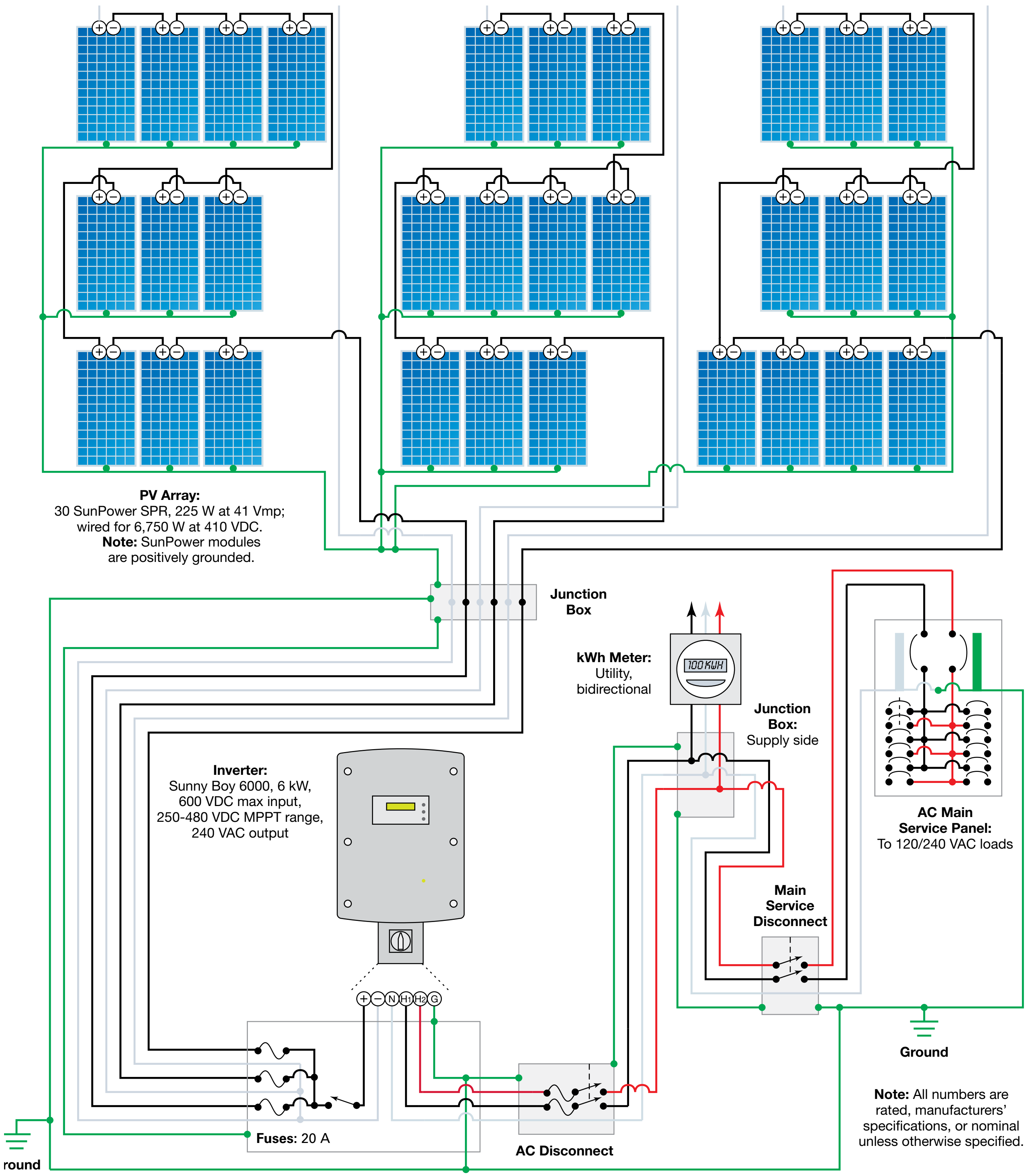
- Have a plan! Do as much of the material prep and planning as possible on the ground.
- Position anchors across the roof width to reduce the potential to swing.
- When transitioning to the roof, tie into the rope while still on the ladder.
- Take breaks.
- Wear gloves—equipment is likely to get hot while lying on the roof in the sun.
- Watch for approaching weather.
- Don't go after falling nuts and bolts.
- Use a ladder standoff for stability, and tie off ladders per OSHA requirements.
- Move your rope grab as you work to keep slack out of the rope.

For more information on OSHA safety requirements as they pertain to solar installations, go to www.osha.gov/dep/greenjobs/solar.html.

discrepancy will be magnified going down the row. I always start the installation on the bottom, so that once a row is in place, there's somewhere to rest the next row of modules.

To minimize the effects of late-afternoon shading, we wired the modules in three sections, in columns, so that there was a western, middle, and eastern string configuration. As the tree's shadow creeps onto the western part of the roof, it will take the strings out one by one. If the strings had been organized by rows, the entire array would have stopped

Kyra Moore and her father in the lift.



Moore Batteryless Grid-Tied PV System

Tech Specs

Overview

System type: Batteryless, grid-tied solar-electric

Location: Boulder, Colorado

Solar resource: 5.5 average daily peak sun-hours

Record Low Temperature: -24°F

Average High Temperature: 87°F

Average monthly production: 764 AC kWh

Utility electricity offset annually: 128%

PV System Components

Modules: 30 SunPower SPR, 225 W STC, Vmp 41 V, Imp 5.49 A, Voc 48.5 V, Isc 5.97 A

Array: Three 10-module series strings, 6,750 W STC total; each string: Vmp 410 V, Imp 5.49 A, Voc 485 V, Isc 5.87 A

Junction box: SolaDeck

Array installation: Unirac SolarMount rails installed on roof plane oriented to a 195° azimuth, 33° tilt

Inverter: SMA America Sunny Boy 6000, 6 kW rated output, 600 VDC maximum input, 250–480 VDC MPPT operating range, 240 VAC output

System performance metering: SunPower Monitoring System

producing as soon as the shadow line crossed the first column of west-most modules. This also had safety benefits by allowing us to work on one side of the roof at a time—we did not have to constantly switch anchor points for our ropes to prevent swinging.

To make the wiring transitions to the attics, I typically use SolaDeck's flashed junction box, which can be hidden underneath the array. This allows the penetration to be hidden under a module and still comply with the *NEC* article 690.34 requirement of being "rendered accessible directly or by displacement of a module." But since this wiring couldn't be located under the array due to attic access, we painted the low-profile combiner box to match the roof and positioned it 2 feet below the array to make a penetration into an accessible garage space where the inverter was located.

The SolaDeck junction box was painted to match the roof.

Since we opted for a supply-side tap for interconnection, we no longer had to make our way from the inverter to the main service panel, but rather to the outside of the house near the meter location. After coordinating with a licensed electrician and the local utility, we ran our inverter output outside to an AC fused disconnect. We then added a junction box to tap into the service lines between the meter and the home's main service panel. We installed a ground rod for grounding the module frames and inverter, and buried a copper conductor and tied it to the existing electrical service ground rod.

After making the last connections on the roof, we ordered the final inspection by the local electrical inspector. Following their approval, the utility company replaced the existing electric meter with a new bidirectional meter and officially commissioned the system for service. At last, we reinstalled the DC fuses in the inverter, engaged the DC and AC disconnects, and started producing home power!

Performance

System performance was predicted using the Solar Pathfinder software and NREL's PVWatts online calculator. PVWatts uses system size, location, historic weather data, orientation, and tilt to estimate production. You can get even more

The AC side of the system with supply-side connection. The PV AC fused disconnect is at the bottom right. The junction box (bottom left) splices the output of the PV AC disconnect to the utility lines from the meter (upper left) and to the main service disconnect (above disconnect and junction box).

Jerry Moore and his daughter (and PV installer) Kyra pose with the completed system.

precise by manipulating the calculator's derate factors. We changed the shading factor to 81% to coincide with the Solar Pathfinder's results, and inverter efficiency of 95%, which resulted in a 0.643 DC-to-AC derate factor. PVWatts predicted this system would produce about 8,020 kilowatt-hours (kWh) per year. The system's first year of production, from January 1, 2009, through January 1, 2010, was 9,175 kWh—14% more than the estimates. The system's energy production continues to exceed household energy consumption.

Access

Kyra Moore (kyra@southern-energy.com) is a 2008 graduate of SEI's women's course. She joined Southern Energy Management (SEM) as a solar technician soon after graduating. Now a NABCEP-certified solar installer, she is a commercial systems designer. Kyra also instructs classes on solar electricity for the North Carolina Solar Center.

Powerful Women

Solar Energy International (SEI) of Carbondale, Colorado, provides technical training specifically for women through its Women's Photovoltaic Design and Installation course. The course is designed to encourage more women to enter the PV industry. And it seems to be working—all of the women involved in our installation were graduates of this course who continued their education and discovered careers in renewable energy. To date, more than 600 women have participated in SEI's course.

Kyra Moore and Rebekah Hren, PV installers.

Managing Your Batteries

Heavy and expensive batteries can be the weakest link in a renewable energy system. And if you abuse them, they can wear out fast. Here's how to get the most out of your investment.

by Dan Fink

Courtesy Allan Sindelar

Take the initial cost of your battery bank, and divide by the number of years until it needs replacement. That's your annual "battery bill." If you can stretch battery life to eight or 10 years, the bill is minimal. If you ruin them in a year, that's a big bill, and you probably were not paying much attention to them. Overcharging, undercharging, and high and low temperatures can all count as "abuse."

Determining if your batteries are being used—or abused—is where battery monitoring systems come in. Professional RE installers and troubleshooters, and system owners alike, can analyze the stored data for clues as to what went wrong—or right—with a system. And battery-destroying problems, like loose connections or chronic undercharging, can be detected and nipped in the bud.

Accurately determining how full your batteries are (state of charge; SOC) is a complex problem. When you fill up your car with gasoline, all the fuel you pump into the tank stays there until you are ready to use it. Filling batteries is different—more akin to a having a small hole in the bottom of the gas tank. Batteries lose a little electrical "fuel" each day, even if unused—called "self-discharge." Plus, a portion of the energy that's pumped in never even gets stored, because battery-charging efficiency is never 100%. To further complicate matters, the faster the rate at which that stored energy is used, the smaller your tank becomes. Finally, temperature also affects battery storage capacity and longevity.

Specific Gravity

The most accurate way to determine SOC is to measure the electrolyte's specific gravity for each battery cell. In a fully charged lead-acid battery, the electrolyte is a strong mix of sulfuric acid and water; in a fully discharged battery, the mix is mostly water. A specific gravity measurement compares the electrolyte's density to that of water at the same temperature.

A hydrometer is the standard tool used for measuring specific gravity and typically costs about $30. The denser the liquid (and thus the higher the SOC), the higher the float rides. Choose a hydrometer that includes a thermometer. Colder electrolyte is denser—without temperature compensation, a hydrometer will show an inaccurately high SOC. To use the device, first put on your protective eyewear, rubber gloves, and old clothes. Then, using the bulb, fill the hydrometer full of electrolyte. Record both the number showing at the liquid level and the temperature reading. Do this for *every* cell of *every* battery in the bank, then compute the SOC for each cell.

This is a time-consuming and potentially back-breaking task, with the prospect of a mess at any moment. Thankfully, there are simpler (and more automated) solutions available for battery monitoring. But make no mistake—a good hydrometer is an essential item in any battery tool kit. It provides *the* bottom line on determining battery SOC.

A hydrometer with temperature correction is the most accurate way to determine battery cell state of charge.

Courtesy Backwoods Solar

SOC, Specific Gravity & Voltage

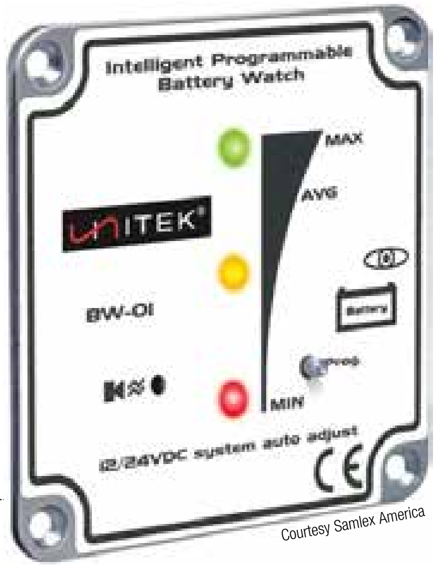
SOC (% Full)	Cell Specific Gravity (at 80°F)*	System Voltage (Nominal)		
		12 V	24 V	48 V
100	1.277	12.73	25.46	50.93
90	1.258	12.62	25.24	50.47
80	1.238	12.50	25.00	49.99
70	1.217	12.37	24.74	49.49
60	1.195	12.24	24.48	48.96
50	1.172	12.10	24.20	48.41
40	1.148	11.96	23.92	47.83
30	1.124	11.81	23.63	47.26
20	1.098	11.66	23.32	46.63
10	1.073	11.51	23.02	46.03

*To correct specific gravity readings to 80°F: Add 0.004 to readings for every 10°F above 80°F; subtract 0.004 for every 10°F below 80°F
Source: Trojan Battery Co.

Monitoring by Voltage

The simplest and cheapest way to monitor a battery bank is by simply reading its voltage with an accurate voltmeter. A variety of products are available—some show the voltage reading directly; others using a "gas gauge" format, showing voltage on a scale from "full" to "empty." Most cost less than $50.

However, this technique works only under certain conditions, and the range from empty to full covers only a short range of voltages, so accuracy is compromised. For voltage monitoring to accurately assess SOC, the battery bank must be "at rest" for at least two hours, with no energy moving in or out. A voltage reading during charging can confirm that a battery bank is full, but offers no other information. When the household is using energy from the battery, the voltage reading will be artificially low; when the battery is charging, it will be artificially high. For a PV system, checking battery voltage is best done during early morning—before loads are in use and before PV modules start sending energy to the batteries.



A simple "gas gauge"-style meter, which converts voltage to reflect a "full-to-empty" reading.

Counting Coulombs

Using specific gravity to determine SOC is messy and time-consuming, and can't easily be automated. Voltage readings are woefully inaccurate. So what's left? Coulomb counting.

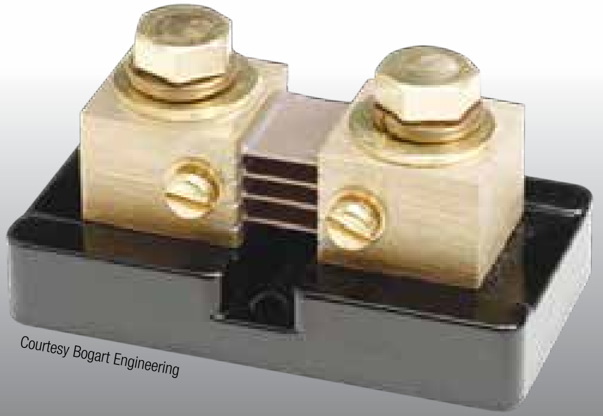
A coulomb is the amount of electric charge that is transported in 1 second by 1 amp. Devices that count and total coulombs are called amp-hour meters or watt-hour meters. A shunt—a high-power, precision resistor that is not affected by temperature—is used. The meter measures the voltage drop across the shunt and, using Ohm's law, calculates the amps and/or watts going into or out of the battery bank. The meter also tallies how long this current is moving in either direction, giving you amp-hours or watt-hours.

More sophisticated amp-hour meters may use multiple shunts, so you can separately monitor your RE energy inputs—like from a PV array and a wind turbine. Many include a battery temperature sensor, which improves accuracy.

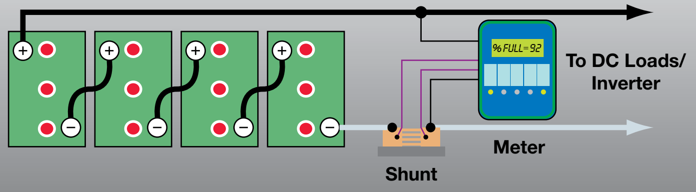
Coulomb counting is not infallible, as charging efficiency and self-discharge will both change as a battery ages. But the technique is very convenient and gives you a darned good estimation of battery SOC. Reading an amp-hour meter is so easy that anyone can learn to do it, and then start the backup generator before the SOC is low enough to cause battery damage.

Amp-hour meters are generally set up to display a simple "percent of full" reading, but they store much more data. When set to show amp-hours, the meter reads "0" when the batteries are full. As energy is used from the battery bank, the meter counts down in negative numbers; as the bank is charged, it counts up. A positive number indicates incoming energy that was not stored because the batteries were already full. Even the most basic of these meters stores some historical data, like the maximum depth of discharge since the last reset and the number of hours the battery bank was under a certain set critical voltage. This data can be used to troubleshoot a system or watch for problems.

A shunt is a precision resistor that provides accurate voltage drop measurements by which amperage is calculated.



Always wire your meter's shunt into the negative side of your battery bank.



Meter Choices

There are a variety of options available with amp-hour meters, including their ability to read multiple shunts, and their capability for having remote displays, data storage, computer interfaces, and even Internet monitoring via smartphones or websites.

Internal meters. If your battery-backup grid-tied PV system is simple, your battery monitor will be simple, too. Stored energy from your batteries is used only during a utility outage, and grid energy is usually used to quickly charge them again after power is restored. Some newer battery-based grid-tied inverters already have their own metering for the battery bank, which you can monitor through the system status display and built-in computer interface.

System-integrated meters. Many newer inverters and charge controllers can be networked together using special hubs and routers for monitoring. Battery monitors can be easily added to that network, so that all of the data from every device can be read on the system status display. This puts the entire system's performance at your fingertips. Even wireless links to the monitor are possible.

In some cases, you'll have to purchase extra equipment, like hubs and displays, for this networking capability. Also, the communications protocols used by equipment manufacturers are proprietary, so if your inverter, charge controller, and battery monitor are made by different companies, you'll need a laptop computer to integrate the data.

Stand-alone meters. These include the original amp-hour meters, and are the most versatile. No matter what sort of system you have, what resources provide your energy, or who designed your power system how long ago, you can monitor your battery bank with a stand-alone meter, and there are models that can monitor multiple shunts for more detailed data.

Courtesy OutBack Power Systems

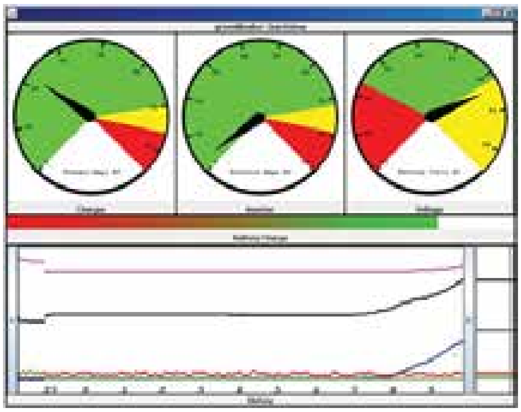
This system-integrated meter feeds the battery SOC data to the network monitor (below left).

The OutBack Mate 3, a system-integrated monitor, keeps tabs on the whole system, including battery SOC from the FlEXnetDC, above right.

Courtesy OutBack Power Systems

A multifeatured stand-alone meter.

Courtesy Bogart Engineering


Courtesy www.greenhousepc.com

Example of a real-time system monitor display that can be accessed and read online.

Display Choices

Stand-alone meters can be mounted some distance from the shunt in a convenient and easily visible place for viewing the display. Integrated and internal meters may have a simple display at the unit, with the rest of the details available through the remote monitor display.

Even the simplest and least expensive of modern amp-hour meters have serial data output, and the more advanced models make it easy for you to connect the system to your PC. You'll need a PC interface and software from the meter manufacturer. Note that to collect detailed historical data, a computer that's running all the time is required. Some enthusiasts use an old laptop that's been retired from daily use just for these logging operations. You can watch your system performance live with a "dashboard" application, analyze your data with a spreadsheet, or even send data to your website or smartphone.

Some system monitors are designed to communicate directly with your home computer network, either through a LAN cable or by wireless. For this data communication, your Internet service and/or routers must be powered on, but your PC doesn't have to be running. Unless you are a computer programmer, you'll also need to subscribe to an Internet system monitoring service (which in some cases is free) to establish a secure site to log into your meter, and a way to build monitoring "widgets" to insert into your website or blog.

Your Internet service must include a static IP address to use any of these web-monitoring features, and that may cost extra. With some satellite Internet services, putting a system monitor online may not be allowed—be sure to check with your Internet provider first.

Installation & Setup

Amp-hour meters are easy to install, but be sure to follow the manufacturer's instructions. Before you start, shut down your *entire* power system using the main DC disconnect. Turn off the PV array breaker and disconnect the battery output cabling in the battery box. You'll need to find a good location for the shunt, keeping in mind that all energy moving into or out of the battery bank must pass through it on the main negative wire. A good location is inside the inverter power panel; many panels have spaces reserved near the main negative buss just for this purpose. You'll need a short cable with lugs on both ends that's the same wire gauge as your battery output cable (since this is part of the negative-side circuit pathway to/from the battery bank).

Next, mount the display panel in a convenient and visible location, and run the cable from the shunt to it. Most displays mount in standard electrical boxes. The cable used is a special multiwire, shielded, twisted-pair bundle that should be purchased directly from the meter manufacturer to make sure it is the right type. If you are installing a system-integrated meter, things are even easier—the special cable from shunt to monitor box will be short, and then you simply plug the monitor into the system network hub with a LAN cable or wireless-to-LAN interface.

After meter installation and powering up your system, your new meter will need to be programmed with your battery bank's amp-hour capacity, the system voltage, and the voltage level at which your charge controller considers the batteries to be full. Then, you must charge the battery bank to full capacity, usually with a generator, until that "full" voltage level is reached. At that point, your meter takes over, and you are in the monitoring business!

A simple amp-hour meter and shunt costs about $200—a small price to pay considering the total cost of an entire renewable energy system and the relatively fragile nature of its battery bank. If you monitor your battery bank regularly and react accordingly, you can extend its life by many years before replacement is needed.

Access

Author and educator Dan Fink (danfink@buckville.com) has lived 11 miles off the grid in the northern Colorado mountains since 1991. He teaches classes 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.*

Battery Monitors:

Bogart Engineering • www.bogartengineering.com • Amp-hour meters

Samlex • www.samlex.com • Unitek Batteryguard

Xantrex • www.xantrex.com • Amp-hour meters

System-Integrated Amp-Hour Meters:

APRS World • www.aprsworld.com

Magnum Energy • www.magnumenergy.com

OutBack Power Systems • www.outbackpower.com

Schneider Electric • www.schneider-electric.com

SMA America • www.sma-america.com

Data Acquisition, Networking & Internet monitoring:

APRS World • www.aprsworld.com

Atkinson Electronics • www.atkinsonelectronics.com

greenHouse Computers • www.greenhousepc.com

WattMetrics • www.wattmetrics.com


ET Solar brought you "Back to Black" last year.
Now we bring you Zero-Rack.
ET Zero-Rack Series modules are Zep Compatible.
Learn more by visiting our website or our booth at PV America.

Easy Efficiency Improvements

PAY OFF

by Tom Harrison

All photos courtesy Infrared Diagnostics

My family's house in Newton, Massachusetts, is a standard family home, but by making incremental improvements in air sealing, insulation, and lighting—and with the help of a whole-house electricity monitor—we have been able to reduce energy consumption more than 50%. A $1,175 investment is saving us about $1,000 per year in energy costs, and has made our home much warmer and more comfortable.

Last May, Flemming Lund of Infrared Diagnostics in Sudbury, Massachusetts, performed an energy audit for us. The results weren't entirely surprising; I didn't expect our aging suburban home to be completely leak-free and perfectly insulated. Nonetheless, the energy audit was extremely useful in pointing out several high return-on-investment steps that we could take to increase our home's energy efficiency.

But the audit was just a stepping stone; the next step was vital: I got down to it. I installed blown-in cellulose insulation in areas where it was deficient, sealed cracks and gaps, replaced old weather-stripping, and then had a follow-up audit to assess progress.

The photos are from the two audits, and show just how much of a difference the work had made. Although Flemming calibrated the infrared camera to account for temperature differences between the two audits, the outside temperature during the first audit was 50°F and 38°F during the second. The before-and-after results are pretty evident, nevertheless.

Loose-fill insulation was all installed by hired contractors, as was much of the air-sealing work. However, I made many of the most significant improvements myself—looking back over the initial audit report, I simply retraced the steps on a cold day, found air leaks by hand (literally) and sealed them with a caulking gun.

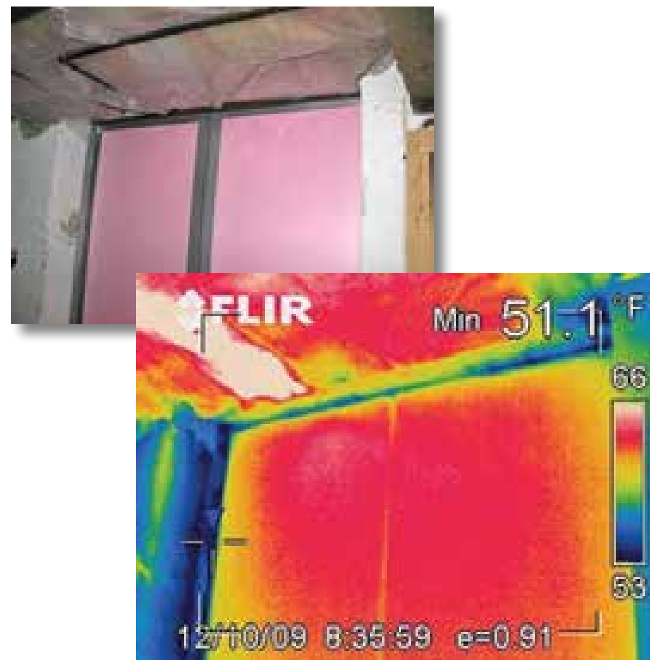
Although the follow-up audit pointed out some problems missed during the upgrade, as well as some new ones that were overlooked during the first audit, it was confirmed that much progress had been made.

Air Sealing...

Aside from the awesome infrared images of improved insulation, perhaps the most valuable information from my follow-up audit was that these simple air-sealing measures more than halved air infiltration, from 0.87 natural air changes per hour (NACH) during the heating season to 0.42 NACH.

The benefits of my air-sealing work confirmed my long-held belief that air sealing should be the first step in improving a home's energy efficiency. It's cheaper and easier than an insulation upgrade, and helps prevent air from moving through insulation, losing R-value. It also shows that hiring a contractor to do the job may not be the right course—much of the benefit came from the simple things I did.

BEFORE: **This image of the bulkhead door leading out of the basement shows how air was leaking around it. Flemming recommended I install an insulated door at the base of the stairs, which seemed an expensive fix for such a seldom-used location.**



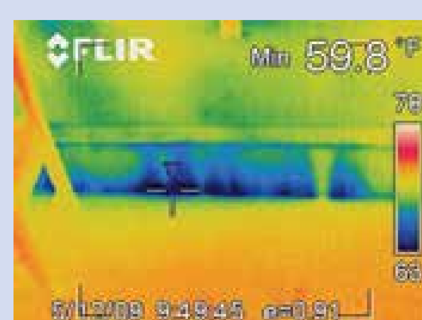
AFTER: **Instead, I installed foam board at the entrance to the stairs. The follow-up audit showed that air was leaking around the duct tape I had sealed it with, so I have since sealed it with spray foam—one example of the value of a second audit.**

What is Thermal Imaging?

While not necessarily part of a professional energy audit, some technicians use thermal imaging to detect heat "leaks" in a home's envelope. Thermal leaks can occur in areas that are poorly insulated, allowing heat to move more easily, or be caused by air leaks (drafts), which allow cold air in or warm air out.

Thermal imaging cameras convert the heat in the infrared wavelength into a visible light display. The spectrum and amount of thermal radiation depend primarily on an object's surface temperature. Warmer objects appear red, and cooler objects appear blue and black. From inside the home, a technician can pinpoint cold spots where interior heat is escaping or cold air is infiltrating.

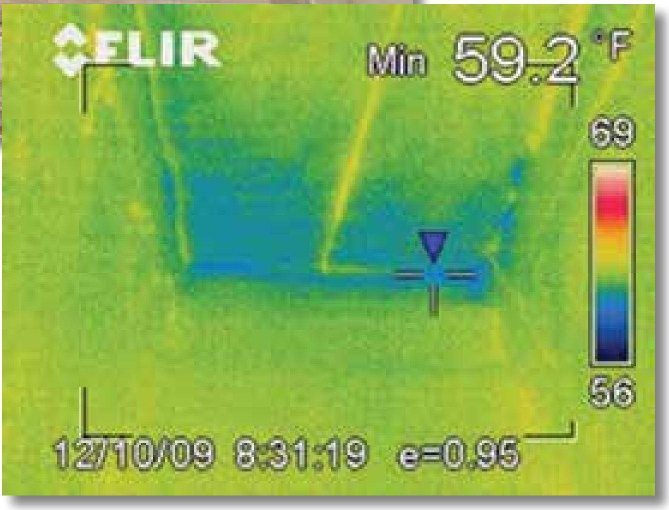
This baseboard looks harmless enough, but because it hides a seam between building materials, it was a prime spot for air infiltration.

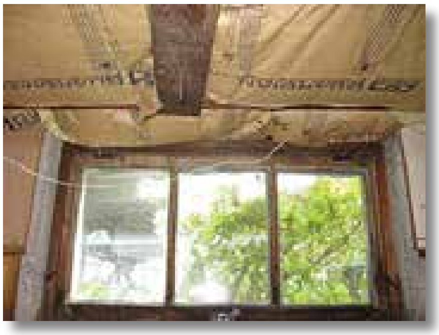


The thermal image shows cold air passing from underneath the baseboard (dark blue and black) into the living space. The solution was a bead of clear silicone caulk.

BEFORE: The entrance to our attic was left open, other than a rickety interior door on the bottom of the stairs. Warm air was rising to escape into the uninsulated attic.

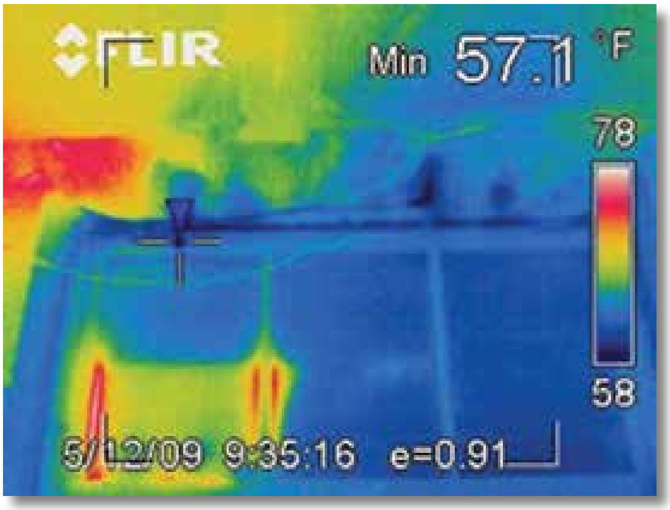
AFTER: We fixed this problem by installing foam board over the attic entrance and sealing it tight.

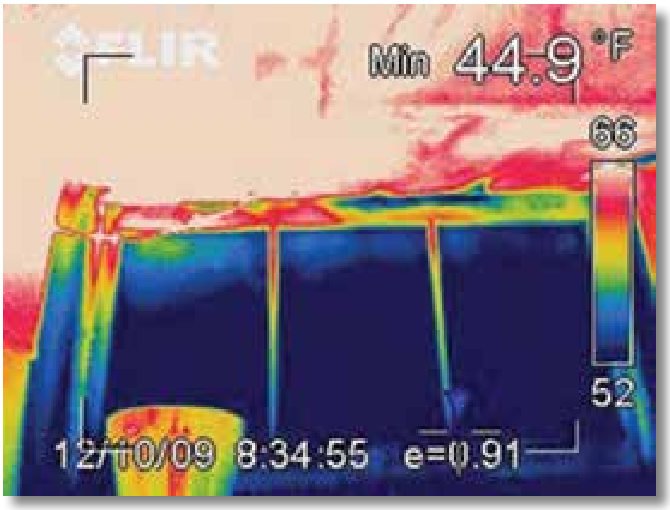




BEFORE: This basement window was a disaster. Flemming recommended replacing it with a new, energy-efficient window, which would have been expensive. Saving that for a later date, I took note that the biggest problem was with air infiltration (shown as dark blue in the photo) and attacked that first.

AFTER: Since the biggest problem was not with the insulating value of the window itself, but with the air leakage around the frame, I inexpensively caulked around the wood frame. Inside heat still permeates the glass, but the air infiltration problem is largely eradicated (notice the warm areas around the window frame).





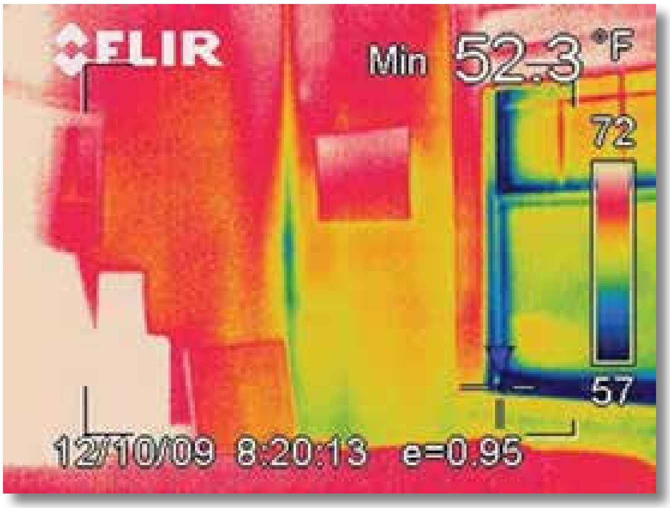
BEFORE: There was serious air leakage coming through the small gap along the rim joist.

AFTER: Sealing the rim joist with closed-cell foam stopped air infiltration, and added insulation to the poorly insulating wood.

Insulation...

Once sealing is done, improving insulation can add to the benefit by helping your house retain heat.

After insulating, we noticed that there are no more cold spots on the walls that create uncomfortable areas in the house. Our upgraded insulation and air sealing made the house more comfortable, easier to heat up in the morning when the programmable thermostat kicks on, and our utility bills much lower.

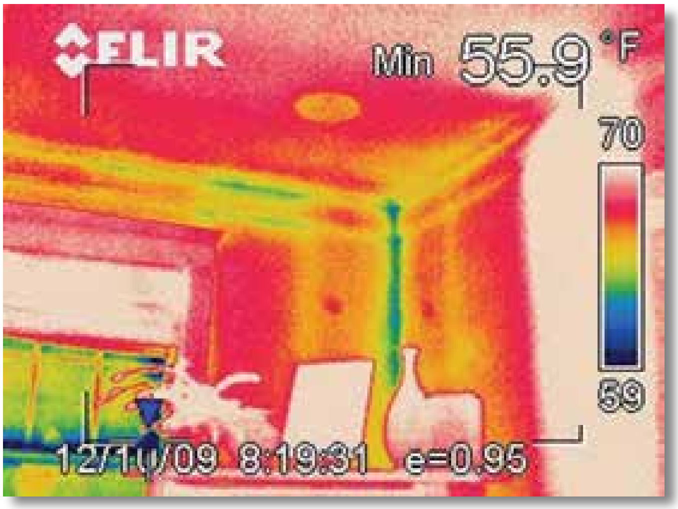


BEFORE: This blue wall reveals one place where our house lacked insulation. It was improperly installed to begin with and it needed fixing.

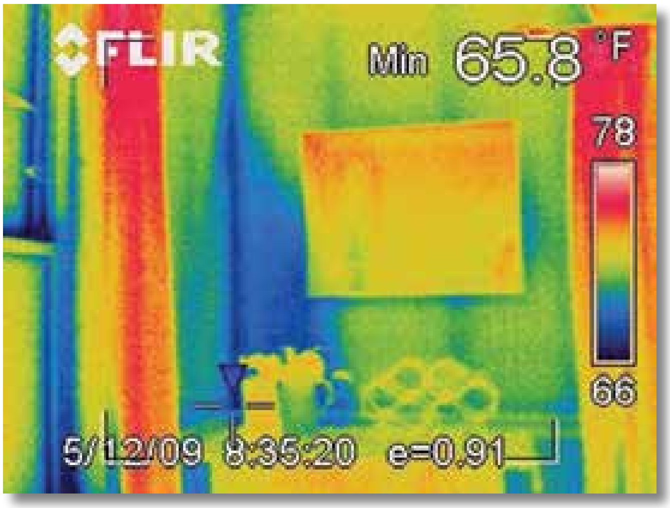
AFTER: Where the insulation was inadequate, we had insulation blown in from the exterior. The result is a warmer, more comfortable house—and lower heating bills.

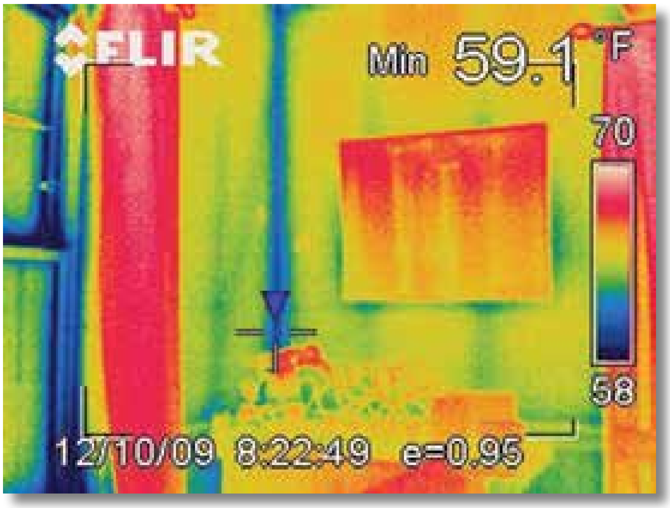
BEFORE: Our 1920s-era, board-sheathed, platform-framed house required wind braces—diagonal studs installed at every corner that prevent the house from shifting. This diagonal member bisected the stud bay at the corners of the house. Care hadn't been taken to completely fill the bays with loose-fill cellulose insulation, as evidenced by the infrared images.

AFTER: A much more comfortable living room, after loose-fill insulation had been blown in from the exterior.



BEFORE: The insulation in this corner was poorly installed as well. Notice the dark blue line at the seam of the walls, where a small gap between framing studs was left unsealed, letting in cold air.



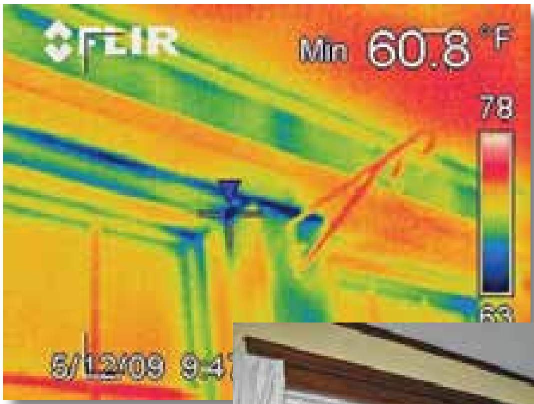


AFTER: The insulation problem is largely fixed. The air-sealing problem, which could have been prevented during construction with a little caulking, can only be fixed if we were to remove the drywall—a major undertaking. We'll have to make do.

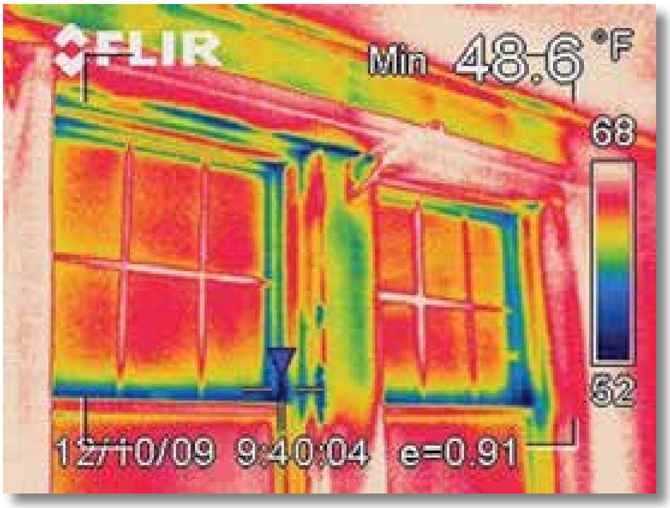
Lessons Learned...

Having taken these steps, we came to realize that there is no silver bullet: Improving the energy efficiency of our house is an ongoing process, and there is still much to be done.

Although the follow-up audit pointed out some problems missed during the upgrade, as well as some new ones that were overlooked during the first audit, it was confirmed that much progress had been made.

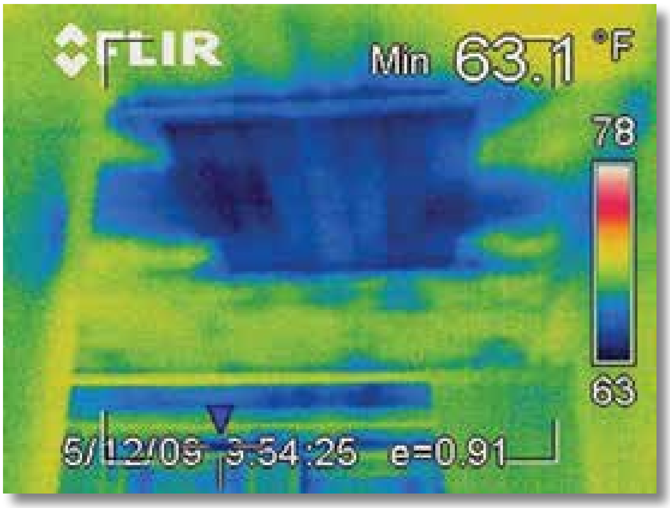


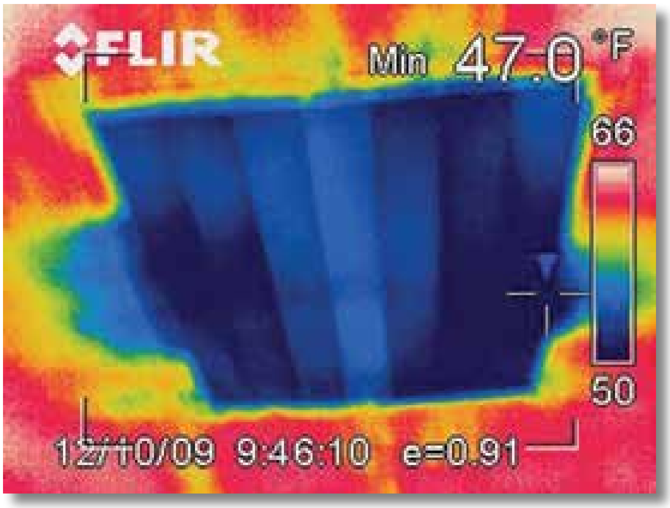
BEFORE: Flemming cited insufficient air sealing during window installation, which accounted for the leakage around this dining room window. He recommended caulking around both the exterior and interior sides of the window.



AFTER: Although I caulked around the window frame, the follow-up audit showed only a small improvement. I have since fixed the problem by filling the old sash-weight cavity with spray-foam insulation.

BEFORE: Another problem was our whole-house fan. Fantastic as it was at cooling the house in the summer, it had an insufficient cover. In the winter, warm air could sneak past it into the attic.





AFTER: I added what I thought to be a quality insulated cover to the fan, only to find out during the follow-up energy audit that the air sealing around the cover was insufficient. I have since tightened the seal with weather-stripping, but it demonstrates the value of a follow-up audit.

Payback Time...

My gas utility, National Grid, had a rebate program that paid 75% of the cost of the air sealing and insulation, which made something of a difference. But the savings are staggering: Before improvements, we paid $168 per month ($2,016 per year) for space and water heating, and cooking. We now pay $89 per month ($1,068 per year), which means we save almost $1,000 per year as a result of our minimal investment.

Weatherization Costs

Item	Cost
Audit	$400
Follow-up audit	200
Insulation	475
Air-sealing materials	100
Total	$1,175
Less Utility Rebate	-$431
Grand Total	$744

Access

Tom Harrison was turning his thermostat down as a teenager in the first energy crisis, and comes from a family whose motto is "waste not, want not." His blog, "Five Percent: Conserve Energy" (www.fivepercent.us), details his family's efforts to conserve energy. He is the chief technology officer at Energy Circle.

This article was adapted from Energy Circle (www.energycircle.com), where you can learn more about residential energy saving, home insulation, and air-sealing.

affordable solar
4840

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

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

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

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

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

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

SPECIFICATIONS RE L16 / 6-VOLT

AMP HOURS (100hr.rate)	441
AMP HOURS (20hr.rate)	401
AMP HOURS (5hr.rate)	332
MINUTES (@ 75 AMPS)	245
MINUTES (@ 25 AMPS)	915
LENGTH	11-7/8" (302mm)
WIDTH	7-1/8" (181mm)
HEIGHT	16-3/4" (425mm)

U.S.Battery Manufacturing Company

SEPA

RE SERIES

1-800-695-0945 WWW.USBATTERY.COM

PV Rack Strategies

by Greg McPheeters & Tim Vaughn

All photos courtesy REC Solar

THE PROS can make mounting modules to rooftops look easy, but a lot goes into making that array look like a million bucks on your home's roof. Here, we look at what makes a rooftop installation go smoothly and quickly, ensuring years of trouble-free energy production—with no leaks.

Getting the Details

Roof type is a major determinant in the installation hardware required. Composition shingle roofs are most prevalent, but certain regions, such as California and the Southwest, have lots of other roof types, like tile, that are more challenging to work with. Make sure you consider the roof type when choosing your attachment methods.

Most systems on the market offer flashing for penetration points—which is always advisable for any region. You'll sleep better at night knowing you installed flashings over all of those bolt holes in the roof.

Rafters typically run up-slope, but not always! Installation tends to be easiest if your rails run perpendicular to the rafters. Crawl into the attic to check, and pay close attention to how rafters are arranged—their size and spacing. In particular, look for any discrepancies in the spacing pattern. Lighter-duty roof construction (typically 2 by 4s at 24 inches on center or greater) will be more susceptible to point-loading issues, particularly in regions with snow-loading requirements, where there will be substantial limits on the spacing of mounting points (increasing their quantity).

Some jurisdictions require rafter attachments to be staggered. For example, for a pair of rails in a single row of an array, attachment points would have to alternate rafters to more evenly distribute the loading on the building. This also increases the quantity of attachment points due to the unavoidable duplication of attachments at the ends of rows.

In snowy regions, it may be wise to install snow fences or guards. Arrays that are installed over doors or walkways are prime candidates to create dangerous snowfall conditions below the array. Leaving room for a snow fence or guard may also affect your layout.

Wiring runs and electrical component placement should be considered when you're designing your initial layout. Take note of where you will mount any J-boxes and how you will route conduit from the roof. Some rack systems have channels built into the rails for easy wire management, facilitating an easier installation.

Grounding can be simplified with products like Wiley Electronics' WEEB or the rack manufacturer's own version of these grounding washers. These can save time and cost over using copper wire and lugs for grounding on each module. However, these products are not accepted by all jurisdictions. Check into these details before committing to a grounding strategy, since some jurisdictions will only approve grounding solutions that are listed as approved in the manufacturer's documentation.

Array height is variable with most rack systems. As a general rule, systems that are closer to the roof can be more aesthetically appealing, but more distance under the array assures better airflow and higher efficiency, since the cells are cooler. Having the module glass 6 to 8 inches above the roof surface is typical and offers a good balance of aesthetics and system performance.

Maintenance and code requirements must be followed carefully. To ensure firefighter safety, more jurisdictions are restricting installations close to roof edges and ridges, or requiring access pathways on larger arrays and installations. In some cases, access will be required or desired for other reasons, such as roof equipment or skylights. While these details can be frustrating to accommodate, they are much more easily accounted for early on in the process, *before* installation.

Complex roof angles, obstructions, and shading all affect options for array position. (Note the screen under the array to keep out varmints.)

There is a wide offering of rack systems on the market, with various advantages to each. This article considers rail-mounting systems only. The industry standard, they are easy to install and level, and are the most versatile in accommodating the majority of modules on the market.

Roof Layout

Grease pens or chalk are great for marking the roof—they are cheap, visible, and temporary. Chalk the basic layout, starting with the outline of the array from your system design, marking corners. Also mark your rail lines under the modules with a different color to avoid confusion. With the system drawn on the roof, you can begin to identify mounting points where rails or structural members will intersect with rafters.

Above: Laying out the array and rail position with a chalkline and tape measure.

Left: Finding rafter position by tapping with a hammer. This is an acquired skill that professional installers quickly master.

Right: Drilling a pilot hole to verify rafter position. If the drill punches through after going in less than an inch, you didn't hit a rafter. Size your pilot hole to match the necessary hole size for your lag bolts (1/8 in. is common).

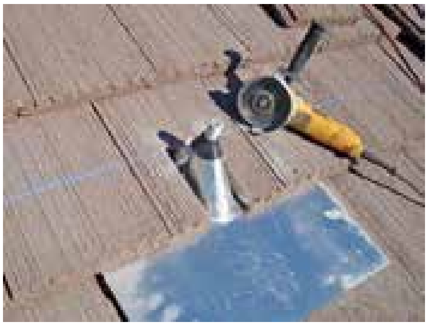
Opposite: Advance planning, accurate measuring, a good eye, and an extra pair of hands all contribute to a successful PV array installation.

Leveling mounting rails with a string line.

Finding Rafters

Take a second look in the attic, then look under the eaves. If the eaves are open, you can see the rafters and note their alignment along one roof edge. Skylights, vents, chimneys, and ridges offer good clues to rafter location, especially if you were able to verify from inside the attic. Mark your estimated rafter locations on the roof near where you expect your rails to be running.

Make your best guess in locating an intersecting rail and rafter, then remove roofing material from there if necessary (for tiles or shakes) and look for clues of rafters in the underlayment. A hammer remains one of the best tools for finding rafters. Lightly tap on the roof, moving side to side along a rail line, and listen for where it sounds most solid, usually indicating the rafter location.



Top: On tile roofs, locating mounting-foot positions becomes trickier. Tile roofs are among the most challenging roof types to work with. Here, the tiles are pried up to allow a tile to be removed in the region where the rafter is believed to be running.

Second: Once the tile is removed and you've confirmed your best bet for rafter location, it's time to probe with a drill to verify.

Third: After a rafter is verified, you can mount the roof attachment hardware (in this case, a standoff) with a lag screw. Even with flashed attachments, roof sealant is used underneath the standoff.

Bottom: Finish the weatherproofing of the standoff by sliding flashing over it. Some installers take the extra step of trimming the tiles to fit back in tightly around the standoff, which is quick and easy with a cutting wheel, shown here.

Probe the spot on the roof with a long pilot drill bit (usually a 1/8-inch-diameter bit). Since you know the rafter depth, you know when to stop drilling—you do not want your drill bit to punch through, especially if a finished ceiling is directly on the back of the rafters.

If your drill bit punches through after an inch or less, you didn't hit a rafter. Seal that hole immediately with an appropriate roof sealant. If you take your eye off of it, you may forget to seal it later. Continue to work with the pilot drill until you are certain you have located a rafter. You can use your first verified rafter as a guide to locating the next rafter, and so on. However, you'll still need to probe each assumed rafter location to make sure.

Install your rack hardware and torque your lag screw—if the lag continues to spin when tightening, it did not hit the rafter (this is often called a "spinner"). Pull the screw out, seal up the hole and try again. When installing lag screws directly to wood, it is important to hit the rafter as close to its center as possible. It is also important to drill the specified size of pilot hole for the lag you are using. If the hole is too small, you risk cracking or splitting the rafter. If it's too large, the screw threads won't bite as well as they should. The length of the lag should be determined by roof sheathing and decking layer thickness, wood type, the number of attachment points, and required pullout strength. There is a minimum embedding of the lag screw into the structural members, with 2 to 2.5 inches being a common requirement. Refer to the manufacturer's specifications for minimum lag screw embedment requirements or consult a structural engineer if you are working with something atypical.

Other Tricks. In some cases, it can be helpful to drill from the underside of the roof with a long pilot drill. Be very careful doing this—coordinate with others on the roof! Electronic stud finders are a viable option, but tend to be expensive and aren't always accurate.

Once you have your mounting points installed and the roof all back together, you're ready to add the mounting rails. Attach them to the mounting points, but leave them loose and don't worry about placing modules yet. Be sure to keep an extra rail or two and/or some string line around for the leveling process.

Squaring Up the Rack

Take the time to level your array, or more accurately, to make sure the array lies in a single, uniform plane. Otherwise, irregularities will be quite visible from the ground. A rack system that has built-in leveling features is easiest to adjust. Railless systems, while often cheaper, can add substantial complexity (time) to the leveling due to not having long, straight rails to work with. Keep this in mind when considering these systems for your project. Rail systems are quicker and easier to level due to the rigidity of the rails and being able to level the rack structure before modules are installed.

Most systems require some rail splices. Consider the array's expansion and contraction—improperly spaced splices can stress mounting points, which can lead to roof leaks (particularly if the system is not flashed) or even total failure. Follow manufacturer guidelines for gapping splices—a minimum gap of about 1/8 inch is typical, depending on local temperature ranges at your site and the lengths of rails used.

Installing & Squaring the Modules

Roofs are rarely square. As you install modules, focus on getting them square to the lines of the structure that will be most visible from the ground. Minor discrepancies in rail alignment relative to module alignment are difficult to spot, but modules that are not aligned to the structure will be very visible.

Don't assume that your modules are square; they often aren't. Sometimes, the process of handling them from ground to roof can affect the alignment of the frames on the glass. To create the best-looking array, a common practice is to start with the bottom row of modules, since the alignment to the bottom roof edge is most visible. A string line can help with the initial line of this bottom row and will help you identify module "creep"—when the first module in a row is installed off square from the line of the structure. Creep is often hard to spot until you are three or four modules down the row, requiring you to make multiple adjustments to correct the alignment.

BASIC LEVELING

- Install rails onto the mounting points, but leave the rail hardware loose to allow them to rest low on their mounting points.
- Line up the top and bottom rails in the middle of their height-adjustment range. Get down low and sight across them to ensure they are in the same plane and to avoid "potato chipping" of the array. Take time to get these top and bottom rails straight and in the same plane, and the rest of the layout will proceed more easily.
- Run a string line between the top and bottom rails or use a spare rail to line up the rails between and tighten them to their mounting points. If the middle area of the roof has a significant sag or upward bow, you may need to raise or lower the top and bottom rails to get everything to line up within their ranges of adjustment.
- Once you think you have everything lined up, check again to make sure everything is in the same plane—be sure to check from both ends of the array. It is often helpful to view the rails from the ground to see how the rails are lining up.
- Roofs aren't necessarily level to begin with, so using a level may not be helpful. If you want the array to look good, it's more important that it match the lines of the roof.
- When you are done, check the torque on *every* fastener on the roof. Tightening the bolts and nuts to manufacturer specifications is critical to a secure and safe installation. Many of these fasteners will be inaccessible once modules are installed.

Above: Sighting along the edge is often enough to align PV modules accurately.

While two rails might each be straight, they may not lie on the same plane. This can result in an unsightly twist, commonly called "potato chipping." This is easily avoided by visually checking rail alignment during the leveling process.

It's often easiest to wire and ground PV modules as you go. Accessing the backs of modules after a full array is installed may be difficult.

This rack allows array wires to be tucked into channels within the mounting rail. This provides protection to the wires and a neat installation.

BOLT TIGHTENING

Many installers use battery-powered impact drivers for rooftop installations. Impact wrenches are typically rated for torques of 10 to 100 times the torque ratings for bolts in your system. Use an appropriate driver that prevents overtightening and always check bolts with a torque wrench. Consider marking bolts with a paint pen once they have been torqued for the last time as a confirmation method. Refer to manufacturer specs for bolt torque specifications.

While string lines can be very useful and helpful, they also tend to blow in the wind and sag if they aren't tight. Most module frames have square edges, which make line of sight an excellent way to confirm alignment. Once a module is roughly in place, one person can sight down the row or string line to position the module, and the other can tighten the hardware.

It is easiest to install and secure module wiring as the installation is progressing. If your rack system has channels for running module leads, put the leads into the rails as you go. If you are using standard lugs and copper wire for grounding, installing as you go will allow you to mount this hardware to the bottom of the modules so that they are hidden under the array.

When you are finished with module installation, double-check all bolt torques. With the modules fully installed, the rails can be trimmed to length. A reciprocating or band saw makes the best cuts. Be careful that you don't cut into the roof!

Icing the Cake

Several rail systems offer rail end-caps to spruce up the installation. Some manufacturers offer module end-clamps, which allow the rails to be cut flush with the array's edge. Most of these clamps have the added benefit of being "one size fits all," working with a variety of module types so long as they have an underside lip on the module frame to clamp to the rail. Finally, to critter-proof your array, consider installing screening around the edges. Racking manufacturers are just beginning to offer simple solutions for this pesky problem.

WORKER SAFETY

A reputable installation company must have a robust safety plan and set of procedures in place. But if you are a DIYer, following some basic safety procedures will help keep you safe during your installation:

- Never work alone.
- Always tie off ladders. Never place them in front of doors or walkways, and never place the feet in soft soil.
- Going up a ladder carrying something in one hand is extremely dangerous. Consider alternative methods, such as a mechanical lift, to get rails, modules, hardware, and tools on the roof.
- Keep off roofs in wet or icy conditions.
- Use a fall protection system if you can fall 6 feet or more from a surface.
- Note location of skylights and roof vents to avoid fall or trip hazards.

The Occupational Safety and Health Administration (OSHA) publishes safety requirements and best practices for solar installations at www.osha.gov/dep/greenjobs/solar.html. Most states have their own specific OSHA requirements, as well.

Some rack manufacturers provide end caps for rails and module clips that attach to the rail underneath the module, so rail ends are flush with the array.

Access

Greg McPheeters (gmcpheeters@snapnrack.com) has been designing solar-electric systems and PV mounting solutions since 2001. Greg is the lead design engineer and innovator for SnapNrack Inc.

Tim Vaughn (tvaughn@snapnrack.com) is a 21-year veteran of the solar and PV industry. Tim is currently the program manager for SnapNrack Inc.

Racking Manufacturers:

Conergy • www.conergy.us
Direct Power Solar • www.power-fab.com
EcoFasten Solar • www.ecofastensolar.com
EZ Rack • www.ezrack.net
HatiCon Solar • www.haticonsolar.com
IronRidge • www.ironridge.com
Jac Rack • www.jac-rack.com
Next Generation Energy • www.zillarac.com
Professional Solar Products • www.prosolar.com
Quick Mount PV • www.quickmountpv.com
S-5! • www.s-5.com
Schletter Inc. • www.schletter-inc.us
Schüco • www.schuco-usa.com
Sharp • www.sharponenergy.com
SnapNrack • www.snapnrack.com
Solar Racks • www.solar-racks.com
SunEarth Inc. • www.sunearthinc.com
Thompson Technology Industries • www.ttisolar.com
Unirac • www.unirac.com
Zep Solar • www.zepsolar.com


The Classic
MidNite Solar Inc


MidNite
CLASSIC

Overcoming OVERHEATING

by Chuck Marken

Courtesy Chuck Marken (3)

All plumbing, including the collectors, in a drainback system is sloped to allow the system to drain.

Most solar water heaters produce about twice as much heat in the middle of summer as they do in mid-winter. Long summer days, higher sun path, higher ambient temperatures and more intense sunlight make great conditions for solar-heating water. While an abundance of solar-heated water is welcome, *overheating* is not, and can be a big problem in antifreeze systems.

The same glycol solution that protects a system from freezing will boil between 220°F and 275°F, depending on the system pressure—and that's a problem. If the solution gets too hot, the buffers in the glycol that prevent acidity can break down, leading to possible damaged pipes, and tripping pressure-relief valves—resulting in having to refill and repressurize the system.

Causes of Overheating

Too much collector for the amount of storage available or too big a system. During summer, the conditions are ideal for solar hot water. With too much collector area compared to storage area there's nowhere for that excess heat to go. In most of the United States, systems should not have more than 1 square foot of collector surface area per 1.5 gallons of water storage. In the sun-drenched Southwest, storage can be increased to 2 gallons per square foot of collector. Increasing storage can prevent overheating, but costs more, takes up more space, and takes longer for the collectors to heat the tank to the desired temperature.

Wrong system type or tilt too shallow. A collector gathers the most energy when its face is perpendicular to the sun—the lower the tilt, the more prone the system is to summertime overheating. Many people prefer a lower tilt for aesthetics, but a "laid-back" antifreeze system (one that's too flat) is more prone to overheating. In snowy climates, laid-back collectors will take longer to shed the snow from the collector glass, leading to decreased winter production. Installing a drainback system instead can prevent this kind of overheating—when the tank reaches the desired temperature, the solution drains out of the collectors.

Lifestyle and load changes. Even correctly designed and installed systems can still encounter overheating problems, typically because of usage changes. When the home is vacant or has fewer occupants than planned for—and, therefore,

Covering some of the collectors will provide protection from summertime overheating.

lower hot water usage compared to what the system provides— the system can overheat. Families also change in size. Then there's individual usage habits for owners living with a previously installed system—the SHW system may produce too much hot water for them.

The Seasoned Solutions

Drainback systems. The warmer the climate, the better drainback systems perform—they don't suffer damage from overheating. Although the collector can overheat, it won't have fluid in it because it drains whenever the collector loop pump shuts off—so problems are avoided.

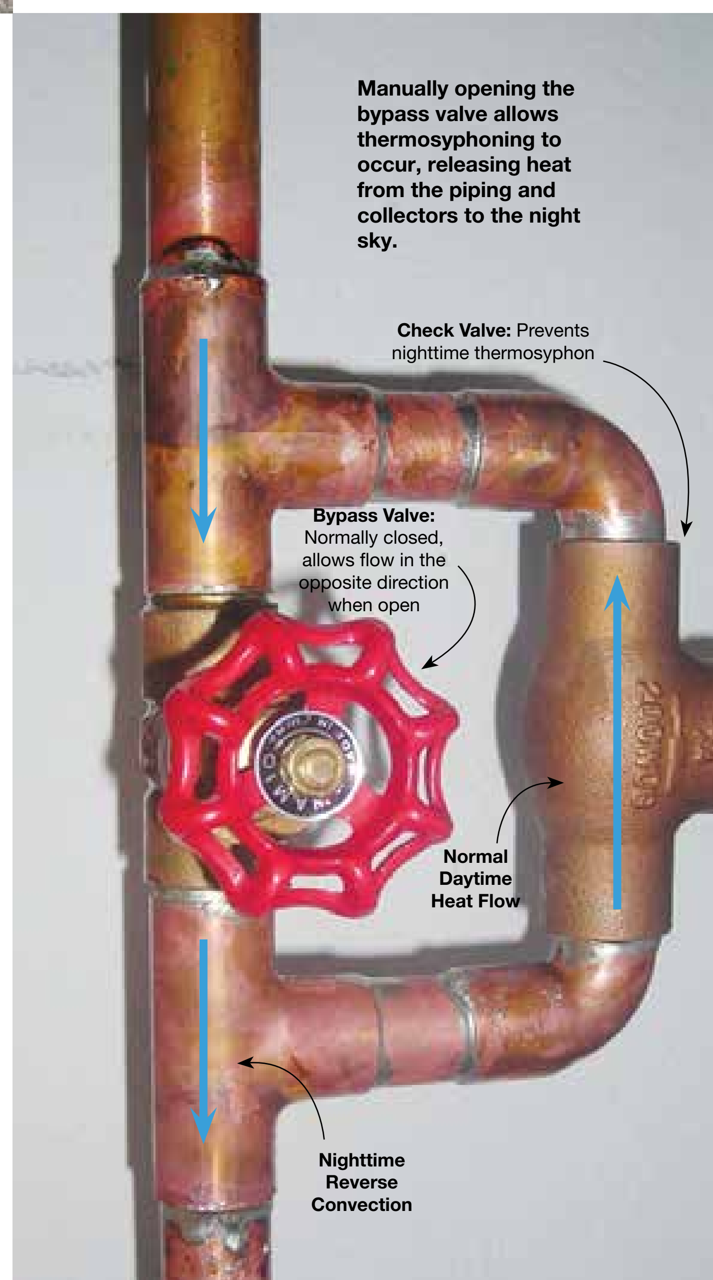
Drainback is the freeze protection for the collectors, but the pump can also be shut off to prevent overheating if the differential control has a high-limit function, actuated by the storage or tank sensor reaching the set point. Most controls have field-adjustable high limits; recommended settings are about 170°F.

Some designers and installers don't like drainback systems—the farther north you go in the United States, the more likely this is true. In the 1980s, these systems got a bad reputation due to freezing because of substandard controls, poor installations, sagging pipe, and a few other reasons. In most locations, drainback systems are the first choice and antifreeze systems are the second choice, although drainback system installation is unforgiving, as the collectors and piping must be sloped correctly. For ground-mounted applications, the choice is almost always antifreeze systems.

Covering the collectors can be an easy solution to thwarting overheating—especially if they are ground-mounted. Covering collectors on steeply pitched roofs can be difficult—climbing can be dangerous. But it's an inexpensive, effective solution to preventing overheating. Covering and uncovering collectors usually happens in the spring and fall.

Check-valve bypass. Installing a pipe bypassing the check valve can help prevent collector overheating. A manual valve is placed in the bypass pipe and is normally closed. In the summer—or whenever the system is prone to overheating—the valve is opened. When open, the system will thermosiphon at night from the storage tank to the collectors and lose heat through radiation to the night sky.

Controller vacation mode. Some controllers have a "vacation mode" setting which monitors the storage tank temperature as it does for a high-limit function. But instead of shutting off the collector-loop pump, the vacation mode turns on the pump at night to dump excess heat through the collector. Most controls



Manually opening the bypass valve allows thermosyphoning to occur, releasing heat from the piping and collectors to the night sky.

Butler Sun systems will automatically bleed excess heat to the air.

Courtesy Butler Sun Solutions

that offer the vacation mode, as with the high limit, have limits that can be field-set. As with all the night-radiation strategies, this method only works well with flat-plate collectors, which lose heat more readily than superinsulated evacuated tubes. Evacuated tubes using heat pipes cannot reradiate heat because heat pipe cycles aren't reversible.

Tilt. Most references recommend mounting a collector at an angle equal to latitude, which make its surface perpendicular to the sun on the equinoxes. However, an unseasonably warm spring or fall can cause overheating in many antifreeze systems. Setting the collector tilt to latitude plus 15° shifts the time at which the angle is optimal to sometime in November and February, limiting or eliminating overheating. The higher angle also enhances winter hot water production by a few percent.

Even more radical tilt angles are sometimes used with antifreeze-type solar space- and water-heating systems. These combination systems use the same set of collectors for both home heating and domestic hot water. Tilting up to 90° from horizontal (like a wall mount) can eliminate summer overheating while only slightly reducing winter heat production.

Automatic solution. Butler Sun Solutions' fluid management system (FMS) takes over in a no-flow situation to avoid overheating. High-temperature fluid moves into a finned tube radiator, where the heat is dissipated to the outside air. Should the system pressure rise to 16 PSI, a radiator cap actuates and allows fluid to flow into a reservoir—temporarily, just as it does in an automobile coolant reservoir. The fluid that enters the reservoir is reintroduced to the system upon cooling. Should you use this system, pay close

A steep collector mounting angle, vertical in this case, optimizes efficiency for the low winter sun, and captures less heat during the summer, when the sun is high and overheating is more likely.

Some differential controllers, like this one from SunEarth, have a vacation setting that allows the system to run in reverse at night, dumping heat from the storage tank back to the cool night sky.

Courtesy Chuck Marken (2)

The Apricus heat dissipator uses a valve to divert the flow to the radiator when the return from the collectors exceeds 170°F. The radiator dumps the heat to the surrounding outside air.

attention to the manufacturer's instructions. The system should be installed with a system pressure no more than a couple of PSI for the FMS to operate correctly.

Heat dumps. A finned air-to-liquid heat exchanger or an extra underground radiant heating zone can be used to prevent overheating. Radiant floor tubing (PEX) can be installed underground and a control set up to pump water through that zone when the solar storage tank reaches a set temperature. The outside zone can be laid as a winter snow-melt system that gives it an additional use.

Another good heat dump is a pool or hot tub. If you are looking for a tipping point to get a hot tub, this might be your "good reason." Many people use excess heat from their small SHW system to help heat hot tubs; larger solar home heating systems can help heat pools.

A hot tub or pool can be used as a dump for excess heat from a domestic SHW system.

Large systems usually use a fan to blow air past a radiator that the storage water is circulated through when the tank is too hot. This design requires significant electricity to energize the blower, in addition to the heat-dump pump.

Apricus, a manufacturer of evacuated tube collectors, uses a radiator, but the operation is passive, using no additional energy. When the return antifreeze temperature exceeds about 170°F, a valve diverts the solution through a radiator, then sends it back to the return pipe after cooling.

Proprietary collector designs. At least three collectors have "built-in" excess heat protection. Flat-plate collector designs by EnerWorks and Pacific West Solar have passive vents that open when the collector temperature hits about 200°F. The vents allow outside air to enter the collector box, limiting the heat available to the collector fluid.

Thermomax's evacuated-tube collector has a memory metal spring that actuates at 266°F, stopping the heat transfer of the individual heat pipe until the temperature falls. However, the manufacturer states that this temperature-limiting feature is meant to protect against component failure, not for protecting fluid from seasonal overheating.

How Hot is Too Hot?

The buffer breakdown temperature of generic propylene occurs at about 285°F. A few years ago, The Dow Chemical Co. introduced DowFrost HD, which has a maximum temperature of 325°F. This extra measure of protection has made the DowFrost a favorite.

Early on in the industry, chronic overheating problems were rare. But the recent popularity of evacuated-tube systems and a tendency for solar hot water installers to emulate PV installers, installing collectors at low tilt angles, has exacerbated the problem.

The best solution is prevention through design, but if that's not your case, you may find a solution from the these strategies. Maybe that hot tub you've been thinking about isn't such a bad idea after all.

Access

Contributing editor **Chuck Marken** (chuck.marken@homepower.com) is a New Mexico licensed plumber, electrician, and HVAC contractor. He has been installing and servicing solar thermal systems since 1979. Chuck is a part-time instructor for Solar Energy International and the North Carolina Solar Center and works under contract with Sandia National Laboratories supporting the DOE-sponsored Solar Instructor Training Network.

Island Power ×2

Off-Grid & On-Grid

by Eric Youngren

Left: Just below the spring, the hydro intake collects 50 to 1,200 gallons per minute, depending on the season.

Above: Both systems utilize butt-welded, high-density polyethylene (HDPE) pipe.

During the winter of 2003, I built my first microhydro system on Orcas Island in Washington state's San Juan islands. At the time, I was installing RE systems all around the Islands. I found a spot on my family's land where I planned to build an off-grid, microhydro-powered homestead. The system was designed and the cash saved for the materials.

As luck would have it, one day I got a call from *Home Power's* Ian Woofenden, who lives on nearby Guemes Island, inquiring about any microhydro projects that could serve as a hands-on workshop.

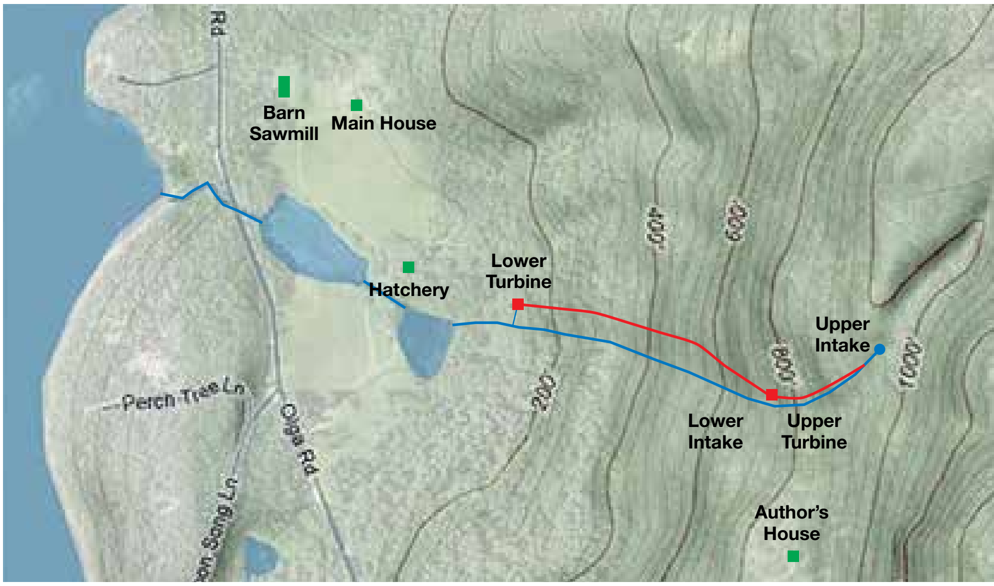
I jumped at the chance to have a 20-person crew for a day. Installation of the 4-inch-diameter HDPE pipe would be a big job and a good time to have a bunch of people to help. The workshop also provided a serious deadline, an extra impetus to get the rest of the system elements in place. Our goal was to be ready with everything so that the workshop participants could install the pipe, connect the turbine, wire the controller and batteries, and then open the valves to make power—all on the same day.

Microhydro History

In 1978, my family moved to Orcas Island from the suburbs of Seattle. As a kid, I spent many happy days playing in the creek that flows through my family's land, from the spring 1,000 feet up the side of the mountain to where the water joins the ocean in East Sound. Like most kids, I learned about the power of flowing water by playing with it. We built pools and dams in the creek, digging new channels for the water to follow as it was pulled ever downward by gravity's incredible power. In the early '80s, my dad and some of his friends started raising salmon in the ponds and creek channels of the lower sections of the creek (see "Long Live The Kings" sidebar).

Starting with the first homesteaders in 1875, everyone who has lived on this land has captured and utilized the bounty of water flowing down the mountain for drinking and irrigation. In earlier days, they also made electricity with the water, but the last hydroelectric system (before I started installing them) appears to have stopped working in the 1950s or early 60s, around the time when the local rural electric co-op installed submarine high-voltage cables to bring Columbia River-generated grid power to the islands.

As a teenager, I learned about the basics of hydro power and started reading *Home Power* magazine, scheming and planning for the day when I could build a system of my own. I learned about the power potential of head and flow, and the dangers of water hammer through trial-and-error experiments and the occasional, spectacularly wet, destructive blowout. I came to truly understand how voltage and amperage combine to create electrical power when it was explained how these two variables behave in the same way that head and flow combine to create hydro power.



Two hydro turbines utilize over 750 vertical feet of head from a mountainside spring near East Sound on Orcas Island, in Washington State.

System 1: DC Off-Grid

Planning the Penstock

For my home site on the family property, I chose a spot up the hill to be close to the spring—a 1-acre flat shelf about 900 feet up that projects out from the steeper slopes of the mountain above and below it. The spring sits about 80 vertical feet above the house, and about 700 feet to the northeast.

I found evidence of previous plans for hydro power: A small intake pond had been excavated in the creek at a spot with rough road access. A simple plywood dam and plastic-lined pond backed up the water to channel it through a rectangular weir for measuring creek flow. That was the easiest and most logical place to build the intake for my system. Because it sat about 50 vertical feet above the house site, I would also be able to use the hydro intake to supply pressurized domestic water to the house. A narrow, level bench at the bottom of a 100-foot drop, about 50 feet lower than the house site and 650 feet to the north, was the best place to site the turbine.

Because of the steep, forested terrain, all the conduit trenching was done by hand, with a mattock and 4-inch-wide trenching shovel. We set into the trench 2-inch-diameter PVC conduit, with plastic pull boxes every 200 feet, and a 1.5-inch plastic pipe for bringing domestic water along with the power to the house.

The Harris Hydro 5-inch Pelton turbine is driven by four nozzles at about 50 psi, spinning a permanent-magnet generator that produces up to 1 kW during the wet season.

DC System Tech Specs

Overview

System type: Off-grid, battery-based microhydro-electric with PV

System location: Eastsound, Washington

Site head: 110 ft.

Hydro resource flow (dry season): 50 gpm

Hydro resource flow (wet season): 150 gpm

Hydro production (dry season): 400 AC kWh per month avg.

Hydro production (wet season): 700 AC kWh per month avg.

Civil Works

Diversion: 12 ft. long by 2 ft. high by 4 in. thick cedar timber weir

Intake: 1.75 sq. ft. stainless steel Hydro-Shear screen

Penstock: 320 ft., 4 in. diameter HDPE, SDR 11

Powerhouse: 8 by 12 ft., lumber frame, locally milled Douglas fir

Hydro Turbine

Turbine: Harris Hydro, 48 V, permanent magnet, four-nozzle Pelton

Runner diameter: 5 in.

Alternator: Permanent magnet 48 VDC

Rated peak power output: 1.5 kW

Hydro Balance of System

Hydro turbine controller: Trace C40, 40 A

Dump load: 48 VDC water heater element

Inverter: Two OutBack FX3048, 48 VDC nominal input, 120/240 VAC output

Circuit protection: 40 A Airpax DC circuit breaker

System performance metering: TriMetric 2020, FlexNet DC

Engine Generator

Make/model: Honda EU 2000

Energy Storage

Batteries: 8 Interstate UL-16, 360 Ah at 6 V each

Battery bank: 48 VDC nominal, 360 Ah total

Battery/inverter disconnect: 100 A breakers

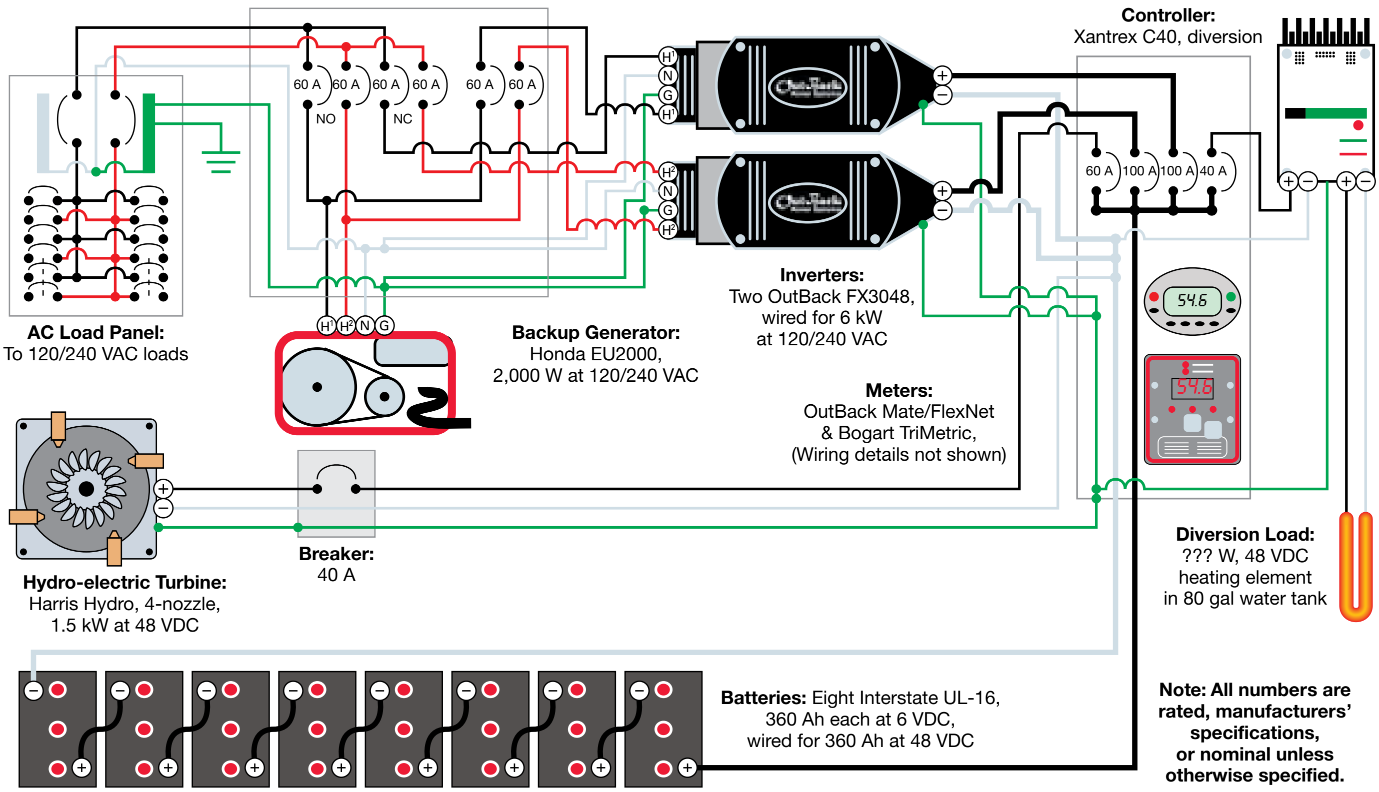
For the turbine base, I found a 24-inch-diameter cast concrete culvert pipe in a local boneyard of surplus and salvage materials. We used a gasoline-powered cut-off saw from the rental shop to shave 2 feet off one end so that it could be set vertically, holding the Harris turbine securely and allowing the water to exit freely out of the bottom. A rotary hammer and a cold chisel were used make a 6-inch-diameter hole in the side of the culvert about 4 inches from the end. The culvert was sunk vertically in a 1-foot-deep hole near the creek. We poured a concrete floor in the pipe level with the exit hole. Then, we dug a short trench across to the creek, caulked a 6-inch-diameter flexible plastic pipe to the tailwater exit hole and ran the other end into the creek below the turbine.

Installing the System

The penstock installation occurred on a rainy day in April 2003. Ian brought 20 workshop students. We rented a polyethylene pipe-welding machine from the pipe supplier and used a small pop-up canopy to keep the rain off the welding crew. The machine has a facer that cuts the pipe ends smooth so they will match and line up perfectly. A heater element softens the pipe ends until a small bead of soft plastic begins to form on the hot metal. At that point, the heater plate is removed and the ends are brought together quickly by pulling the lever on the pipe clamp jig and held under pressure until the joint cools. It is a relatively simple process that makes a strong and leakproof joint with only a minimal bead on the inside of the pipe to minimize water friction in the line.

A polyethylene welding machine was used to assemble the upper penstock.

Hydro System 1: Off-Grid



OutBack Power Systems inverters convert DC hydro power to AC for the author's home.

Our pipe-welding station was at the top of the penstock installation to take advantage of gravity. As each 20-foot section of pipe was added to the penstock, we simply dragged the lengthening pipe 20 feet down the hill. However, as the penstock got longer, it became heavier and wanted to slide down the hill on its own. We used rope to temporarily anchor it to trees and roots during the descent. Once all 300 feet were in place, we attached a bolted flange adapter with a rubber gasket to the PVC manifold at the turbine. Later, I added galvanized cable anchors bolted to the bedrock and boulders to permanently hold the pipe in place on the steep hillside.

The turbine was set on top of the vertical concrete culvert section using a frame of cedar 2 by 4s. This allowed a friction fit for the turbine—the frame held it securely, yet the turbine could still be easily removed from the base without tools for maintenance and nozzle replacement. The 48-volt DC wiring was placed in flexible plastic conduit to allow the turbine to be lifted up and swung to ground level to access the nozzles on the underside without needing to disconnect any wiring.

Connecting to the Turbine

The turbine is a four-nozzle, vertical-shaft Pelton design. Borrowing ideas from other systems I had seen on the island, I used flexible hose with cam-lock quick-disconnect fittings for connection to both the turbine nozzles and the manifold. The manifold is made from PVC wye fittings that reduce and split the single 4-inch pressure line into five 2-inch pipes, with

Water pressure was used to blast the trench for the lower penstock.

brass gate valves in each pipe. A fifth valve, at the very end of the penstock, is for supplying water to the building site. A 4-inch-diameter wye on the penstock above the manifold is for future system expansion. By adding a second turbine in parallel, more power can be made during the highest flow times of the year (winter/spring).

From the turbine, 2-gauge wiring runs up the hill 650 feet to the batteries in the power house. A Trace C-40 diversion-load controller keeps the batteries from being overcharged by dumping excess current into a 48 V heater element in a water storage tank.

After the pipeline installation, I built a proper intake dam, with cedar timbers set across the creek. A 16-inch square of stainless steel Hydro-Shear screen placed under the overflow notch captures water but allows debris to be washed easily across the surface of the screen. After seven years of continual operation, the intake screen is still working perfectly, with the only screen-clogging problem being a slow growth of algae that needs to be scrubbed off with a wire brush every few years.

System 2: AC Grid-Tied

In Sync with the Grid

After the success of the system at the top of the creek, we decided to move ahead with an even larger system, using the remaining 650 feet of elevation that the creek drops after it passes my turbine and before it reaches the salmon ponds, stream channels, and incubator boxes in the hatchery building at the bottom of the hill. The hillside is steep, rocky and very porous—so much that the entire creek goes subterranean for most of the way down the mountain. At the base of the hill, the water resurfaces through the lower springs, which sit just above the highest hatchery ponds.

Our plan was to capture the water just below the Harris turbine system, run it down the hill in the shortest route possible to a power house just above the highest hatchery ponds. An existing road would enable us to minimize the impact to the land, and the tailrace would reintroduce the water into the watershed just above the lower springs, keeping the water flow to the hatchery unchanged.

This grid-tied system couples a 60 W AC induction motor/generator to the utility grid through a grid-protection control panel. Our local utility, Orcas Power and Light Co-op, gave us permission to interconnect a system up to 100 kW. During the peak winter to spring season, the creek flow regularly exceeds 1,000 gallons per minute (gpm) and we wanted to maximize power production during those peak months. Dan New from Canyon Hydro flew over from Deming and we hiked the watershed. After some assessment, we decided to use 800 gpm as our design flow rate. Canyon's engineers designed a system using a two-nozzle, 10.5-inch Pelton turbine.

A 6-inch penstock was chosen to keep head loss within reason. I located used 6-inch, thin-wall steel pipe with ends

Left: The author connects the 6-inch steel pipe to the HDPE pipe with a flange adaptor.

Right: One thousand lineal feet of steel pipe was used in the bottom of the lower penstock. The steep terrain necessitated creative installation and anchoring systems.

The Canyon Industries turbine consists of a 10.5-inch Pelton turbine and a 60 kW, 480 VAC, three-phase alternator.

AC System Tech Specs

Overview

System type: Grid-tied, batteryless microhydro-electric

System location: Eastsound, Washington

Site head: 650 ft.

Hydro resource flow (dry season): 50 gpm

Hydro resource flow (wet season): 1,200 gpm

Production (dry season): 7,000 AC kWh per month

Production (wet season): 32,000 AC kWh per month

Civil Works

Diversion: Stone & concrete weir

Intake: 12 sq. ft. stainless steel Hydro-Shear screen

Penstock: 700 ft. of 6 in. HDPE & 1,000 ft. of 6 in. diameter, 0.141 in. thick, roll-grooved steel with Victaulic couplers

Power house: 20 by 20 ft. concrete foundation & timber frame

Hydro Turbine

Turbine: Canyon Hydro model 1051-2, two-nozzle Pelton

Runner diameter: 10.5 in. cast stainless steel

Rated peak power output: 60 kW

Balance of System

Hydro turbine controller: Thomson & Howe grid protection panel, 480 V, 3-phase, 60 Hz

for use with Victaulic couplings—two cast-iron jaws bolted around a rubber gasket to make a watertight and high-pressure-worthy joint. That steel pipe was the least expensive pipe available for the higher-pressure sections of the run. The pressure at the top of the pipe was lower, so we started with 700 feet of 100 PSI-rated HDPE plastic pipe for the top section, reserving the steel pipe for the bottom 1,000 feet.

What I did not anticipate was how much labor it would take to install the heavy steel pipe on the steep rocky mountainside. If I were to do it again, I'd use two parallel runs of 4-inch-diameter, heavy wall HDPE. The material would have cost more than the 6-inch steel pipe, but the installation would have taken a few weeks, rather than a few months! A single run of 6-inch, heavy wall HDPE would have reduced the internal dimension significantly and introduced too much head loss. Two runs of 4-inch, heavy wall HDPE would have had enough internal dimension to keep head loss in the allowable range.

We installed the system during the spring and summer of 2006, preparing the route using "hydro excavation." A long stretch of 1 1/2-inch HDPE pipe connected to my hydro penstock and a high-pressure fire hose with a long brass nozzle was used to shoot a jet of water to clear the route for the penstock. Some of the sections needed substantial amounts of earth cleared to make a straight path. It's really quite impressive how much dirt and rock high-pressure water can move!

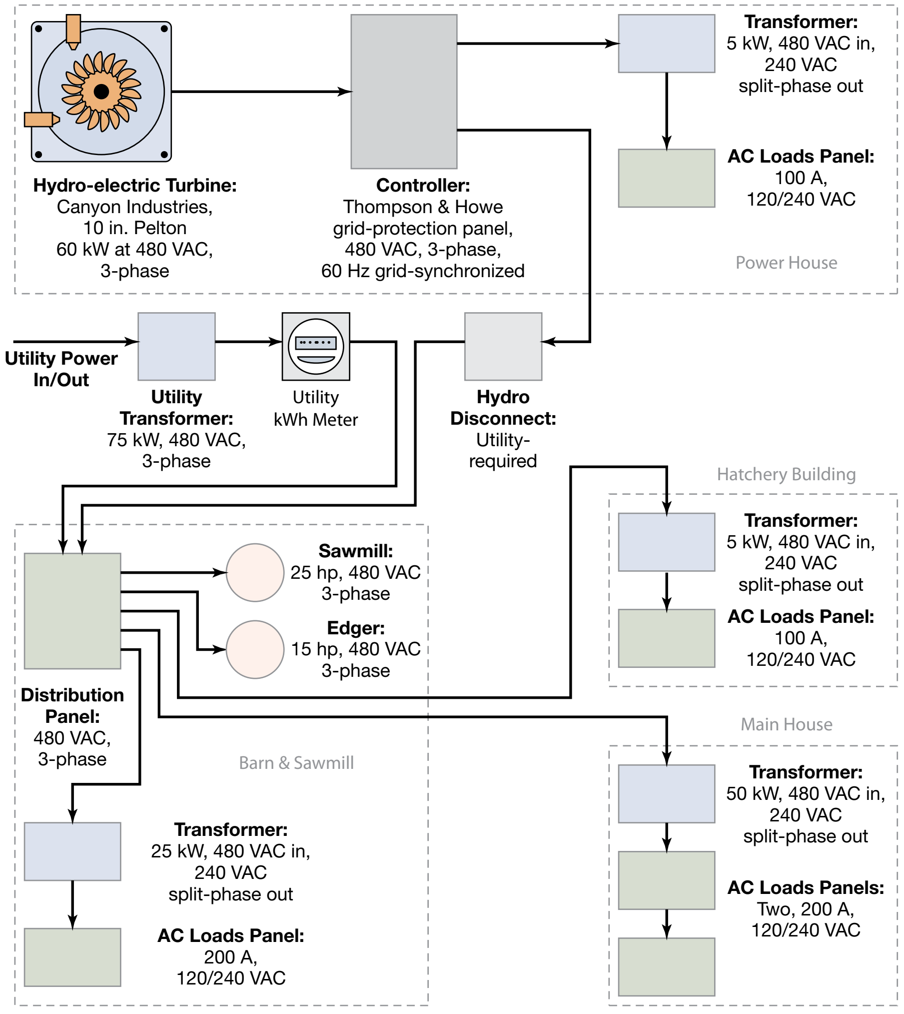
The 20-foot sections of 6-inch pipe each weighed about 250 pounds and required about four people to move. We devised pipe-lifting and positioning techniques using ropes, straps, "come-along" hand winches, and a rope capstan winch mounted on a chain-saw body, combined with tree-mounted anchor points, blocks of timber, or "cribbing," and hydraulic jacks.

Parts of the route passed over exposed bedrock, so we used a 1-inch-diameter rotary-hammer to drill anchor holes for securing eye bolts and pipe anchor attachments with two-part epoxy. In places without exposed bedrock, the hillside is loose shale rock that provided little solid ground to attach to. In those locations, we dug holes for gabions—large wire cages filled with rocks and concrete—into the loose rocky hillside to form a solid anchor point and prevent the heavy, water-filled pipe from sliding downhill.

The Canyon turbine arrived with a steel frame designed to be cast into the concrete of the power house floor. The middle of the frame is left open so the water can exit the turbine. We built a concrete basement under a third of the power house floor, with a pedestal to hold the turbine. The floor above the tailrace section is 4-inch-thick, red cedar planks. A 2-foot gap in the wall at the lowest level is connected to a short concrete-sided channel to the streambed.

We had to address long-distance electrical transmission issues to get the power to the grid. We relocated the utility's transformer closer to the power house and switched from 120/240 single-phase to 480 V three-phase power. By switching to 480 VAC, the energy from the turbine can travel on smaller-gauge wire. The 480 V power also powers an electric sawmill and several large wood-processing machines in the shop.

Hydro System 2: Grid-Tied



The author with the 10.5-inch Pelton runner for the Canyon Industries turbine.

Production Payoffs

These two systems have given me quite an education in hydro-electricity, and energy economics in general. The contrasts between the systems are insightful. My small off-grid system was built for about $7,000 and paid for itself almost immediately, since the cost of bringing in grid power to the remote home site would have been at least $10,000. Now, we'll never need to pay a utility bill. The 23+ kWh that it produces each day is more than enough for my off-grid home. Because electricity consumption is moderate, the investment in generation was scaled to match it.

The bigger grid-tied system took much more time and effort to complete, and cost more than $100,000. In hindsight, there was a fair bit of hubris in our design decision to maximize the power potential of the creek. That system will take at least a decade to return the investment, assuming it's pushing out as much power as possible all the time. We are

The main component of system integration is a Thompson & Howe grid-protection panel that disconnects the turbine from the grid during power outages and maximizes power output by regulating flow rates, maintaining consistent head pressure.

LONG LIVE THE KINGS
Restoring Wild Salmon

In 1980, Jim Youngren and his friend Walt Moller had the idea of raising salmon in the watershed. There were no native salmon because the final 20 feet of the creek's drop to the bay was over steep rocky cliffs that no salmon or sea-run trout could jump. So they sourced some fertilized salmon eggs from a mainland fish hatchery and raised them in ponds. When they released the first batch of a few thousand smolts to the ocean they really had no idea if they would come back or not. But they did! A few years later they were back, ready to spawn and die—beginning the cycle anew. A concrete fish ladder was built where the creek meets the bay to provide the salmon with a way to get up into the fresh water to fully mature before spawning. That was 30 years ago and the fish are still coming back, supported now through the efforts of the nonprofit group, Long Live the Kings (www.lltk.org).

power producers now, keeping the electrons flowing out to the grid, in exchange for checks from the utility. That's a totally different perspective on microhydro from my off-grid system that churns away in the background, keeping our small bank of batteries charged and dumping surplus power to heat water most of the time.

Access

Eric Youngren (eric@solarnexusinternational.com) is a NABCEP-certified PV installer with more than 10 years of experience designing and installing RE systems. In 2008, he founded Solar Nexus International, a value-adding distributor of pre-integrated solar systems and manufacturer of the SolarNexus off-grid power system appliance.

Components:

Canyon Hydro • www.canyonhydro.com • 60 kW hydro plant

Harris Hydro • 707-986-7771 • Home-scale hydro plant

Hydroscreen • www.hydroscreen.com • Hydro-Shear intake screen

Thomson & Howe Energy Systems Inc. • www.smallhydropower.com/thes.html • Hydro controls & grid-protection panel


MIDWEST RENEWABLE ENERGY ASSOCIATION
ENERGY FAIR
JUNE 17-19, 2011
CUSTER, WISCONSIN
WWW.MIDWESTRENEW.ORG
The 22nd Annual
Energy Fair
clean energy & sustainable living
THE PREMIER ENERGY EDUCATION EVENT IN THE NATION!
Over 200 Workshops
More than 275 Exhibits
Inspirational Keynotes
Entertainment
Kids' Activities
SOLAR • WIND
GREEN BUILDING
ORGANIC LOCAL FOOD
TRANSPORTATION
mrea
midwest renewable energy association
715-592-6595 • www.midwestrenew.org

RENEWABLE ENERGY

Healthcare in Haiti

by Carol Weis & Walt Ratterman

Partners in Health (PIH) provides quality healthcare to some of the poorest people in the world. With the original focus to serve Haiti's mountainous Central Plateau region, PIH has established 11 healthcare facilities that serve more than a half million people—regardless of their ability to pay. Only one of these facilities is tied to an electrical grid, while the others rely on diesel generators and inverter /charger battery systems to power the hospitals' loads. The cost of diesel fuel—both the purchase price and the delivery price—is one of the largest budget items, taking funds away from healthcare needs, such as medicine and clinical personnel.

SunEPI founder Walt Ratterman was the project manager and lead trainer at the Partners in Health (PIH) hospital site in Haiti's Central Plateau, where a 10 kW off-grid system was installed and 21 Haitian technicians were trained.

Courtesy SELF

Carol Weis

In September 2009, the Solar Electric Light Fund (SELF) partnered with SunEnergy Power International (SunEPI) to provide solar electricity to the first of the PIH Haitian facilities in Boucan Carré, located in the central plateau region. As part of the installation, USAID donated funds for a technician training led by Walt Ratterman, Herb Kanski, Carol Weis, and Christopher Freitas. Twenty-one hospital technicians from around the country attended the training, including a Haitian technical college professor looking to bring renewables into his program in Port au Prince. In addition to the nine-day technician training, there was a half-day training given to the medical staff to educate them on the abilities and limitations of the PV system.


Courtesy Walt Ratterman

The heavily rutted road up to Boucan Carré sees a lot of traffic on market day. Rough road conditions make it difficult to transport fuel to the remote hospital site.

System Goals

Even in Boucan Carré, a town of nearly 50,000, there is no utility power. Most homes have no electricity, and only a few benefit from generator power.

The local hospital—run by Zamni Lasante (the Creole name for Partners in Health) — had been powered by a 35 kW diesel generator, along with an aging, undersized central inverter/charger battery system comprised of two Trace DR modified square-wave inverters with four paralleled strings of Trojan T105 batteries.

To serve the hospital and dormitory loads, including lights, fans, lab equipment, computers, and the water pump, the generator typically ran from 9 a.m. until 5 p.m., and then started again at night to service the dormitory loads for several hours, for a total daily run time of 10 to 12 hours. The old DR system powered the staff dormitory and hospital ward loads for several hours each night until the decrepit batteries discharged too much to operate the inverters. Fuel for the generator is hauled to the hospital in 55-gallon plastic drums in the back of small, four-wheel-drive pickup trucks, as the river and the rutted road does not allow a tanker truck delivery.

The new PV system needed to achieve three specific goals:

1. Provide consistent, "clean" power to the hospital's sensitive lab equipment, with consistent voltage and frequency, and provide reliable electricity to general daily loads, such as lighting and fans, in both the hospital wards and the staff dormitory.
2. Decrease the generator run time to save money by reducing fuel use, generator maintenance, and the costs of fuel delivery.
3. Provide a source of energy to critical loads in case of generator failure or fuel shortages.

Different Power

To achieve the first goal, a true sine wave inverter was installed with appropriately sized batteries to carry a significant portion of the hospital's loads for most of the day. The old inverters were decommissioned from this site to be used at another clinic, and the well-used batteries were recycled.

An additional step of isolating sensitive laboratory loads from the generator was necessary. During the middle of the

Solar Electric Light Fund (SELF)

The Solar Electric Light Fund (SELF) has installed PV systems at more than 40 health clinics in seven countries, including Haiti. Fifteen of these projects have been for Partners In Health (PIH), including the 10 kW installation in Boucan Carré that secured critical loads and reduced the clinic's diesel fuel consumption by 64%.

Reducing generator run times became a key PIH objective and, after the 2010 earthquake, SELF designed larger systems for five PIH clinics. The generosity of many in-kind and cash donors enabled SELF to plan for installing 129 kW at these clinics—nearly 26 kW per clinic on average—in 2011.

In addition, SELF received a $1.5 million grant from the Inter-American Development Bank for PV systems on five community centers and to install street lighting at a transition camp. NRG Energy also selected SELF to implement its $1 million pledge to the Clinton Global Initiative, which will put more PV systems on 11 schools, a fish farm, street lighting, and drip irrigation systems near the clinic in Boucan Carré. Such clustering of applications will demonstrate the viability of the PV solution for electrifying rural villages in Haiti and throughout the developing world.

Courtesy Walt Ratterman

Herb Kanski of Tetra Tech teaches a generator section in Creole to the 21 Haitian technicians in the class. All PIH hospitals rely heavily on generators to perform the medical services needed in rural areas.

Finally, some loads—ones that had large draws and would cause excessive battery cycling—were isolated on a generator-only panel.

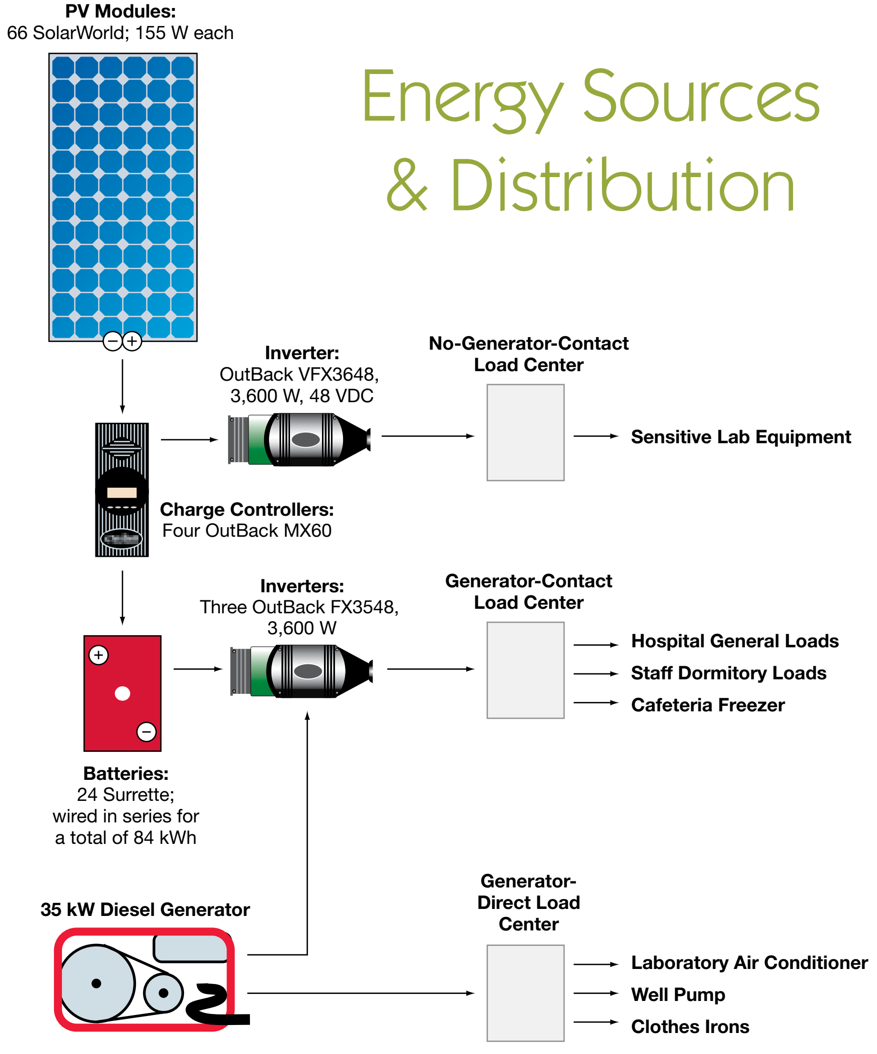
Fuel Savings & Services

Achieving the second goal—saving money by cutting fuel costs—was not straightforward. Since the generator was still needed to augment battery charging and to run larger loads, the challenge was figuring out when it should run.

Generator specifications show that the relationship between fuel consumption and kilowatt-hour load is not linear. True cost savings occur by reducing overall generator run time, as well as creating conditions so the day, and under normal operation, the generator was needed to augment solar-charging to the batteries and run some of the larger loads. When the generator runs, all loads—including sensitive ones—connected to the inverter/charger system are automatically transferred to the generator. Without regular maintenance, generator electricity can easily fall out of voltage and frequency specifications. Plus, it is typically not considered "clean" enough for the hospital's sensitive lab equipment, resulting in premature failures or malfunction of equipment.

To operate some of the costly lab equipment used to diagnose HIV/AIDS (one of the leading causes of death in Haiti), a stable, clean sine wave, along with tight voltage and frequency windows, is needed. To serve this need, one inverter was designated as a "no-generator-contact" inverter, meaning that the inverter and the loads it powers would never be connected to the generator and therefore be ensured of providing cleaner electricity.

In addition to the no-contact inverter loads, there were also "generator-contact" loads at the hospital. These loads would be connected to the PV/battery system through a separate inverter, but when the generator was on, they would be allowed to connect to it without worry of damage.



generator always runs at 50% capacity or more. The important analysis to be done was to determine if all large generator-only loads could be coordinated. Further design details focused on accurately programming the controls to ensure that, when the sun was shining, the PV system would take precedence in charging the batteries. At the project's onset, the optimistic goal was to reduce generator run time by 50%.

And last, addressing the critical nature of services the clinic provided to the remote area was important. With limited access to the clinic in severe weather—plus the long history of devastating hurricanes and political unrest—having an independent, on-site energy source would allow the hospital to continue providing medical services during the most desperate situations.

Courtesy Walt Ratterman

Students review the wiring of the OutBack Power system.

Empowering Clinics

Electricity is an increasingly essential commodity in healthcare facilities in the developing world. Improvements in the distribution of vaccines, and the global push to deliver antiretroviral drugs and services to HIV-positive patients worldwide, have introduced new demands for electricity in sites with little or no access to reliable power. Over the years, significant effort and funds have been dedicated to providing energy services to health facilities—with a particular focus on expanding the vaccination chain. Unfortunately, many of these efforts have proven not to be sustainable over the long term.

Although it is nearly always preferable for a health facility to purchase power from an independent party (e.g., a utility), such an option is not always economically or technically viable. For instance, many developing country health facilities are connected to a national grid, which may provide intermittent and poor-quality power. Improving the quality of that power often requires significant institutional reforms and capital expenditures, which are long-term endeavors and are outside the manageable interest of the health sector support program. Many other health facilities have no access to grid power or have intermittent, poor-quality power from a local minigrid.

Designed by USAID's Energy Team, PoweringHealth.org is a Web site for those seeking solutions to provide continuous, high-quality energy to health facilities in developing countries. The site offers energy audit spreadsheets that organizations can download to perform their own assessments, online health clinic power system design software, and a slew of resources to help groups figure out the best approach to implementing power systems to meet their needs.

Designing the System

The hospital's original rough load analysis, done a year before the system's installation, estimated that the new inverter/charger system would need to handle at least 47 kWh per day. This figure anticipated an additional amount of unknown dormitory and auxiliary loads, all of which were typically connected to the generator for 10 to 12 hours each day.

This rough estimate was used to ballpark a PV system size, with the understanding that donated equipment was only going to offset part of the hospital's loads. On the second day of class, the students interviewed staff members about the number of hours the loads were typically used and traced every load on each circuit breaker. The resulting energy analysis was more than *double* the original estimate and provided enough information to determine which circuits should stay on the generator-only service panel, and which ones could be moved to the new PV system, as either contact or no-contact loads.

System Details

The system includes 66, 155 W SolarWorld PV modules mounted on a locally made custom rack on the hospital's main roof. To deter thieves, special hardware covered by welding steel plates over them locks the modules in place, and the rack base was welded to rebar and attached to the roof with concrete.

The PV modules were split into four subarrays, each with its own combiner box that routed to four separate MPPT charge controllers. The modules were wired in series in groups of three to match the controller input voltage window. Each positive conductor from the series string was wired to a 15 A circuit breaker in the combiner box. In the combiner box, all the series strings connected in parallel and a larger wire,

Courtesy SunEPI

To create a theftproof installation that was also able to withstand high winds, local Haitian company Green Energy Solutions designed a rack that used welded clamping brackets to secure modules and hide mounting hardware. This rack was welded to the building rebar and then concreted to the roof.

carrying all the ampacity, continued in conduit from the roof to the charge controller.

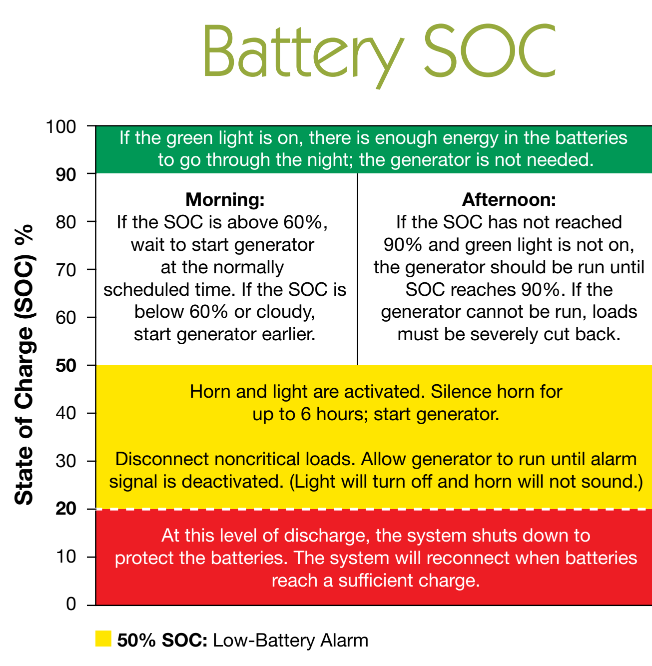
All of the balance-of-system equipment (inverters, controllers, and batteries) was located on the west side of the hospital's equipment room. The batteries were located directly behind the inverters in another separate room to prevent battery gases from corroding the electronics. The 24 2-volt, 1,766 Ah batteries were wired in series, making an 84 kWh battery bank.

Monitoring, Education & Operation

By the fifth day, the PV system was installed and charging the batteries, and the group focused on setting up an on-site monitoring system. Since this system served all the hospital workers, the staff dormitories, and the immediate local residents, all participants needed to understand system monitoring and load limitations. It was decided that having signal lights in a highly visible area was important to show the battery's state of charge (SOC). This allows the larger

Signal lights and an alert horn were installed in the hospital's main courtyard to indicate to the staff if the battery was full or if loads needed to be conserved. The red light and horn come on at 50% SOC, signaling that all noncritical loads should be turned off and the generator should be started. The green light indicates the battery is at 90% SOC.

Courtesy SunEPI



Courtesy Walt Ratterman

Courtesy Walt Ratterman

Top: Healthcare for women and children is a strong focus for PIH. Services include pre- and postnatal care, vaccinations, and birth assistance. Right: Providing consistent, "clean" electricity to the laboratory's sensitive equipment is a priority to assure reliable test results and to prevent premature equipment failure.

community to determine if they could continue using loads, if the generator needed to be run, or if loads needed to be reduced. A green and a red light were used to indicate battery SOC, with green signaling 90% and red signaling 50%. The typical protocol was to run the generator from 10 a.m. to 3 p.m., provided there were no emergency medical loads. On a sunny day, the PV system would start charging the batteries at about 8 a.m. By 10 a.m., the generator would be turned on, which would carry most of the hospital loads and any large loads, like air-conditioning and water pumping. This would protect the batteries from deep discharge, and the programming of the PV charge controller and the inverter/charger allowed the PV array to continue charging the batteries even with the generator running. At 90% SOC, the green light would turn on. If no emergency surgical loads were needed, one of the technicians could shut down the generator, with the PV array continuing to charge the batteries until they were full.

Although the deep-cycle lead-acid batteries used in this system can be discharged to 20% SOC, the signal light and audible alert was programmed to come on at 50% SOC, to promote conservation of all non-critical loads at this juncture, to allow some reserve power to remain in case of an emergency, and to allow longer battery life. Under normal conditions, the technician disengages the alarm and starts the generator to charge the batteries. If the generator is not functioning, the procedure is to shut off all non-critical loads and wait for the PV system to charge the batteries.

Testing Theories

After allowing the batteries to charge with no loads connected for two days, the hospital loads were activated at noon on the third day. By 4 p.m., with thunderclouds accumulating, battery SOC registered 99%. At 8:30 the following morning, the monitoring system showed the battery SOC was 73%.The solar gain later that morning had upped it to 76%.

In theory, if all nights were similar to the test run, and the technician assured that the battery reached at least 90% SOC each afternoon, there would be sufficient battery capacity until the next day.

The second night showed significantly more loading. By 4 p.m., SOC had dropped to 91%. The next morning at 8:30 a.m., contrary to all of our best guesses, the battery minimum SOC showed a low of 47%, with the current SOC at 49%.

The second night's increased demand, which used 44% of the battery capacity, prompted further load investigation. More wires were discovered that were traced to outside buildings not originally part of the load analysis. Two inefficient refrigerators in an exterior kitchen, as well as several circuits running lights and outlets, were identified, and alternatives were discussed with the group.

Logging, Education, Operation

The daily operation duties chart and logging sheet prompts system technicians to record the time, weather, battery SOC, battery volts, the kWh meter reading, whether the alarm and red light activated, and the number of hours the generator was run that day. It also provides a simple decision matrix of when to turn the generator on and off according to varying conditions.

Normal procedures dictate that the technician checks the battery SOC at 7 a.m. If the weather is sunny and the SOC is above 60%, the technician waits until 10 a.m. to start the generator. If it is cloudy, the technician starts the generator

Courtesy Walt Ratterman

SunEPI project engineer Christopher Freitas leads a training on troubleshooting OutBack inverters.

to sustain morning hospital loads. At 3 p.m., the technician verifies whether the green light is on, indicating the battery is at 90% SOC and, if so, shuts off the generator. In case of signal light failure, the technician also checks the SOC on the Mate to verify battery SOC has reached 90% before turning off the generator.

A monthly maintenance agreement was originally drawn up with a local RE company, Green Energy Solutions, to check battery water levels, inspect the system, review daily logs, and do brief educational trainings with the local technicians, as necessary. SELF has since hired a technician to do monthly service work at this and other hospitals the organization is electrifying.

PV System Performance

In mid-November 2009, after two months of the system's operation, Walt Ratterman returned to Boucan Carré to compare the system performance with project's original goals and learned that:

- The power-sensitive lab equipment had been running without problems on the no-contact inverter, and the rest of the system was easily supporting general hospital loads.
- Generator use had been reduced to five hours per day or less, thus reducing the monthly fuel costs by more than 50%.

The hospital staff has learned a lot about system management, and is making progress in learning how to keep accurate logs on the system's operation.

The old, inefficient refrigerator and freezer had been replaced with two efficient refrigerators. A vaccine fridge that was previously run on liquid propane gas was also replaced, saving more fuel. The staff had removed some of the loads going to non-essential, off-site locations.

The ability to monitor performance data on a regular basis is an important element in keeping the energy systems functioning properly, and in catching problems before they become costly to correct. The system monitor currently records operation but the data can only be accessed on site. SunEPI and SELF are now working together to implement a remote monitoring system for Boucan Carré. Once completed, this monitoring system will allow the system's data to be accessed over the Internet.

Among all the tragedies that occurred during the January 2010 earthquake, both Walt Ratterman and Herb Kanski died

The class with the completed 10-kilowatt array. Herb Kanski and Walt Ratterman (far left) are pictured with the PIH technicians from around the country.

Carol Weis

in Port au Prince while meeting to design the next nine public hospitals. Both their spirit and their huge knowledge base has been one of the many devastating losses of this event. Fortunately, the Boucan Carré system did not sustain any damage, and is currently providing electricity to doctors serving hundreds of patients a day. The lessons that are learned from this system continually guide the designs and protocols for the next rounds of hospital PV systems.

Access

Carol Weis (carol@solarenergy.org) continues her work as a renewable energy educator in Haiti and other countries, bringing sustainable energy to rural health clinics and schools. Carol works part-time for Solar Energy International and is a project engineer for SunEPI. She is a certified ISPQ Master PV Trainer and holds a NABCEP PV Installer Certification. She has worked as a licensed electrician and solar installer in Colorado.

Walt Ratterman, SunEPI's CEO, was tragically lost to the Haitian earthquake on January 12, 2010. Walt's hands-on PV experience included residential and commercial PV installations in the eastern United States, as well as rural PV installations in Nicaragua, the Galapagos Islands, southern Ecuador, Peru, Arunachal Pradesh in India, Burma, Thailand, Haiti, Rwanda, and many other countries. Much of his work is available as a resource on both SunEPI and Powering Health websites (see below) His guidance, humor, and dedication to helping the less fortunate is missed dearly throughout the world.

Donations: Modules and power equipment were donated by SolarWorld, and training and local installation costs were underwritten by USAID. The Good Energies Foundation provided additional support. SELF arranged for the purchase of batteries and other equipment. Walt Ratterman of SunEPI and Herb Kanski of Tetra Tech led the training and installation team in Haiti, and managed all of the complicated logistics, local installation, and translation efforts.

Other Organizations:

Partners In Health • www.pih.org

Powering Health • www.poweringhealth.org

Solar Electric Light Fund • www.self.org

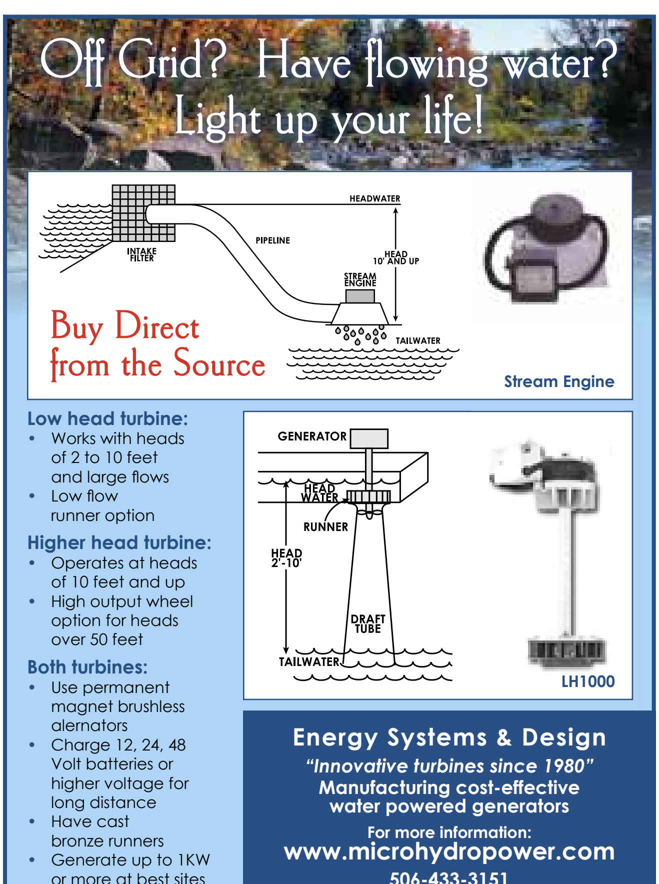
Solar Energy Power International • www.sunepi.org

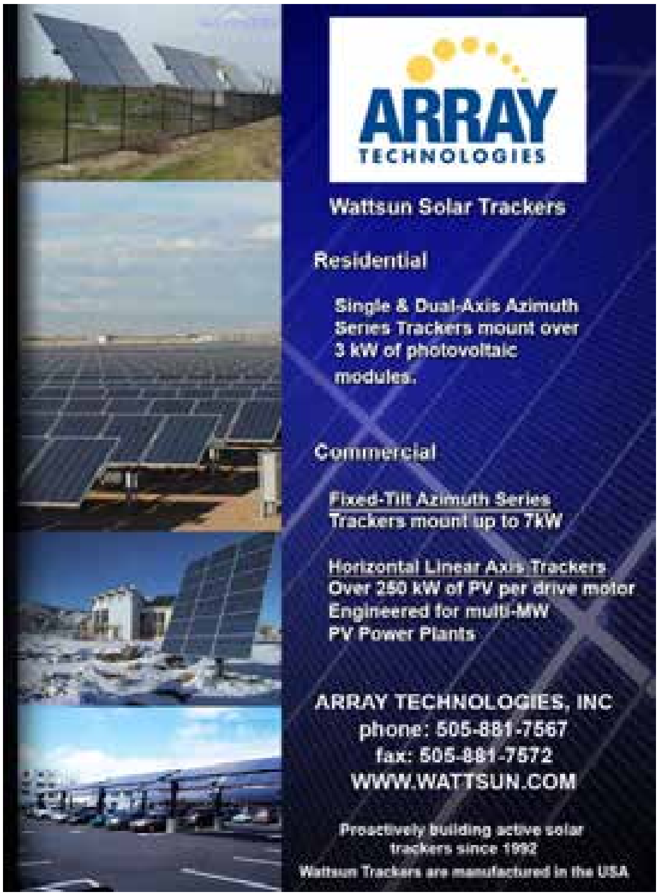
System Components:

OutBack Power Systems • www.outbackpower.com • Inverters & monitoring

SolarWorld • www.solarworld-usa.com • PV modules

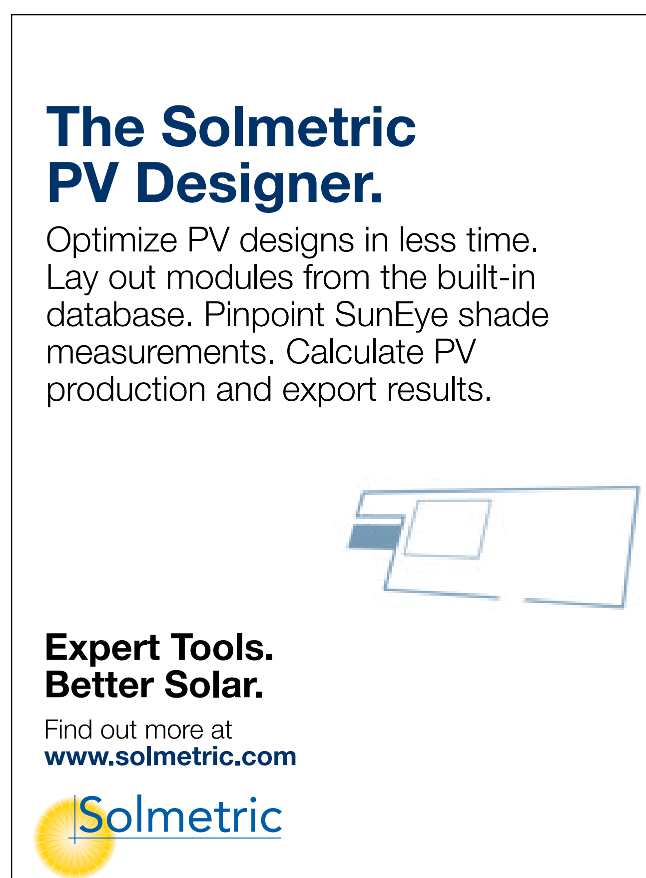
Surrette • www.surrette.com • Batteries




ARRAY
TECHNOLOGIES
Wattsun Solar Trackers
Residential
Single & Dual-Axis Azimuth Series Trackers mount over 3 kW of photovoltaic modules.
Commercial
Fixed-Tilt Azimuth Series Trackers mount up to 7kW
Horizontal Linear Axis Trackers
Over 250 kW of PV per drive motor
Engineered for multi-MW PV Power Plants
ARRAY TECHNOLOGIES, INC
phone: 505-881-7567
fax: 505-881-7572
WWW.WATTSUN.COM
Proactively building active solar trackers since 1992
Wattsun Trackers are manufactured in the USA


IS YOUR LIGHTNING ARRESTOR A JOKE?
With lightning you get one chance, so get the best!
MidNite Solar's
SPD (Surge Protective Device)
The MidNite SPDs are designed to clamp surge voltage to safe levels for inverters and charge controllers. Other arrestors do not even begin to clamp surge voltages until 7000 or 8000 volts.
• 8 thermal fused metal oxide varistors achieve 128,000 Amps peak clamping force.
• LED Indicators
• SPD115 - 115VDC
• SPD300 - 120/240VAC +300VDC
• SPD600 - 480VAC +600VDC
ETL Listed to UL1449 Rev3
www.midnitesolar.com


Specializing in photovoltaic system design of any type.
Call one of our solar design technicians for system design or visit our web store for thousands of renewable energy products.
800-383-0195
NORTHERN ARIZONA
WIND&SUN
Electricity From the Sun
http://store.solar-electric.com
4091 E Huntington Dr • Flagstaff, AZ 86004
Providing renewable energy since 1979


The Solmetric PV Designer.
Optimize PV designs in less time. Lay out modules from the built-in database. Pinpoint SunEye shade measurements. Calculate PV production and export results.
Expert Tools. Better Solar.
Find out more at
www.solmetric.com
Solmetric

PV Changes in the 2011 *NEC*

by John Wiles

The 2011 *National Electrical Code (NEC)*, published by the National Fire Protection Association (NFPA), is now available, and adopted by some jurisdictions automatically on January 1, 2011. It will be adopted throughout the country over the next three years (possibly longer in some areas).

PV systems and equipment manufacturers, designers, installers and inspectors should get a copy of the 2011 *NEC* and the 2011 *NEC Handbook* (in print or digital). Both the *NEC* and the *Handbook* indicate the code changes with highlighting.

As soon as it becomes available, inspectors typically start reviewing the new *Code* for clarifications of the previous editions, even though their jurisdiction may not adopt the newest *Code* for several years. In many cases where safety enhancements are involved, an authority having jurisdiction (AHJ) will permit or even enforce the requirements of the new *Code* before it is officially adopted.

Overview

For the 2011 *NEC*, the Code-Making Panel 4 (CMP-4) processed Article 690, Solar Photovoltaic PV Systems, and 705, Interconnected Electric Power Production Sources. Previously, CMP-13 had processed those articles. Unfortunately, many carefully thought-out and substantiated proposals were rejected.

Many areas of Article 690 were clarified, some were not, and some added requirements. The 2011 *NEC* moved several sections from Article 690 to Article 705.

General

690.2 Definitions. With the return of *bipolar* arrays, definitions to distinguish *subarray* and *monopole subarray* were added. Bipolar arrays have not been in evidence since the mid 1990s and at that time safety issues with them resulted in *Code* changes.

690.4(B) Identification and Grouping. Extensive marking requirements were added for all circuits in a PV system. Safe maintenance was the justification. When you open a junction box or combiner, circuit identification should be easy.

690.4(E) Wiring and Connections. *Qualified persons* (defined in Article 100) shall install all PV equipment and systems. Specific skills and training including safety training are mentioned in the definition.

690.4(F) Circuit Routing. Circuit routing requirements, such as routing conductors and conduit along beams and rafters, instead of hanging between structural members, were added to reduce the likelihood that firefighters will come into contact with energized circuits. PV circuits inside and outside the building are affected.

690.4(G) Bipolar Photovoltaic Systems. More stringent requirements, such as the physical separation of circuits for bipolar arrays, were added to avoid exceeding the voltage rating on equipment. Inspectors will have to look closely at the voltage ratings of the arrays, inverters and conductors of new systems to make sure monopole subarrays and their circuits are separated when voltage ratings are exceeded, since UL Standard 1741 does not specifically address these types of inverters.

690.4(H) Multiple Inverters. Directory requirements were established for multiple inverters on a single building, so that disconnecting means can be located for each inverter.

Circuit Requirements

690.7(A) Maximum Photovoltaic System Voltage. An "informational note" (previously called a "fine print note") gives a source of temperature data that could be used to calculate cold weather open-circuit voltage.

690.8(B) Ampacity and Overcurrent Device Ratings. An extensive revision was made to clarify and align PV overcurrent device rating and conductor size calculations with basic requirements found elsewhere in the *Code*. See "Code Corner" in *HP141* for details. DC PV conductor ampacity calculations do not always use the 1.56 Isc factor.

690.10(E) Back-fed Circuit Breakers. Clamping requirements for back-fed circuit breakers in stand-alone systems now include requirements for multimode inverters in grid-tied PV systems with battery backup.

690.11 Arc-Fault Circuit Protection (Direct Current). A new requirement was added for a DC PV arc-fault circuit interrupter. It is required for PV systems having a maximum system voltage of 80 volts or greater with PV circuits on or penetrating a building. The arc-fault protection method must detect series arcs in DC PV circuits, interrupt them, disable equipment, and annunciate. Equipment for off-grid systems is available that addresses this need; other equipment is in development.

Disconnecting Means

690.13 Exception No. 2. A disconnecting means will be permitted in the grounded conductor for maintenance actions and made accessible only to qualified people.

690.16(B) Fuse Servicing. Disconnecting means from all sources of energy shall be located at the fuse location or a directory shall be provided to show disconnect location(s). This requirement is aimed at systems with large inverters, which have DC fuses bolted to an input bus bar, with no way

Code Clarifications

Clarifications to the *NEC* may include grammatical corrections or further explanation. The 2011 *NEC* includes clarifications in the following sections:

690.4(A) Photovoltaic Systems.

690.7(E) Bipolar Source and Output Circuits.

690.9(A) Circuits and Equipment. Exception.

690.9(B) Power Transformers.

690.9(E) Series Overcurrent Protection.

690.13 All Conductors.

690.16(A) Disconnecting Means.

690.43 Equipment Grounding. Clarifications in (A) through (F).

690.74(A) Flexible Cables.

to de-energize those fuses without opening every one of the possibly hundreds to thousands of fuse holders in the distant combiner boxes.

Wiring Methods

690.31(B)Single-Conductor Cable. Informational Note. PV wire has a nonstandard outer diameter and conduit fill tables cannot be used.

690.31(E) Direct-Current Photovoltaic Source and Output Circuits Inside a Building. Corrects a long-standing typographical error and indicates that only DC circuits, not AC inverter output circuits, must be in a metal raceway. Allows metal-clad (type MC) cable to be used for DC circuits inside a structure. Four new paragraphs of requirements have been added regarding routing, protection and marking PV circuits inside the building. Addresses conductor protection, maintenance and firefighter concerns.

Conductors under the roof shall be located a minimum of 10 inches below the roof decking. In accessible areas, small metallic raceways and cable assemblies shall be protected from physical abuse. All access points and exposed conduits will be marked as containing PV power sources.

Grounding

690.43(C). Mounting structures for PV modules shall be identified as equipment-grounding conductors or shall have all parts bonded together and to the equipment-grounding system.

690.43(D). PV module mounting devices used for grounding modules shall also be identified as grounding devices.

690.47 Grounding Electrode System. Substantially revised and clarified. The requirements 690.47(C) in the 2005 *NEC* were merged with the requirements of 690.47(C) in the 2008 *NEC*. See *Code Corner* in *HP133* for details.

690.47(D) Additional Electrodes for Array Grounding, which required additional electrodes for array grounding at all ground- and pole-mounted and some roof-mounted PV arrays, was deleted.

Connection to Other Sources

690.62 Ampacity of Neutral Conductor. This section was moved, with clarifications, to 705.95.

690.63 Unbalanced Interconnections. Referred to 705.100, without changes.

690.64 Point of Connection. Referred to 705.12 with only two changes that affect supply-side connections and multimode inverter utility connections. 690.64(A) becomes 705.12(A) and 690.64(B) becomes 705.12(D).

Storage Batteries

690.72(C) Buck/Boost Direct-Current Converters. Because these devices are designed to alter voltage and current of a PV module or array, a new section has been added to establish how ampacity and voltage requirements are to be calculated for these devices. Although in Section VIII, Storage Batteries, these requirements may also be used for module circuit DC-to-DC converters.

Interconnected Electric Power Production Sources

705.6 System Installation. Qualified persons must do installations of parallel power production sources. Article 100 defines "qualified persons," similar to 690.4(E) Wiring and Connections.

705.12(A) Supply Side. The sum of the ratings of power production sources shall not exceed the rating of the service—you cannot connect bigger PV systems than the utility service conductors can handle.

705.12(D)(2) Exception. This section describes a method of sizing AC output circuits for battery-sourced, multimode inverters operating in utility-interactive systems. The 120% bus bar (or conductor) equation, where allowed, may use 125% of the rated grid-tied inverter current instead of the rating of the back-fed circuit breaker.

Utility-Interactive Inverters

705.60, .65, .70, .80, .82, .95, and .100 contain requirements that duplicate information in various sections of 690.

The Future

Proposals for the 2014 *NEC* are due to the NFPA by November 4, 2011. Sections that are being examined for revisions include: 250.32—Buildings or Structures Supplied by Feeders or Branch Circuits; Figure 690.1(A)—Identification of Solar Photovoltaic

System Components; 690.2—Definitions; 690.4(D)—Equipment; 690.6—AC PV Modules; 690.x—Microinverters; 690.y—DC-to-DC converters; 690.7(E)—Bipolar Source and Ouput Circuits; 690.14—Additional Provisions; 705.12—Point of Connection; and others. If you see a section of the *Code* in 690 that is not abundantly clear, contact me with your proposed changes and substantiations.

For updates on proposals being developed by the PV Industry Forum, visit the Solar America Board of Codes and Standards website at www.solarabcs.org.

Note: This will be the last *Code Corner* written by John Wiles. He will continue to discuss code issues in his "Perspectives on PV" column in the IAEI News (www.iaei.com). These articles will also be available on his website (see Access).

Access

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

Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist, previous "Perspectives on PV," and *Code Corner* articles

Plenty Corny

by Kathleen Jarschke-Schultze

I've been saving seeds for many years now. My friend Jaycin told me once, "Let one of every plant in your garden go to seed." His advice launched me on another small path to self-reliance and sustainability. But I learned from experience to put gardening zone calendars aside—when you live in the mountains, you're in your very own microclimate.

Seedy Neighborhood

I have developed a custom lettuce blend that works wonderfully well in our garden. I use the last of the potatoes in storage for next year's seed. My pumpkins, snow peas, some beans, broccoli, and tomatoes are from seed saved last year. Once you have cilantro in your garden, you will always have cilantro in your garden, since it freely reseeds.

The seeds I fail to collect are spread naturally and sprout as volunteers in the spring. This has been very helpful in determining accurate planting dates for different crops. When the volunteer potato shoots first appear, I plant my seed potatoes. When the tiny lettuces and broccoli show up in last year's rows, I know it is the perfect time to plant those crops. Of course, if it is a good-looking volunteer sprout, I transplant it into this year's beds, or leave it and plant around it.

I have accumulated a collection of small jars and containers to hold my seeds. I also save all the little desiccant packets—a hygroscopic substance used as a drying agent—that seem to come with every boxed product these days. Putting these in with my seeds protects them from moisture and keeps them dry. Everything goes into a hard plastic storage bin with a snap lid.

In the winter, the bin lives under my bed. As soon as the seed catalogs start showing up in the mail, I drag it out and peruse my collection. It doesn't matter how many seeds I have saved—those "new-to-me" varieties are irresistible. I try a few new open-pollinated varieties every year. If they grow well in my garden, I save their seed.

This winter, I was leafing through my favorite seed catalog, *Bountiful Gardens.* All of their seeds are open-pollinated. As usual, I was dazzled by the descriptions, and the names—the wonderful, dream-laden names: Pineapple and Mortgage Lifter tomatoes, Hidatsa Shield Figure beans, Monster of Viroflay spinach, and Homemade Pickle cucumbers.

A Maize

The one crop that has eluded my green thumb is open-pollinated corn. Oh, I have grown corn every year. I used to grow Silver Queen, an excellent-tasting white hybrid. But I have labored for years to find open-pollinated ears that will grow well here.

I have tried Country Gentleman, Golden Bantam, Stowell's Evergreen, Trucker's Favorite, and Bloody Butcher varieties. That's five seasons right there. I can only grow one variety at a time, mostly because of the near-continuous breeze that flows down our small canyon spring through fall. With a cold mountain at the top of the canyon and a warm lake at the bottom, we enjoy a thermal flywheel effect. What is good for our 1 kW wind turbine is not so good for crops, especially in our dry climate.

I grow corn in what would be considered drought conditions. Our average rainfall is 20 to 22 inches per year, so we use drippers to water almost all of our crops, including corn. I remember the first time I was in the Midwest (attending a renewable energy fair) and saw the cornfields. Miles of corn and not an irrigation ditch or rolling sprinkler setup to be seen. I asked someone how it was watered. It rains, by gum, it rains in the summertime in the Midwest, and regularly. California girl that I am, I really had no concept of summer rain.

Last season, I decided to try Festivity, a multicolored open-pollinated corn that can be eaten young for sweet corn. The catalog description alone was enough to get me dreaming: "We are so excited to offer this new open-pollinated sweet corn from Lupine Knoll Farm. A rainbow-colored corn—bred for tolerance to cool soil and low-fertility situations. The seed we offer comes from stock that survived frost as seedlings. Most cobs have a blend of white, yellow, red, and purple kernels. Unlike most multicolor corns, which only develop color when past maturity, Festivity is colorful at the fresh eating stage."

It turned out Lupine Knoll Farm is a local organic farm. What could be better? I bought seed and planted five 20-foot rows. For some reason, the deer here don't eat corn plants, so I planted the crop outside of the fenced garden.

Even though it was not a particularly good year for corn in our county, this corn grew. It did not reach its full height, but the main stalk and many of the side suckers bore ears. The ears were sweet and corny-tasting. First, the kernels are white

and yellow, then they change color. The really great thing is that the corn is still sweet and tender at the beginning of the colored stage. We tried to eat the fresh ears as they ripened, but they got away from us.

If I found an ear that had colored too far, I left it to mature. At the end of the season, I had two 7-gallon buckets of shucked ears to dry. Next stop: the drying shelves in my greenhouse.

Dried

Bob-O had set up drying racks on my planting shelves using the little protective plastic corners that came with Evergreen PV modules shipped on a pallet. There were 30 modules to a pallet, four corners to a module, so I have plenty of stacking corners to repurpose.

I reuse plastic trays from old electric food dryers and low-sided plastic plant flats from nurseries. They stack up just fine, with plenty of air space in between. Bob-O installed an old 33 W module outside of my greenhouse and connected it to a 12-inch 12 VDC cooling fan inside. By propping the fan up on its side, all of the airflow is directed through my stacked drying trays.

I dried the corn and then rubbed it off the cobs. Leather gloves worked well for that task. I ended up with 2 gallons of dried corn.

The Old Grind

Since my corn was a descendant of Painted Hills corn, which you can dry and grind, I decided I would make some cornmeal. I dug out our ancient hand-crank mill, and Bob-O and I took turns grinding the corn into meal. Turning the crank was slow going, and the grinding was a workout for our biceps. I made cornbread—it wasn't half bad.

Motivated by tired arms, Bob-O bought a grain mill attachment for our Champion juicer. It works like a champ on dried corn. Easy, fast, fresh organic cornbread has become a household favorite.

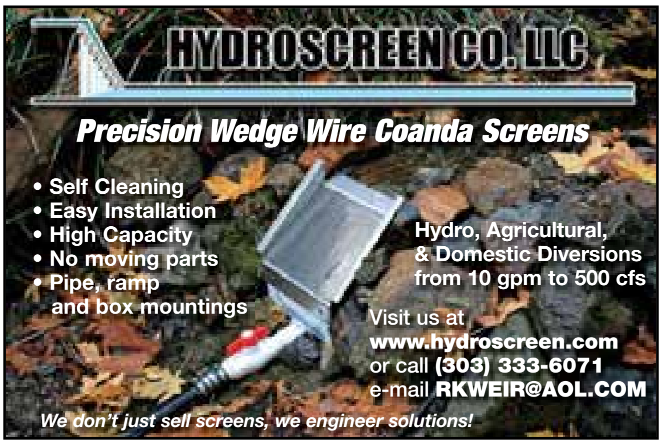
Seeking out ways to become self-reliant and sustainable in any facet of your life is indeed its own reward. From a little seed, freedom, food, and our future are as rainbow-colored as my corn.

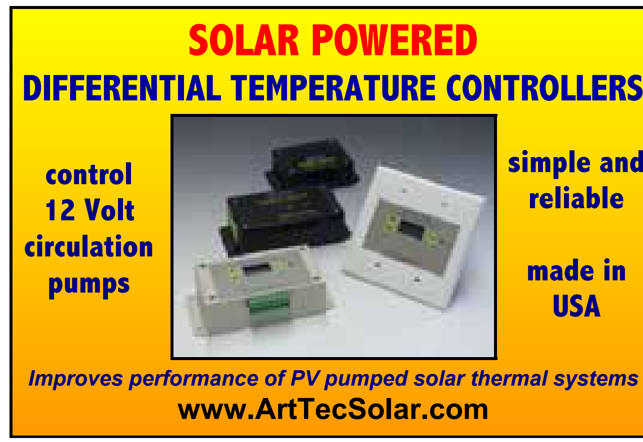
Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is trying out a new cold frame scheme in the garden at her off-grid home in northernmost California.


RightHand Engineering, LLC
Experts in Renewable Energy Monitoring:
• Non-recurring fees
○ Residential
○ Community Kiosks
○ Multi-site Telecom
○ WinVerter Software
○ Custom Solutions
○ Consulting
• On & Off Grid
• Display, Log, Alarm
• On-Site Displays
• Internet Accessible
www.RightHandEng.com
(425) 844-1291

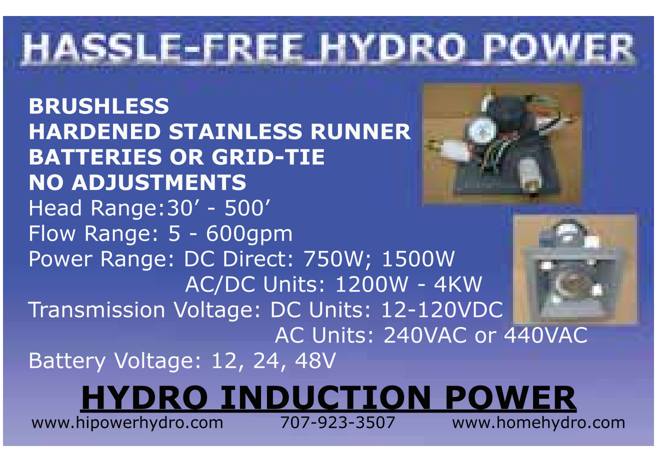

H-HYDRO.COM
A turbine sized to your site:
from 50W to 500kW,
82-700mm pitch diameter.
Do-it-yourself or OEM
Engineered composite
or hardened stainless spoons.
Since 1999.
Custom systems from 2kW up.


HYDROSCREEN CO. LLC
Precision Wedge Wire Coanda Screens
• Self Cleaning
• Easy Installation
• High Capacity
• No moving parts
• Pipe, ramp
and box mountings
Hydro, Agricultural,
& Domestic Diversions
from 10 gpm to 500 cfs
Visit us at
www.hydroscreen.com
or call (303) 333-6071
e-mail RKWEIR@AOL.COM
We don't just sell screens, we engineer solutions!


SOLAR POWERED
DIFFERENTIAL TEMPERATURE CONTROLLERS
control
12 Volt
circulation
pumps
simple and
reliable
made in
USA
Improves performance of PV pumped solar thermal systems
www.ArtTecSolar.com


SOLAR CHILL
LOWEST ENERGY
PV COOLING
DC or AC
520.885.7925
SOUTHWEST-SOLAR.COM


User Friendly Hydro Power
Alternative Power
& Machine
Now Featuring Permanent Magnet Alternators
4040 Highland Ave. Unit #H • Grants Pass, OR 97526 • 541-476-8916
altpower@grantspass.com
www.apmhydro.com


HASSLE-FREE HYDRO POWER
BRUSHLESS
HARDENED STAINLESS RUNNER
BATTERIES OR GRID-TIE
NO ADJUSTMENTS
Head Range:30' - 500'
Flow Range: 5 - 600gpm
Power Range: DC Direct: 750W; 1500W
AC/DC Units: 1200W - 4KW
Transmission Voltage: DC Units: 12-120VDC
AC Units: 240VAC or 440VAC
Battery Voltage: 12, 24, 48V
HYDRO INDUCTION POWER
www.hipowerhydro.com
707-923-3507
www.homehydro.com


RAE
STORAGE BATTERY
ESTABLISHED 1945
Authorized Rolls Battery Dealer
www.raestoragebattery.com
Renewable energy does not mean continuous energy. Therefore, you must have dependable, reliable batteries...
Rolls, the World's Best.
• Unsurpassed cycling
• Industry's largest liquid reserve
• 10 & 15 year average life span
• 7 & 10 year warranties
Phone 860.828.6007
Fax 860.828.4540
POB 8005 Berlin, CT 06037

AAA Solar Supply....116
ABS Alaskan Inc. 85
AEE Solar 3
Affordable Solar Group 77
aleo solar North America 61
altE 52
Alternative Power & Machine 120
Apex Solar 103
Appalachian State University 93
Array Technologies 113
ART TEC Solar 120
Backwoods Solar Electric Systems....85
Bogart Engineering 76
Bornay 78
Butler Sun Solutions 112
BZ Products 112
Canadian Solar 28
Conergy Inc. 43
Delta Energy Systems 53
EcoFasten Solar 93
Electron Connection 92
Energy Systems & Design....111
Enphase Energy....18
ET Solar 69
EZ RACK....117
Fronius USA ....BC
Fullriver Battery USA....86
groSolar....31
Harris Hydro....60
Hartvigsen-Hydro 120
Home Power on Facebook 122
Hydro Induction Power 120
Hydrocap Corp. 121
Hydroscreen Co. LLC....120
Lighthousesolar....16
Magnum Energy.... 8/9
Maverick Solar 103
MidNite Solar Inc. 87, 113
Mitsubishi Electric....19
MK Battery 15
Morningstar Corp. 78
NABCEP 68
Northern Arizona Wind & Sun....113
Northwest Energy Storage 101
Off-Grid Engineering Inc....85
OutBack Power Technologies.... 10/11
Power-One ....IFC
PowerSpout 112
Quick Mount PV....29
RAE Storage Battery Co. 120
REC 2
RightHand Engineering....120
Rolls Battery Engineering ....IBC
S-5!....38
Schletter Inc....103
Schneider Electric 41
SMA America LLC. 25
SnapNrack....17
Solar Data Systems Inc....40
Solar Depot/DC Power Systems.... 4/5
Solar Heat Exchange Manufacturing...117
Solar Pathfinder....117
SolarWorld....35
Solectria Renewables 37
Solmetric Corp....113
SolSolutions LLC 111
Southwest Solar 120
Southwest Windpower....42
Stiebel Eltron Inc. 67
Sun Electronics....121
Sun Frost 121
SunDanzer....86
SunEarth....121
SunWize Technologies....33
SunXtender 32
Super Bright LEDs....112
TED - The Energy Detective 117
The Energy Fair....102
Thermomax 93
Trina Solar....22
Trojan Battery Co. 23
U.S. Battery 79
UniRac Inc. 1
US Solar Distributing....39
Zomeworks Corp....116

For easy online access to advertisers, visit www.homepower.com/resources/advertisers

Edge-of-Cloud Effects

It is no surprise that under clear skies a PV system's power output will be high—and that under cloud cover output will be lower. But what can happen to output when it's partially cloudy? On these days you may see PV output jump around dramatically. If you watch your meter closely, you may even see power output exceeding the array rating.

At my house I have a 1,700 W array connected to a 2,000 W inverter—I have seen my inverter power output read up to 2,124 W, which is 125% of the array's rating. This is due to "edge-of-cloud effect," which happens when the sun's rays are briefly intensified by the edges of nearby clouds.

These events are exciting to observe, since they are outside of the norm. We normally see only about 70% to 80% of the system's rated power output—due to high module temperature, dust, inverting losses, etc. Edge-of-cloud effects provide only momentary bursts of increased output, so the increase in *energy* (kWh) production is negligible. Also, edge-of-cloud effects only occur in cloudy weather, which means the sun will spend some time *behind* the clouds, causing significantly lower energy output compared to a clear-sky day.

Sometimes, edge-of-cloud effects will cause higher solar radiation than a clear blue sky.

The author's 1.7 kW PV array at 125% of its rated output due to an edge-of-cloud effect.

Justine Sanchez

When sizing wires and overcurrent devices, system designers multiply the PV output rating by a factor of 1.25 to account for potential increases in array output. That buffer is intended for "continuous" (three hours or more) conditions, such as reflection from snow or water that may cause output to exceed STC ratings—not for momentary conditions such as edge-of-cloud effect.

If the array output is close to or exceeds the inverter rating, some power "clipping" may occur that wastes the excess power from an edge-of-cloud event. For my 2,000 W inverter, the manufacturer says power clipping will occur if array output exceeds about 10% of the inverter's continuous output rating. Some people oversize their inverter so that even temporary spikes of power output can be harvested, while at the same time extending the life of the inverter by not running it close to its maximum rated output.

—Justine Sanchez