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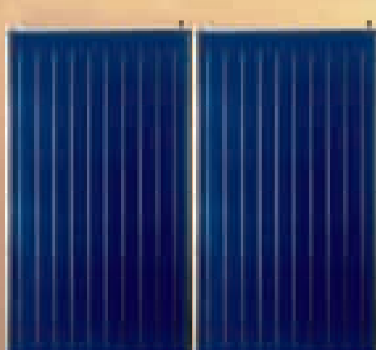

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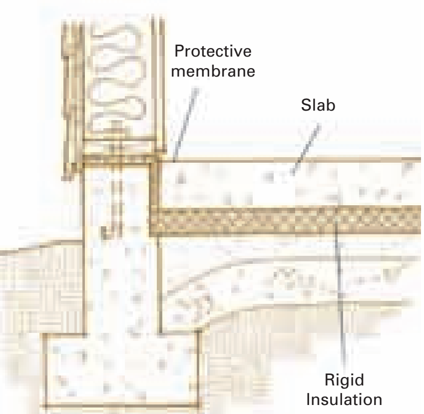


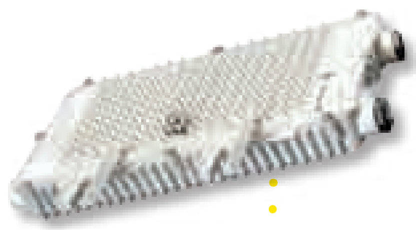



Clockwise from bottom left: www.morningstarcorp.com, Martha Garstang Hill, Candace Gossen, John Swain & www.mkd-arc.com, Tom Robinson, Laurie Guevara-Stone, www.enphaseenergy.com

## On the Cover

Michelle Kaufmann Designs' Smart Home, one in a new wave of energy-efficient and green-built modular homes.

Courtesy John Swain & www.mkd-arc.com





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**from us** *to you*

# Measuring Matters

We're all about using renewable energy, and we want to provide the tools to help people find systems that suit their energy needs. But if you only know that you use "a lot" of energy, you will discover only that it will cost you "a lot" to make it with sunshine. If you want to reduce your home's energy use and also formulate a plan for an RE system, you will need to get specific about what is using all that energy. Sometimes that's easier said than done.

Your utility bill will show how many total kilowatt-hours (kWh) per month your entire household uses, but that won't really show you where to make your improvements. So how do you get accurate numbers for individual loads? An inexpensive meter such as the Watts Up? or Kill A Watt can measure 120 VAC plug-in loads, but what about hardwired loads and 240 VAC loads? In some cases, you can look at the nameplate to find the appliance's power rating (in watts), and multiply by hours of use. In other situations, it's harder, especially with cycling loads such as clothes dryers, water heaters, and heat pumps. That's where hardwired utility-style kilowatt-hour meters can come in handy.

Recently, the energy club in my neck of the woods installed five inexpensive, refurbished utility-style kWh meters on one conventional, electric-tank water heater and four electric backup heaters connected to solar hot water systems. So far, we're seeing roughly 10 kWh consumed per day by the conventional heater, and half of that or less consumed by the SHW backup heaters.

We're also going to monitor two heat pumps and their backup heaters. Manufacturers claim that heat pumps are two to five times more efficient than other electrical heating sources. But it's difficult to find real-world numbers from actual homes, since heat pumps are rarely monitored separately from the rest of the house.

Measuring the energy use of specific appliances helps us be smarter about how we use energy, and helps us make better renewable energy decisions. Over the next few years, we hope to have some hard data to share, and we hope our research will help existing and future RE users.

Maybe someday monitoring technology will be incorporated into every home design, making it easy for homeowners to understand how much energy each appliance is using—and better yet, how much each is wasting.

—Ian Woofenden for the *Home Power* crew

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*Think About It...*

*"We can create a more sustainable, cleaner and safer world by making wiser energy choices."*

*—Robert Alan, American writer, artist, social activist*

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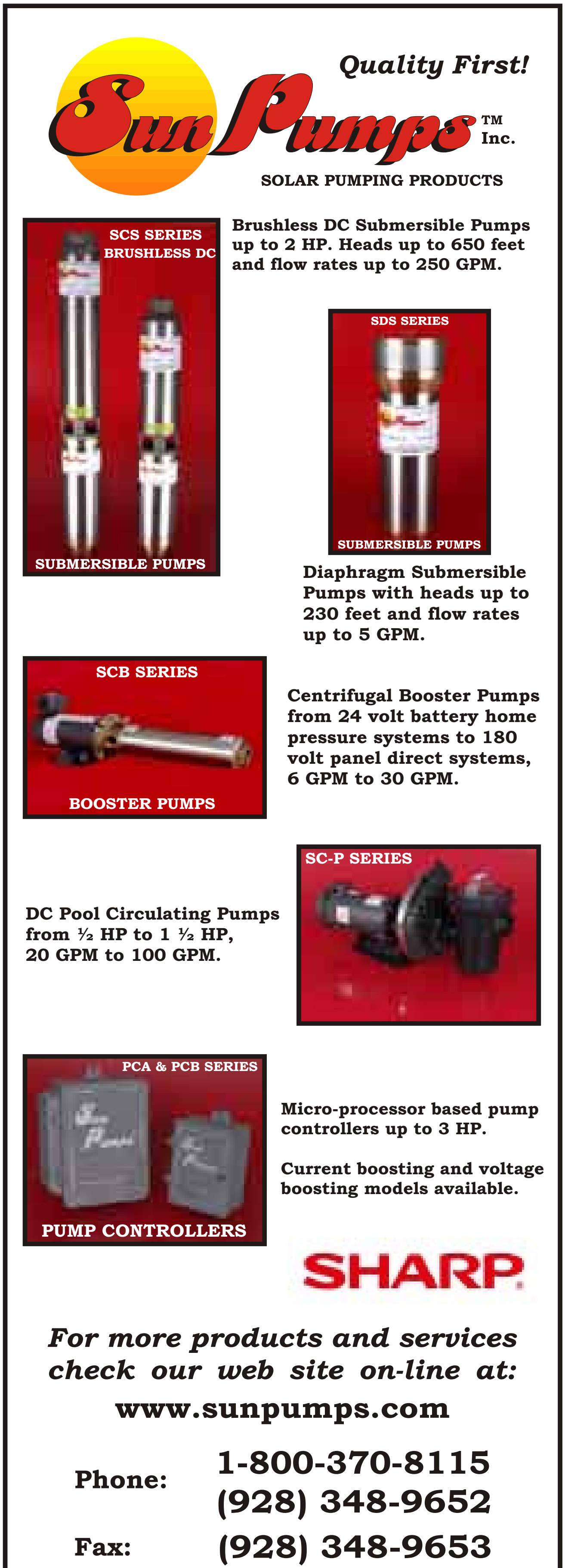


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## Stepping Out with Solar Power


Courtesy Solar Power International

**California governor Arnold Schwarzenegger checks out the latest in solar technologies at the Solar Power International conference.**

The impacts of the federal investment tax credit (ITC) extensions for renewable energy and the recent international economic downturn were hot topics last October at the Solar Power International conference in San Diego, California. Keynote speakers included California governor Arnold Schwarzenegger, who spoke about how California has led the nation in solar legislation and implementation, and General Wesley Clark, who focused on how energy independence will increase national security. John Jacobs, executive vice president of NASDAQ, discussed the current Wall Street predicament and the large rise in venture capital flowing into clean energy projects.

While each speaker had a unique perspective regarding the solar industry, all agreed that solar seems to be the bright spot in the economic crisis. With the passage of the federal ITC extensions, Rhone Resch, president of Solar Energy Industries Association (SEIA), pointed out that the solar industry is predicted to receive $320 billion of new economic investment and provide 440,000 new jobs.

These topics, among many others, were discussed over the four-day conference, considered by many in the solar industry to be North America's premier solar business event. Hosted by the Solar Electric Power Association and SEIA, and presented in conjunction with California Center for Sustainable Energy's Solar Energy Week, the event was attended by an estimated 23,000 people. The 425 exhibitors included solar manufacturing equipment and material suppliers, installers and system integrators, policy makers, and nonprofits.

The expo hall featured row after row of new international solar equipment manufacturers. And while all the sparkling, new PV modules and big-time utility-scale inverters were impressive, perhaps most striking were the booth setups themselves. Many solar businesses had multistory arrangements that allowed for temporary business offices to be set up on the upper levels for one-on-one meetings, while event-goers checked out product displays on the expo floor.

In addition to the expo hall, the conference offered many educational and networking opportunities to those working or interested in the solar industry, including pre-conference workshops, tours, conference sessions and CEO roundtable discussions, and even a downtown block party to celebrate the ITC extensions and overall massive solar industry growth.

This conference is intended to be primarily a business-to-business event, where solar energy professionals from across the globe strengthen existing business relationships and develop new ones. Everywhere you looked there were business meetings being held in every possible location, from meeting rooms and hallways to nearby restaurants.

The excitement this time surrounded "big" solar: commercial, industrial, and utility-scale systems. With ITC extensions now available to utilities, large-scale solar growth is poised to establish the United States as the new hot market for the global solar industry. While the current economic crunch will likely slow down venture capital flowing to new projects, many in the solar industry see this as simply a short-term issue. In her closing speech, SPI chairwoman Julia Hamm challenged the solar industry to "be bold, be innovative, be strategic," advising collaboration between the solar industry and utilities to "turn this economic hardship into a silver lining."

With ITC extensions now available to utilities, large-scale solar growth is poised to establish the United States as the new hot market for the global solar industry.

The 2009 Solar Power International conference is scheduled to take place next October at a larger venue in San Jose, California, in hopes of being prepared for the growth in the solar industry that 2009 is predicted to bring. For more information, visit the Solar Power International Web site at www.solarpowerconference.com.

—Justine Sanchez

## SolarWorld Opens Largest Cell Manufacturing Facility in North America

**Hillsboro, Oregon**—On October 17, 2008, SolarWorld USA opened a new cell manufacturing facility in Hillsboro that will ramp up to a 500-megawatt annual production capacity by 2011. More than $500 million will be invested in the new facility that houses both crystal growing and cell manufacturing equipment. SolarWorld's Vancouver, Washington, plant will continue crystal growth activities. The third SolarWorld U.S. plant, located in Camarillo, California, has been retooled and dedicated exclusively for photovoltaic module assembly.

In 2006, SolarWorld AG acquired the crystalline PV module manufacturing assets of Shell Solar, which had previously operated as Siemens Solar and Arco Solar, dating back to 1977. Today, SolarWorld's family of companies is dedicated exclusively to solar energy. The Hillsboro facility is a sign of the company's continued growth and investment in global PV supply.

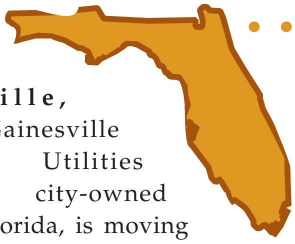
"The Pacific Northwest possesses a hotbed of talent in both silicon manufacturing and clean technologies. Oregon is the obvious choice for where to undertake this new level of solar cell manufacturing," says SolarWorld's U.S. chief operations officer Boris Klebensberger.


Courtesy Christina Williams

As an Oregon-based business, *Home Power* is proud of the state's ongoing efforts to accelerate renewable energy use and equipment manufacturing. SolarWorld's move to Oregon was facilitated by the proactive efforts of Governor Ted Kulongoski, the Oregon Department of Energy, and the city of Hillsboro. Together, they created an environment that assisted SolarWorld's decision to open their new facility in Oregon, which will create high-tech jobs, and more PV for the U.S. and beyond.

—Joe Schwartz

## SHORTS



**The Sunshine State is living up to its name, with two revolutionary plans to increase solar energy production.**

**Gainesville, Florida**—Gainesville Regional Utilities (GRU), a city-owned utility in Florida, is moving forward with an ordinance for a *utility-driven* feed-in tariff for solar electricity. Under the plan, the utility agrees to buy all electricity produced by solar-electric systems for 20 years from the time a project is installed—at a guaranteed set rate that is above market value.

If city commissioners pass the ordinance as expected, GRU would be the first municipally owned utility in the nation to adopt a feed-in tariff policy. This policy would allow customers to profit if they produce more solar electricity than they use. California, which is currently the only other state with a feed-in tariff, allows customers to offset their utility bills but not profit from surplus production.

The plan is modeled after Germany's feed-in law, which provides customers with preferential prices for solar-generated electricity. GRU executives were among a group of utility executives who recently traveled to Germany with the Solar Electric Power Association to see how European utilities are encouraging private investment in renewable energy.

Germany's feed-in tariff is credited with making it one of the largest, and arguably most successful, solar markets in the world. The hope is that Gainesville Regional Utilities' plan will bring that level of success to Florida.

**Lakeland, Florida**—Florida's third-largest public power utility, Lakeland Electric, has partnered with solar energy giant SunEdison to install 24 megawatts of PV power. With an average of 214 watts each among Lakeland Electric's more than 100,000 customers, the PV program promises to be one of the largest utility-backed projects in the United States.

SunEdison will be responsible for funding and installing the systems for Lakeland Electric, as well as monitoring and maintenance. Both ground-mounted and roof-mounted systems will round out the 24 MW of installed PV capacity.

## Microinverters Hit the Market

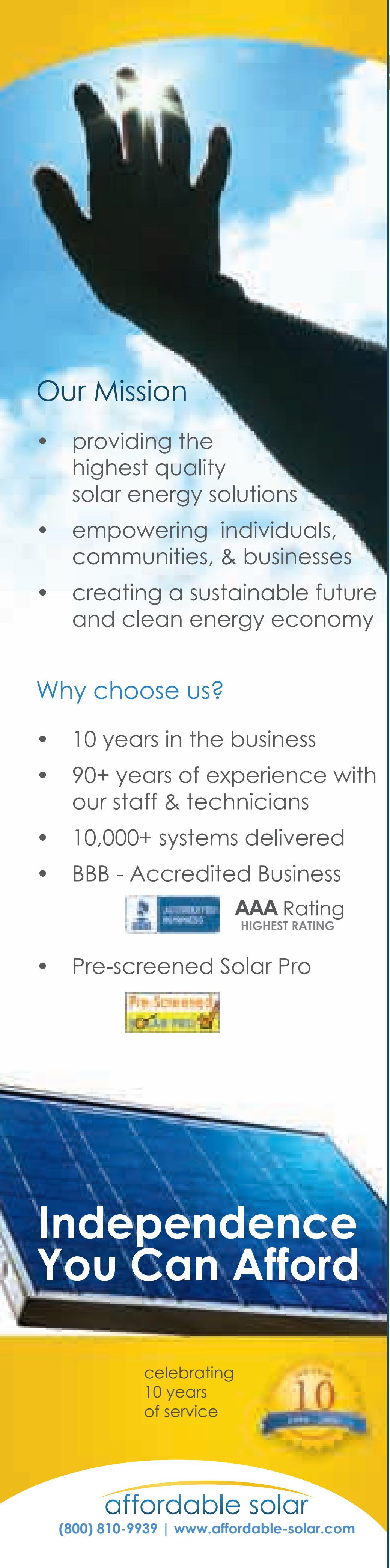
With maximum power point tracking on a per-module basis, **Enphase Energy's** (www.enphaseenergy.com) microinverter system is creating much buzz in the PV industry. The microinverter allows each module to operate independently of others in the array, reducing power losses caused by partial array shading, mixed module types, mixed orientations, and equipment failures.

Each module is wired to a single microinverter, which is generally mounted behind the module on the array racking system. The AC output of each microinverter is plug-and-play cabled in parallel to the other module/inverter pairs in the array. AC electricity is connected to the utility grid via a back-fed circuit breaker in the main load panel. This approach eliminates high-voltage DC wiring and DC disconnect gear required for central-inverter-based PV systems. Because the output of the array is standard AC, the installation is more familiar and straightforward for electricians and inspectors.

The Envoy, a communications gateway, can be used to send information over a broadband Internet connection to Enphase's Enlighten Web site and monitor the performance of each module/inverter pair. Friendly graphics allow users to view their system performance and easily identify system problems on a per-module basis. Also offered is 24/7 system monitoring and analytics automatically performed by proprietary software, allowing Enphase technicians to detect system problems and offer solutions to system owners.

While these microinverters are new players in the PV industry, each comes with a 15-year standard limited warranty. For more information, see "PV Micromanaging" in this issue.

—Justine Sanchez



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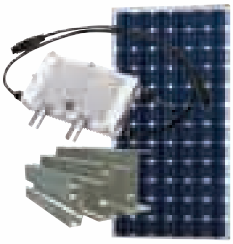

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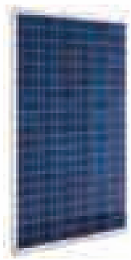

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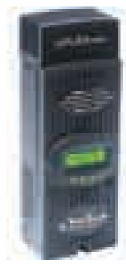

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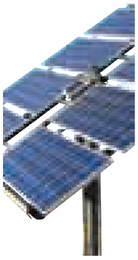

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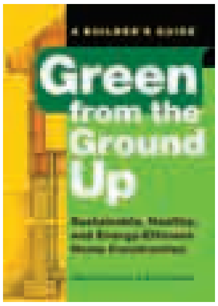
## Fronius & Motech Make Efficiency Gains

**Fronius USA** (www.fronius-usa.com) inverters gained an efficiency boost this fall with the launch of their IG Plus series. Boasting California Energy Commission weighted efficiencies of 96%, the inverters are available in sizes from 3 to 12 kW. These inverters include a built-in, six-string combiner box to simplify installation and keep costs down. The AC output of each unit can be field-set to 208, 240, or 277 volts, to allow for use in either residential or commercial applications.

Another enhancement is the ability to disconnect the inverter from the wiring connection area, making disconnection for service or repair a snap. Simply unplug it from the bottom wiring area, and you're good to go.

Taiwan-based **Motech Industries** (www.motech.com.tw), with more than 20 years of experience in PV cell manufacturing, has introduced the PVMate series inverter in the United States. Their transformer-based models are UL listed, and available in sizes ranging from 2.9 to 5.3 kW. This inverter line has a CEC weighted efficiency of 96%. The PVMate has a built-in four-string combiner box, and the ability to disconnect the inverter from the DC/AC wiring box for servicing without having to unwire the system.

—Justine Sanchez



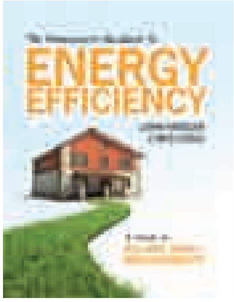

### Green From the Ground Up: Sustainable, Healthy, and Energy-Efficient Home Construction

Taunton Press, $24.95

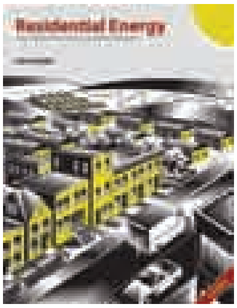
From David Johnston and Scott Gibson comes a new resource for the builder, contractor, and involved homeowner interested in the what, why, and how of green construction. This 2008 release provides a comprehensive overview of the various systems, materials, theories, and methods used for new construction and retrofits in the residential market. Color photos, sidebars, graphics, and straightforward text speak to novices and professionals alike.

### The Homeowner's Handbook to Energy Efficiency: A Guide to Big and Small Improvements

Saturn Resource Management, $24.95




John Krigger and Chris Dorsi take the mystery out of home efficiency projects, from simple fixes to large-scale renovations. Detailed instructions walk readers through the process of assessing energy usage, and predicting the benefits and estimating the costs of remodeling options.




### Residential Energy: Cost Savings and Comfort for Existing Buildings

Saturn Resource Management, $35.00

Used as a textbook for technical schools and courses, this entry-level resource breaks down the fundamentals with formulas, graphics, and tables. Regularly updated and expanded editions deliver up-to-date information on building efficiency, comfort, and durability—with an emphasis on residential heating and cooling.

—Rachel Connor

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## SunEnergy Power International

# Shining Light into Dark Corners of the World

Courtesy SunEnergy Power International

Four days from the nearest road in the mountainous jungle, along the Thai/Burma border, a medical training center and clinic struggled without electricity. Doctors treated patients by candlelight and kerosene lamps, and relied on a small portable engine–generator to charge batteries for basic medical and training equipment. Free Burma Rangers, a local humanitarian group, set up the facility to train medical teams to go on foot into the mountains to care for the region's numerous tribal and ethnic groups—but the primitive conditions limited their efforts.

Enter Walt Ratterman, the face of and driving force behind SunEnergy Power International (SEPI). An electrical contractor with three decades of experience working on commercial electrical construction and solar installations, 56-year-old Ratterman set up the nonprofit in 2005 in an effort to improve the quality of life in remote, rural regions of the world through the use of renewable energy. Through their own projects and partnerships with other like-minded groups, the SEPI crew lends their industry know-how to humanitarian RE projects around the world.

**In a region torn apart by years of civil war, and characterized by armed conflict, generalized violence, and human rights abuses, even limited electricity makes a world of difference.**

For its latest project in the Thai/Burma area, SEPI partnered with the Border Green Energy Team in Mae Sot, Thailand, which provided local support and helping hands. Thanks to the collaborative efforts, the medical facility now has the electricity needed to improve its training and provide a greater level of care. A 3 kW PV system supplies electricity for lighting, computers, a satellite communications system, projectors, microscopes, and an eye-surgery machine.

"In a region torn apart by years of civil war, and characterized by armed conflict, generalized violence, and human rights abuses, even limited electricity makes a world of difference," says Ratterman, who spends most of his time globe-trotting to oversee SEPI projects ranging from solar water pumping systems in Pakistan to microhydro resource assessment in Ecuador.

In its three years, SEPI has worked on dozens of RE installations and consulted on numerous other projects—including nationwide assessments of electrical distribution systems in Ethiopia, Guyana, and Haiti. Next up is a solar-electric project in Sierra Leone for remote medical clinics. Then on to Haiti to build RE systems for 30 HIV/AIDS clinics and a handful of hospitals. After that, back to the Thai/Burma region for an installation on a hospital. With each trip, SEPI brings a little more light to those in need.

—Kelly Davidson

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**Solar Power & Pump Co. USA**, www.togosolar.com, Tel. (866) 246 7652 (toll free), Fax (580) 225 1120

Courtesy Solar Living Design

PROJECT: Ive–Benjamin residence

SYSTEM TYPE: Residential grid-direct PV

INSTALLER: Solar Living Design, www.solarlivingdesign.com

DATE COMMISSIONED: July 2008

LOCATION: Lakewood, Colorado, 39.7°N latitude

AVERAGE DAILY SOLAR RESOURCE: 5.5 peak sun-hours

ARRAY CAPACITY: 9.12 kW STC

AVERAGE ESTIMATED ANNUAL PRODUCTION: 12,901 AC kWh (per PVWatts)

AVERAGE ANNUAL UTILITY ELECTRICITY OFFSET: 100%

MODULES: 48 Sanyo HIT Double bifacial, 190 W STC each

INVERTERS: Two Sunny Boy 5000U, 10 kW rated output

ARRAY INSTALLATION: Integrated awning designed by Solar Living Design, 22° tilt

# Sun & Shade with a 9.12 kW PV Awning System

Besides plans for PV, Diana Ive and her husband Delmar Benjamin wanted a patio constructed to shade the large, south-facing deck and bank of southeast-facing windows, which admitted too much sun into the house during the summer months.

So when Diana stumbled across a rendering of a solar-electric awning over a walkway that used glass-on-glass modules, the wheels started turning. She sought out local PV installer Greg Koss of Solar Living Designs to see how the modules could be integrated into a patio structure. Koss found the modules: Sanyo's HIT series of bifacial modules, which generate energy from both sides of the module while allowing some light to pass through. But the question of how to best incorporate the modules into a shade structure was turned over to Delmar.

Famous in aviation circles for flying his Gee Bee racer, an airplane many called the "Widow Maker," Delmar had lots of experience working and designing with aluminum after decades in the aviation industry. He agreed to design the awning structure to support the modules, paying special attention to strategies for hiding the wiring and keeping the back of the array free from shading.

**Delmar agreed to design the sealed awning structure to support the modules, paying special attention to provide strategies for hiding the wiring and keeping the back of the array free from shading.**

"Delmar paid exceptionally close attention to detail," Koss says. "I can remember hanging one of the aluminum beams: Delmar checked the measurement, and it was 1/8 of an inch off. We pulled it, drilled new holes, and got it back up within 1/16 of an inch." In the end, it was this attention to detail that made everything slide into place perfectly, resulting in a beautifully constructed array.

After the PV installation was complete, simulated white marble porcelain tiles were laid on the patio deck below the array canopy. With their relatively high reflection value, they help bounce more of the sun's energy to the bottom of the modules. After laying the tile, says Koss, the array's output increased by about 6%.

—Justine Sanchez, with Greg Koss


## How do we build the most efficient commercial PV inverters in the world?

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# PV Meter Reading

**For batteryless, grid-tied systems, inverter meters are the system watchdogs, telling you how much power and energy is being generated, and alerting you to problems–if you know how to interpret what they're saying.**

**Today's inverter meters make it easy to keep tabs on your PV system.**

Courtesy Khanti Munro

## Output Power (Watts)

This is an instantaneous reading of how much AC power the system is producing and back-feeding into the AC load center. Because this value is the final output of the system, inefficiencies and variables, such as module temperature, irradiance, dust, and inverter efficiency, have already been accounted for. At midday, with clear and sunny skies, this value should be 70% to 80% of the array's STC rating.

## Energy Produced (Kilowatt-Hours)

This value tells us how much energy has been produced so far that day. Cumulative energy production may also be reported. Although the daily kWh produced depends on several factors, including array size, site location, time of day, time of year, and cloud cover, at the end of a sunny spring or fall day, you should see the average kilowatt-hours per day your system was designed for. For example, if your system was designed to annually produce 2,500 kWh, at the close of an average solar day, your meter should read close to 6.8 kWh.

Troubleshooting tips: If output power (W) or energy (kWh) values are significantly lower than expected, visually inspect the array and look for shading (perhaps trimmed hedges have grown back) and dirty PV modules, and check for blown series string fuses.

## PV Array DC Voltage (Volts)

Array input voltage can be interesting to observe, especially during hot or cold weather. Voltage decreases as PV cells heat up and increases as the cells get colder. Array voltage should remain within the inverter's voltage input specifications under all temperatures experienced at your site.

## PV Array DC Current (Amps)

As solar irradiance increases or decreases, this value fluctuates. For example, as clouds roll in and block the sun, the current reading (and the output power) of the system will be reduced. This is normal, and you will see these numbers rise again when the cloud-cover disappears.

## ...And More

Some inverter meters include other readings, such as utility AC voltage, amperage, and frequency; pounds of carbon dioxide offset; historical maximum system output (watts and volts); and total inverter operating hours. Inverter meters also have an error menu that can be accessed and used for troubleshooting.

—Justine Sanchez

# Protect Against Rising Energy Costs With a SunWize© Grid-Tie System




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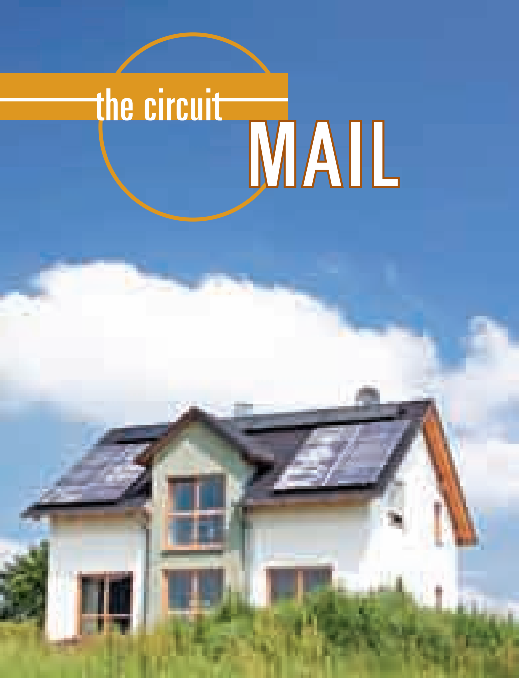

### FREE PV, FREE INSTALLATION

**How would you like to have a free solar-electric installation? Wishful thinking? Illegal? No. Perfectly legal. And simple.**

**Included in the "$700 billion bailout" is a provision that the 30% energy tax credit for photovoltaic installations will continue. And after January 1, 2009, it will not be limited to a $2,000 cap for residential systems. So, now you get a 30% tax credit. Many states and local electric companies also offer additional rebates or credits.**

**Now we get to the free part. If you are over the age of 59½, you can draw out your retirement account funds. The problem is that you must pay federal and state income tax on those funds. If you are still in a high income-tax bracket, then there is a substantial tax rate, and many people choose to defer taking any money out of their retirement account until they must.**

**The new tax credit, and additional rebates and credits, means that often any tax paid on the retirement funds removed will be offset by credits or rebates. The result is that you simply move some of your retirement money from your retirement account to pay for a solar-electric array, with no cash out of pocket. The investment will reduce your utility bill and increase the value of your home.**

**Colin Lamb • via e-mail**

Courtesy www.miele.com

### SAVE ENERGY WITH INDUCTION COOKING

Induction cooktops can be powered by homemade electricity and are ideal for net zero-energy, all-electric solar homes, using up to 35% less electricity compared to regular electric-coil cooktops.

Induction cooking is faster than gas, stays cooler to the touch than electric for easy cleaning and safety, and does the job without wasting much heat into the kitchen air. And it's energy efficient.

Induction cooktops pulse electromagnetic waves directly to the food inside a pot or pan that acts as the conductor. Regular electric cooktops waste electricity by first heating up the element, then the glass/ceramic top, then the pot or pan, then the food. When you're done cooking, it all has to cool off by dumping heat into the air.

Like a car powered by an electric motor, induction uses electricity only when and where needed, so there are few warm-up losses, no idling waste, and very little cool-off waste.

But this technology is expensive up front: $1,500-plus for a four-burner built-in model ($100-plus for single-burner hot plates). Repairs are not cheap or easy, but not frequent, either—my mother still has her Kenmore induction cooktop from 1985.

Bottom line—if you "need" it, get it. But, if you just "want" it, make sure you have cooking performance in mind primarily so you don't misappropriate your sustainability dollars on induction just because it's "energy efficient." Invest that money in your building envelope, which in turn saves on HVAC, which then leaves money for appliances. Done right, the remaining savings can be spent on induction cooking or renewable energy.

Mike Cohn • Environmental & Consumer Advocate, San Francisco

### BATTERY CYCLE LIFE

*The battery guide published in* HP127 *included specifications for battery cycle life for each battery model listed in the article's table. The article did not mention that the battery industry has no standard testing protocol for battery cycle-life specifications. The battery cycle-life data published by various manufacturers is determined with testing procedures set*



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*by each manufacturer, and some are more conservative with their cycle-life ratings than others. As a result, cycle-life data currently does not give an "apples to apples" comparison.*

*Standard testing protocols exist for newer technologies like inverters and photovoltaic modules. These standards are good for consumers and the renewable energy industry as a whole.* Home Power *strongly encourages the battery industry to develop standardized battery cycle-life testing protocols. Doing so will help system designers and installers, as well as end users, in selecting the best battery for a given application and create realistic expectations for battery longevity.*

*Joe Schwartz* • Home Power

## SINGLE-WALL HEAT EXCHANGERS

*The article on heat exchangers that was published in* HP128 *included language from Section 405.1 of the* Uniform Solar Energy Code (USEC)*. The article stated that double-wall exchangers were required on solar energy systems heating potable water, with no exceptions. Some readers took issue with this statement.*

*To clarify: In the context of codes, an "exception" is a special blanket alternative to a code provision. It will be published below the provision and start with the word "exception" in bold print. Exceptions usually have one or more conditions that must be adhered to for the exception to be an accepted alternative to the requirement. There are no exceptions to 405.1 published in the 2006* USEC*.*

*The* USEC *also includes an Appendix D that gives guidance for "Engineered Systems," including this definition: "Engineered Solar System: A system designed for a specific building project with drawings and specifications indicating materials to be installed, all as prepared by a person registered or licensed to perform solar design work." The guidance in the appendix gives conditions that must be adhered to in order to conform to the intent of the code when a single-wall heat exchanger is specified in an engineered system:*

Appendix D 3.2
Single-wall heat exchangers shall be permitted if they satisfy all of the following requirements:
1) The heat-transfer medium is either potable water or contains essentially nontoxic transfer fluids having a toxicity rating or class of 1 (see Section 206).
2) The pressure of the heat-transfer medium is maintained at less than the normal minimum operating pressure of the potable water system (UPC:L3.2).
Exception: Steam complying with Section L3.2 (1).
(3) The equipment is permanently labeled to indicate that only additives recognized as safe by the FDA shall be used in the heat-transfer medium.

*Appendix D 3.2 pertains to engineered systems, the approval of which is up to the local authority having jurisdiction (AHJ), a.k.a. the local building or plumbing department.*

*At first glance, Section 405.1 and Appendix D 3.2 may seem to be at odds. This has led many AHJs to make new, specific rulings related to the use of single-wall systems that are gaining popularity nationwide, while ensuring their safety. This past November, for example, Oregon's Building Codes Division proactively approved the use of single-wall systems statewide as long as several conditions are met.*

*Chuck Marken • Solar Thermal Editor*

## MODEL T EV

Electric cars are green technology at work. But they usually look just like gas cars. How about an electric car with classic style that is fun to drive? In two years, I built such a car from scratch in my garage.

I bought the parts to an original Model T chassis from a farmer in southern Illinois. A broken front crossbeam was removed and a good used one was riveted into place. All frame and chassis parts were sandblasted and painted with two-part epoxy. Front end and rear ends were rebuilt. An Advanced DC motor was coupled to the Model T driveline. A K&W BC-20 charger charges nine 8-volt Trojan batteries. A Curtis 1209 chopper controls the traction motor. A DC-to-DC converter changes the 72 V drive voltage to 12 V for the headlights (which originally used acetylene gas), as well as a CD player and radio.

All body parts are new but are the exact replicas to a 1910 Model T Torpedo, which was the working guy's first sports car. The T's top speed is about 35 mph and its range is about 15 miles. It can climb parking garage ramps with ease, and I've driven the car in most kinds of weather. The T has great traction in the snow. This car is used daily for errands and jobs. The Model T EV turns heads and gets smiles wherever it goes. Now I'm planning to sell it and move on to another electric vehicle project, since I enjoy building things.

Charley Sheridan • Evanston, Illinois

## MORE ON THE MAP

One of the maps in "PV vs. SHW" (*HP127*) shows that South Carolina has no net metering. This has recently been changed. Also, it shows no incentives in North Carolina and Tennessee. North Carolina has a 35% state tax credit and Tennessee has a grant program for businesses. I just don't want folks in those states to read your article and be discouraged to pursue solar.

Kurt Johnson • SunPower Corp.

## ERRATA

*In "Financing the Solar Dream"* (HP128)*, we erroneously reported that SunRun's electricity comes at a variable rate. It comes at a fixed rate (as noted in the table but not in the text).*

*In "New Light for Learning," (HP128), the batteries used in the system were reported as Deka sealed lead-acid. They are actually Trojan flooded lead-acid batteries.*

## TO CONTRIBUTE

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# Ask the EXPERTS!

## Proper Ventilation

**I read that for each occupant in a properly ventilated home, 10 to 40 cubic feet per minute (cfm) should be exchanged with fresh outside air. Sounds like a lot of air exchanges to happen 24 hours a day, especially if it is really hot or cold outside.**

**What is the normal rate for a typical, well-insulated, stick-frame house that does not have special systems like heat recovery ventilators (HRV) or powered venting? How much exchange occurs from leakage and typical door opening in seasons where all the windows are normally shut (i.e., during very hot or cold conditions)? And why is ventilation so important?**

**Julian Weckner • Vail, Colorado**

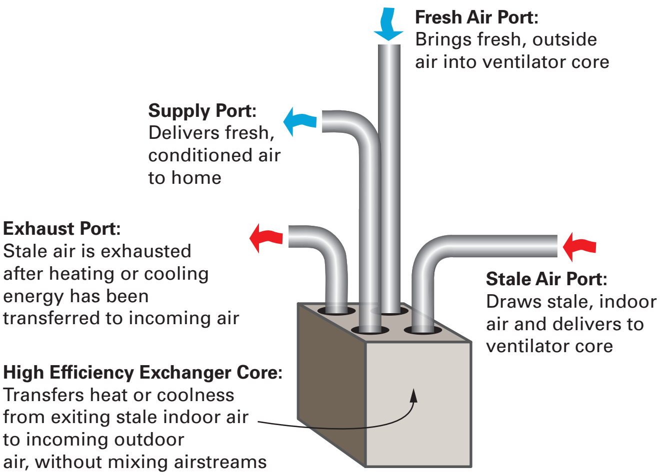
According to the U.S. Environmental Protection Agency and the U.S. Green Building Council, the average American spends 90% of his or her time indoors (mostly sleeping). Unfortunately, all of this indoor living may not be so good for us. Indoor air pollutants from off-gassing furniture, cooking, mold, pets, and many other sources can make indoor air two to five times more polluted than outdoor air. In response to these statistics, the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) created Standard 62.2, "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings." This standard has become the construction industry's guideline for mechanically ventilating the interior of houses.

To figure out how much ventilation in cubic feet per minute (cfm) is recommended for your home, multiply the square footage of the home by 0.01. Then, multiply the number of bedrooms in your home plus 1 by 7.5 cfm (the air exchange required per assumed occupant). Add these results together. For example, the calculation for a 2,400-square-foot house with three bedrooms would be 54 cfm [(2,400 x 0.01) + (4 x 7.5)] of constantly supplied fresh air. There are exceptions to the rule, but this is the basis of the standard.

A leaky home can cause 40% to 60% of the home's interior air volume to be exchanged each hour. Although this may satisfy the air-exchange rate for the standard, this abundance of "exchanged" air must be heated or cooled, which can lead to increased energy use. And the uncontrolled source of the air means that contaminated air can enter the house. Most of the natural infiltration in a home is caused when hotter air rises and exits through the top of the house (chimneys and attics) and cooler air enters through gaps and cracks in floors, crawl spaces, and foundations.

Let's use our 2,400-square-foot house to compare natural air exchange to ventilation recommendations. Let's say that this home has 20,000 cubic feet of air space. If 40% of this air leaks to the exterior each hour, that's a natural exchange of 8,000 cubic feet per hour, or 133 cfm—more than twice ASHRAE's recommended value of 54 cfm. Compare this to a well-sealed house with a natural air exchange rate of 5%, which would have a natural exchange rate of 17 cfm. Adding the mechanical ventilation requirement of 54 cfm to this would only amount to about half of the natural exchange rate of the leaky house.

## Heat Recovery Ventilator (HRV)




Interestingly enough, the standard doesn't set guidelines for how the specified ventilation is achieved. In some homes, a bathroom exhaust fan running constantly would satisfy the standard. In most cases, balanced ventilation—such as heat recovery ventilators and energy recovery ventilators—are the best option. These ventilation systems pull in fresh outdoor air, while exhausting indoor air. An air-to-air heat exchanger transfers some of the energy in the outgoing air to warm or cool the incoming air.

Building scientists might say, "It is better to build it tight, provide source control, and ventilate it right." We know how to stop air infiltration by weatherization techniques and using effective air barriers like house wraps. We can control the sources that contribute to poor indoor air quality by choosing building materials, furniture, and other products that do not off-gas harmful chemicals, and by removing moisture and combustion by-products.

Bart Laemmel • B2 Building Science

**"Indoor air pollutants...can make indoor air two to five times more polluted than outdoor air."**

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## Generator Grid-Tie

**I have an old 6 hp, 600 rpm Lister diesel engine that's been running on waste veggie oil for about six months. It drives a 3-kilowatt, 240 VAC, 60 Hz generator, which powers various equipment in my shop.**

**I'm now wondering if I might convert it to back-feed the grid to take advantage of net metering. Aside from any legal issues, what would I need technically? Can the AC generator work with some kind of grid-tie inverter to back-feed the grid, or would I need a DC generator? If this could work, what type, voltage, and brand of grid-tie inverter would work best? I would like to run the generator for eight to 10 hours a day to offset some of our electrical loads. Though it will not be enough to run the whole farm, it could offset a good portion of our electricity use.**

**George Berz • Fresno, California**

Congratulations, George. You've made an important piece of internal combustion history come alive! Diesel-fueled stationary engines from the U.K.-based R.A. Lister Company were first produced in 1929. They are legendary for their low fuel consumption and tolerance of varied fuels, plus quiet, reliable, and low-rpm operation. Lister clones are still produced in India, and are widely used there for pumping water and generating electricity in remote areas.

However, using this engine and generator to offset a portion of your electricity use may not be cost-effective here in the United States. To determine if it's a wise idea, try connecting a steady load of about 1 kW to your generator through a kWh meter (like the inexpensive Kill A Watt unit) and measure exactly how much fuel the generator consumes to produce 1 kWh. Compare the utility's retail electricity rate that you pay per kWh, the wholesale rate that they will pay you for electricity you generate, and your cost per kWh for bringing the fuel to your Lister. Even with your "free" fuel source, you'll still have to consider the costs of procuring, transporting, and processing the vegetable oil, as well as engine wear, maintenance, and your time costs. The profit margin will be slim at best, and most likely negative.

If you somehow still find the math favorable, consult with a renewable energy dealer for advice on which battery-based grid-tie inverters to consider and the cost of the balance-of-system components, wiring, permits, and inspections you'll need. It's unlikely that any "direct" batteryless grid-tie inverter would be guaranteed to work properly with the output of your generator, even if you were to convert it to produce DC directly. These inverters are intended for either the DC output of a photovoltaic system or the wild three-phase AC output of a small wind or hydro turbine rectified to DC.

Courtesy Dan Fink

Once you have a grid-tie system cost estimate from a dealer, you can predict how long it would take you to pay off the investment—I would guess many years, if ever. Instead, consider adding a solar-electric array with battery backup to your grid-tie system instead. Then, in the dire case of a grid blackout with no solar input, you can listen to the gentle "putt-putt-putt" of your veggie-oil-powered Lister while your inverter powers your home from the battery bank.

Dan Fink • www.otherpower.com

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## Living Roof Materials

**I want to install a living roof on my home, and already had the waterproof membrane installed by a roofer. But I've had trouble finding a source for the other components, such as filter layers, planting media, and plants. Please help!**

**Hal Craddock • Lynchburg, Virginia**

Living (also called "green") roofs can improve your home's energy efficiency by providing additional insulation, and can reduce your home's environmental impact by using and slowing rainwater runoff instead of it flowing across impervious surfaces to ultimately end up in storm drains. However, these roofs have strict waterproofing, drainage, and structural requirements that are best addressed by professional designers or contractors. Therefore, make sure that your roof structure is engineered to local building codes and capable of supporting the green roof's added weight. Also, be sure that you have obtained the proper permits and are confident that the membrane has been properly installed before you begin adding layers.

When shopping for the nonliving roof components, start with manufacturers that are members of Green Roofs for Healthy Cities (www.greenroofs.org). Another good resource for environmentally preferable products is BuildingGreen's GreenSpec online directory (www.buildinggreen.com/menus), which features listings for living roof systems, components, planting media, and plants.

While I suspect most of the living components would be available to you locally, consult with a landscape architect or living roof contractor before you make your purchases—your plant choices depend on much more than your roof's microclimate. The roof's slope, load capacity, media composition, and, ultimately, maintenance requirements are just a few of the factors that the experts can help you consider to select appropriate vegetation.

Mick Dahlberg • Solar Energy International

LyaC

**Living roofs are especially attractive for the home heating and cooling savings they can offer.**

## Solar Combo?

**It is well known that photovoltaic (PV) module output suffers when the modules get hot. Has anyone ever suggested trying to cool them with a coolant loop? Why aren't PV modules made with the capability to be cooled—sun on one side; coolant on the other? I know it would take energy to move the coolant, but it seems like it wouldn't take much. Or maybe convection could circulate the coolant, eliminating the need for a pump entirely.**

**Woody Ligon • Farmville, Virginia**

Not only has the suggestion been made, but it usually is taken one step further to include using the heated water for domestic purposes. At least one company—Dawn Solar Systems—has developed a system that circulates water through PEX tubing behind PV shingles to remove heat from the roofing and preheat domestic water. But this is a specific case of PV shingles, which lack air circulation and are prone to high temperatures.

This idea has not been adopted for other types of PV modules for these reasons, some of which also apply to your proposed PV module cooling idea:

- Electricity and electrical components should not come in contact with water since electrical shorts and harmful oxidation may occur.
- Combining electricity production and water heating in one unit doubles the system complexity. When one or the other fails, you're faced with replacing a more expensive unit.
- Solar hot water collectors rely on a high heat differential between the incoming water and collector temperature to be effective, but PV modules should not be allowed to reach these temperatures.

Lots of folks have experimented with this idea, but the experimenters and the market have so far concluded that the extra complexity and cost are not worth the minimal energy gains. For my investment, I'll stick with separate, relatively simple, purpose-made systems.

Michael Welch • *Home Power*

Courtesy Dawn Solar Systems

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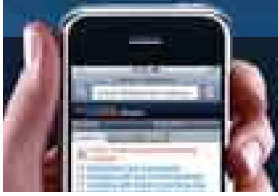

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## Battery Equalization

**I've been a reader since *HP1*, and have upgraded my off-grid solar-electric system four times, from one module to thirteen; from a 12-volt, 600-watt inverter to a 24 V, 4,000 W unit; from 6 V golf cart batteries to 2 V submarine batteries to three sets of 6 V deep-cycle L16s.**

**The main problem over the last 20 years has been battery life. I've talked with a few installers who advised me to equalize the batteries twice or even four times a year. Even with the sunny climate here in Hawaii, equalizing at 30 V for three to four hours or until the specific gravity reaches the right place on the hydrometer on all the batteries without using a generator is impossible.**

**When wired into the 4,000-watt Trace charger/inverter, a generator will charge the batteries at 30 V when it is idling. Is that sufficient, or should I run the generator at the maximum of 13.8 amps? How many amps are needed to equalize my eight L16 batteries? How often should they be equalized, and for how long? What specific gravity should I strive for?**

**Karim Wingedheart • Maui, Hawaii**

I remember you well—you've been off grid about as long as I have! For battery equalization—a controlled overcharge of the battery—I use the battery ampere-hour meter to determine overcharge and try to overcharge the batteries each day by at least 2% of their capacity. Weekly, I set the PV regulators to equalize and overcharge the batteries by at least 5% of their ampere-hour capacity. Monthly, I use the generator to overcharge the batteries by 10% of their capacity. I don't pay attention to the battery voltage during equalization, but to the amount of overcharge (in ampere-hours) that the battery receives. I don't routinely do hydrometer measurements.

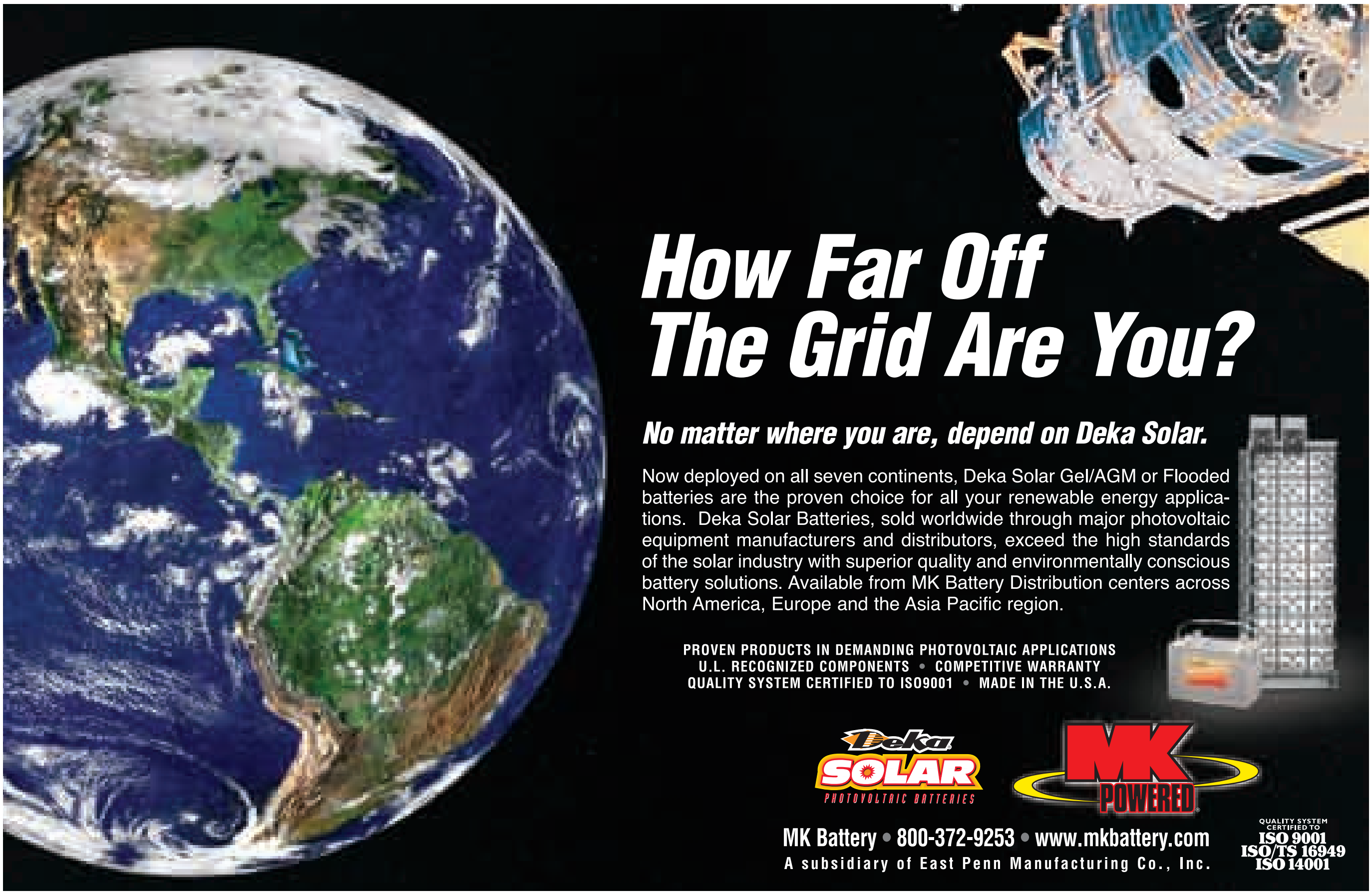
This regimen requires having an array large enough to not only meet electrical consumption demands, but also to provide needed overcharge. If your array cannot do this, consider adding more modules. If the array is not up to the job, then an engine-generator must be used.

I try not to use the batteries too heavily. My average depth of discharge nightly is about 12% of the battery capacity. On most sunny days, the battery is fully recharged before noon (and then the daily overcharge begins). If the battery drops below 30% depth of discharge, I start the generator. I use the generator an average of 160 hours per year—mostly during the depth of Oregon's cloudy winters.

Battery makers and distributors are just now becoming aware of the type of cycling that a battery sees in PV service. Their usual recommendations are for batteries that are deeply discharged, then refilled rapidly (a far tougher service than in a well-designed PV system).

If you are using the generator to equalize, do it at least monthly. Voltage doesn't matter—it's the amount of overcharge ampere-hours that matter. Recharge until the ampere-hour meter shows a 10% overcharge, and don't forget to add water to the electrolyte as needed.

Richard Perez • *Home Power*



## Solar Hot Water Installation Cost

**I want to install a solar hot water system for space-heating at my home in Chicago. After a satellite survey of my property, the one company I called gave me an over-the-phone quote of $23,000 to install a four-panel system with forced-air heating integration. From reading your magazine and searching the Web, I expected an installed solar hot water system to cost about $5,000.**

**Is this company taking advantage of me or is it a lot more expensive to have one of these systems if you live in a climate where the temperature occasionally drops below 0°F? As much as I would like to save the planet, there is no way that a $23,000 solar hot water system with an annual savings of only $400 makes sense. I can install a 2 kW PV system for that price, or improve the insulation of my house and buy Energy Star appliances.**

**Paul Beerkens • via e-mail**

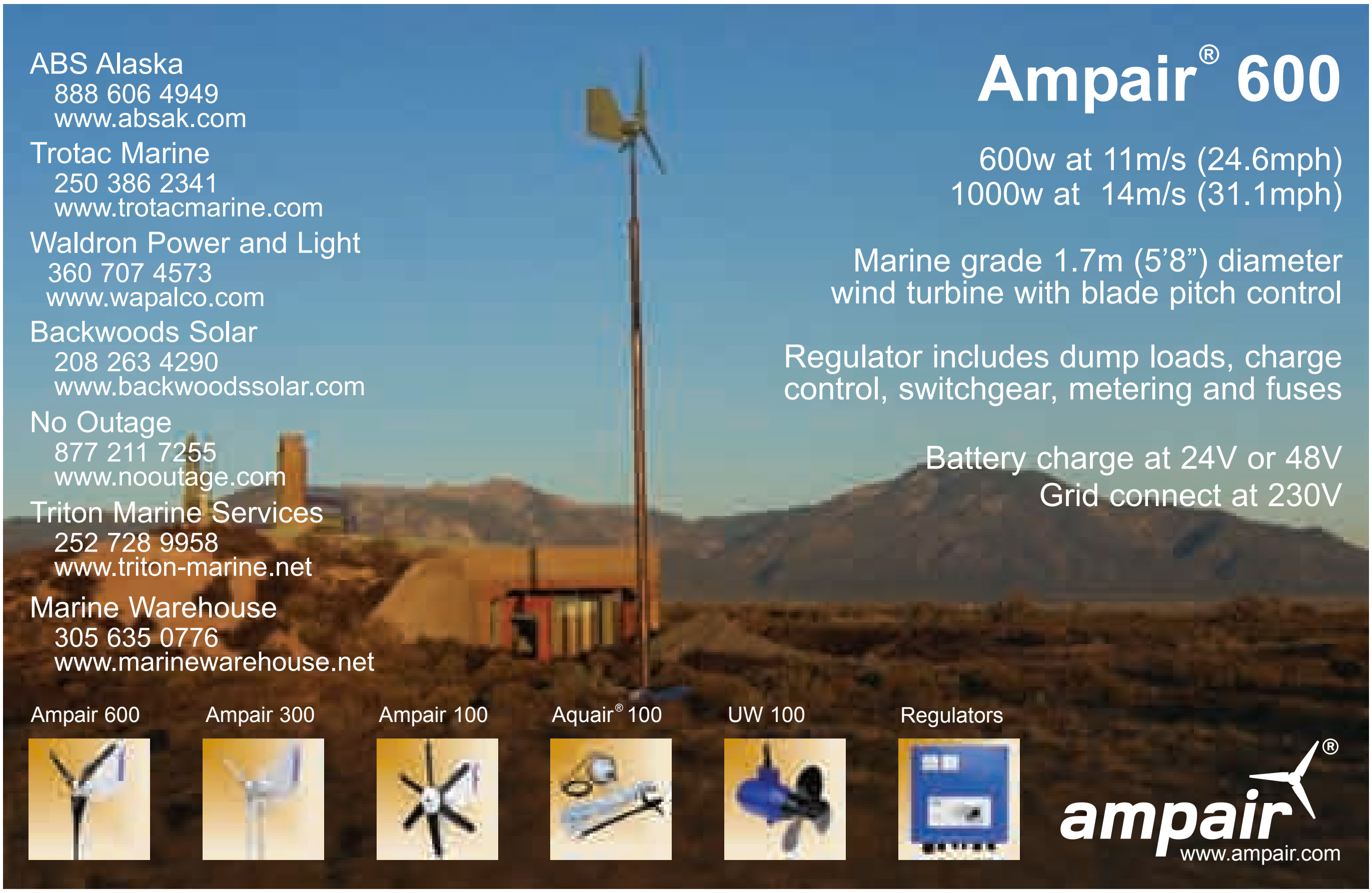
The quote you received is called a ballpark bid. I typically give over-the-phone ballparks at $7,000 for the first collector and $3,500 for each subsequent collector for space-heating systems. But, that's in Albuquerque, New Mexico, a place where labor is less expensive. For Chicago, I would have told you to expect an estimate between $17,000 and $20,000 for a four-collector system. The estimate after a site visit would usually go up or down from there depending on the space-heating component and the retrofit difficulty.

Solar hot water and space heating systems are more expensive in colder climates and climates with less solar energy available. Solar water heating systems pay back much more quickly than space-heating systems because the water heating system is used year-round; the space heating system is typically used only about half that (or less).

If your home is underinsulated, spend the money there first. Insulation and reducing infiltration (weatherproofing) has been shown by many studies to cost about 2 cents per kWh. Energy conservation and efficiency measures are called negawatts, and are the best bang for the buck unless your home is already energy tight.

Chuck Marken • Solar Thermal Editor


Courtesy EnerWorks

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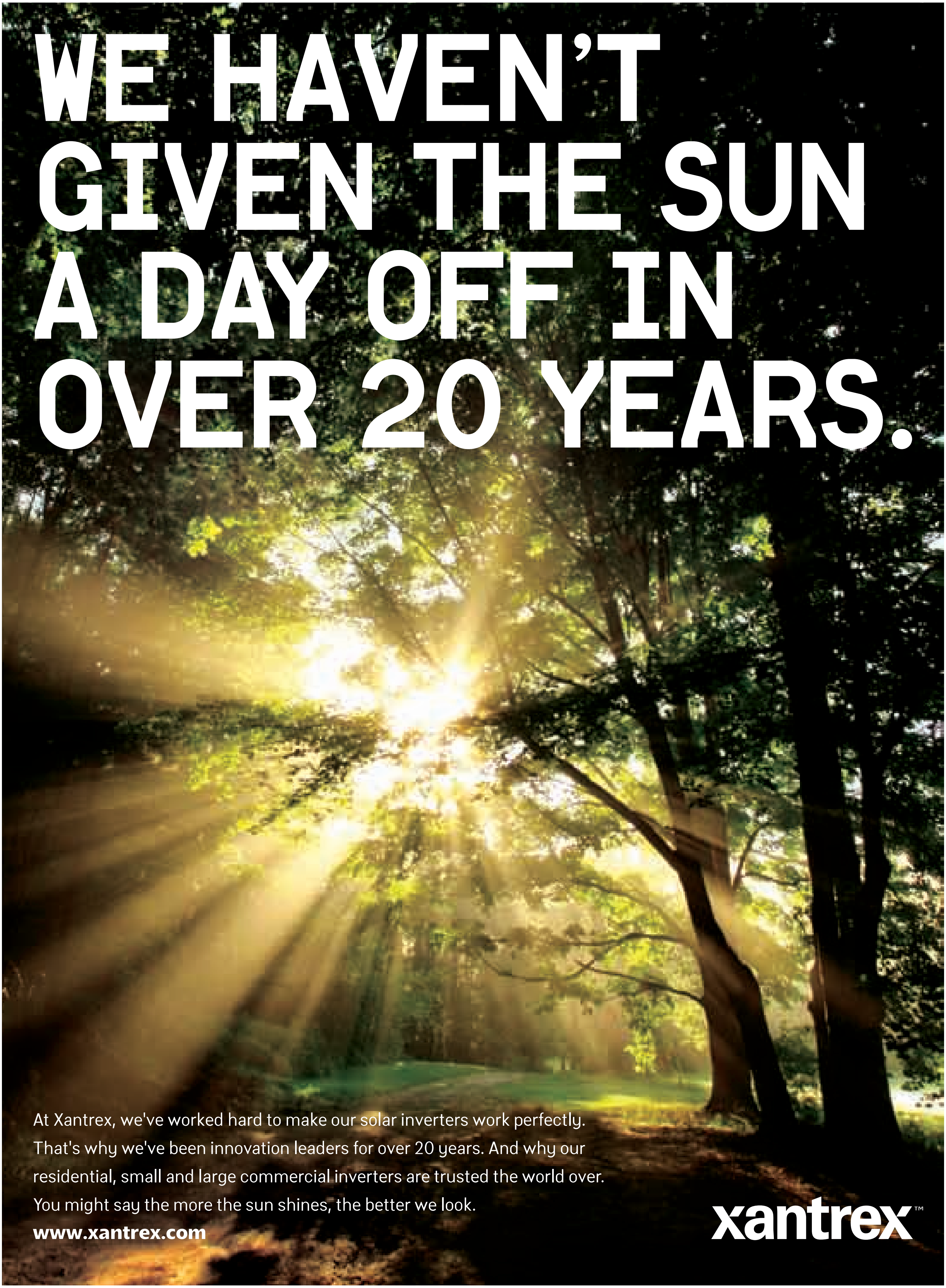

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# Beyond the Box

## Modern Modular is Going Green

with Claire Anderson

Prefab homebuilding is undergoing a revival, but it's nothing like its predecessors. In its new incarnation, "green" prefab promises an efficient way of building a high-quality, energy-conserving home with smart, earth-friendly materials.

Courtesy John Swain & www.mkd-arc.com (3)

Architect Michelle Kaufmann's foray into the world of prefabricated homes was purely practical. In 2001, she and her husband, builder Kevin Cullen, began searching for a modest home in the overinflated San Francisco Bay area real estate market. After six months of being unable to find an affordable, energy-efficient, eco-friendly home, they decided they needed a new approach—create their own.

They purchased a lot in a semi-rural town in Marin County, California, and worked to complete their green design—a home that would use less water, energy, and materials than a conventionally constructed home.

**Photos: Michelle Kaufmann Designs' prefab Glidehouse.**

Courtesy John Swain & www.mkd-arc.com (3)

The result is a three-bedroom, 1,560-square-foot home designed for function and tailored to the climate. Strategically placed dual-paned windows and doors throughout maximize cross-ventilation and natural lighting while minimizing the need for artificial lighting and mechanical climate control. Exterior gliding wood shades help mitigate heat gain from the hot summer sun, while maintaining ventilation. The sloped roof of their "Glidehouse" facilitates hot air inside the home to move up and out of the house through small, operable clerestory windows. Oriented south, the roof also accommodates a 4.5-kilowatt solar-electric array. Inside the house, energy-saving LED and compact fluorescent lighting, and Energy Star appliances, help keep energy use low. Durable, low-maintenance materials, such as composite concrete countertops and weathering steel siding (alloyed for weather resistance by creating a thin rust sheen), were used inside and out.

**Photos: Michelle Kaufmann Designs' newest modular, the Smart Home, is a model of green building and energy efficiency.**

## Navigating the Building Lexicon

**Kit home**—Kit homes, which include log homes, domes, and timber-frame homes, are typically assembled at the home site, either by an experienced owner–builder or a contractor. They usually include only the exterior shell of the house, and require further construction and carpentry for completion.

**Panelized home**—Wall, roof, and floor sections/panels are manufactured in a factory, which offers the advantages of better oversight over material quality and waste reduction, and more control over costs. Structural insulated panels (SIPs), which can be fabricated and customized at the factory, then assembled at the building site, are one example of panelized construction.

**Manufactured home**—Built on a trailer chassis and manufactured off-site using lightweight metal framing, these homes are considered portable and temporary structures. Little to no on-site labor is required. In 1994, the U.S. government revised the Housing and Urban Development building code to include higher standards for manufactured homes' mechanical systems, structural design, fire safety, and energy efficiency. Prior to 1976, these structures were known as "mobile homes."

**Stick-built home**—A home built using conventional framing methods entirely on-site.

**Modular/Prefabricated home**—Skilled factory workers assemble complete building "modules" off-site. Once complete, they are transported by truck, ferry, or train to the building site, where the modules are set onto a site-built foundation. Most modular homes require some finish work, such as tying the individual modules together and connecting wiring and plumbing. Modular homes have similar characteristics to site-built homes and must pass the same code requirements.

Courtesy (clockwise from top left): www.alchemyarchitects.com (2), www.eco-infill.com, TJ Thoraldson & www.hivemodular.com; www.ideabox.us

Intrigued by their unique home construction project, friends and colleagues asked how they could have modern, green houses too. "People are desperately trying to find healthy, green, efficient homes for their families," says Michelle. "However, the information and solutions are not always easy to find. People are uncertain of what to do and the best way to do it. People are busy, have budgets, and want simplicity. Where were the easy, affordable green solutions?"

## Efficient Homes with Mass Appeal

When Michelle and Kevin were searching for a place to live, green home options were limited—and expensive. After their home-building experience, Michelle made it her professional goal to "marry good design with minimal environmental impact, and create 'green' homes that could be widely available." She says that translated into "creating a prepackaged solution using the principles of mass production combined with sensible, uncomplicated floor and roof plans, eco-friendly materials, and low-energy options."

**Prefab, modern, and "green" models include (clockwise from top left): Alchemy Architects' weeHouses: two-story and cabin; Eco-Infill; B-Line Medium from Hive Modular; and Ideabox.**

# Pushing the Envelope on Green Prefab

For many people, the word "prefab" suggests standardized structures with little pizazz—functional, but unlikely to garner a second glance. That's far from the case with today's modern, green modulars: a diverse array of attractive, durable, eco-friendly products are being combined to create unique, livable, high-performance homes that fit the landscape.

Most prefab designs lend themselves to some modification so customers can customize a plan to accommodate a challenging building site, change window placement for better solar gain, or even add an office annex.

Here are some of the companies across the country that are pushing the envelope on green prefab.

| | **Alchemy Architects** Minneapolis, MN | **Blu Homes** Boston, MA | **Eco-Infill** Denver, CO | **Hive Modular** Minneapolis, MN | **Ideabox** Salem, OR | **pieceHomes** Los Angeles, CA | **Michelle Kaufmann Designs** Oakland, CA |
|---|---|---|---|---|---|---|---|
| **Web site** | www.alchemyarchitects.com | www.bluhomes.com | www.eco-infill.com | www.hivemodular.com | www.ideabox.us | www.piecehomes.com | www.mkd-arc.com |
| **Location of factory** | Various factory partners | West & Northeast | Denver, CO | Various factory partners | Various factory partners | Various factory partners | Various factory partners |
| **Footprint (sq. ft.)** | 345–2,090 | 450–1,700 | 375+ | 1,000–2,500 | 400–1,500; + 215 s.f. cubes | 320–2,500 | 700–2,820 |
| **Multiple floors avail.** | 3 | 2 | 4 | 4 | 1 | 4 | 3 |
| **Avg. time to complete in factory (months)** | 2–3 | 1–1.5 | 1.5–2 | 3 | 2 | 1–4 | 2–5 |
| **Avg. cost to complete setup on site** | Varies; site-dependent | 35% of total project costs | Varies; site-dependent | $90 / sq. ft. | Varies; site-dependent | Varies; site-dependent | Varies; site-dependent |
| **Wall construction** | 2 x 6; SIPs option | 2 x 6 | 2 x 6; SIPs option | 2 x 6 | 2 x 6 | 2 x 4 or 2 x 6 | 2 x 6 |
| **FSC-certified lumber** | Option | Option | Option | Yes | Yes | Option | Yes |
| **Wall insulation** | R-19 | R-21+; open-cell foam | R-21+; fiberglass batt | R-21; high-density fiberglass batt | R-21 | R-13 or R-21; fiberglass batt | R-22.5; open-cell foam (Icynene) |
| **Floor insulation** | R-35 | R-30 to R-38; spray foam | N/A, basement or crawl space | N/A, basement or crawl space | R-38 | R-30 | R-32; closed-cell foam |
| **Roof / ceiling insulation** | R-44 | R-35 to R-48; open-cell foam | R-38+; fiberglass batt | R-50; loose-fill fiberglass | R-40; cellulose | R-33+ | R-30 to R-34; open-cell foam |
| **Roofing** | EDPM (white or black) | TPO membrane; living roof option; standing-seam metal | Metal, composite; living roof option | EDPM or white Durolast; living roof option | Standing seam metal | EDPM; living roof option | Standing seam metal |
| **Passive solar** | Option | Yes | Option | Yes | Option | Yes | Option |
| **Low-flow shower heads (<2.0 gpm)** | Option | Yes | Yes | Yes | Yes | Yes | Yes |
| **Low-flow faucets (<1.5 gpm)** | Option | Yes | Yes | Option | Yes | Yes | Yes |
| **Low-flush toilets (<1.6 gpf)** | Option | Yes | Yes | Option | No | Yes | Yes |
| **Dual-flush toilets (<1.6 gpf / <0.9 gpf)** | Option | Yes | Option | Preferred standard | Yes | Option | Option |
| **LED lighting / fixtures** | Option | Yes | Option | Option | Option | Option | Option |
| **CFL fixtures** | Option | Yes | Option | Option | Yes | Yes | Yes |
| **Energy Star appliances** | Yes | Yes | Option | Option | Yes | Yes | Option |
| **Windows** | Wood or vinyl; Energy Star | Vinyl or wood; Energy Star | Vinyl, aluminum, or fiberglass-clad; Energy Star | Wood-aluminum; Energy Star | Vinyl; Energy Star | Frame depends on location; Energy Star | Wood/ aluminum; Energy Star |
| **PV / SHW system-ready (wiring & plumbing runs in place)** | Option | Option | Optional PV, factory installed | Option | Optional PV, factory installed | Option; all models prepped for PV & SHW | Option |
| **Avg. price per sq. ft.** | $117–228 | $135–175, fully installed | $150–$200 | $75–165 | $100 | $225 | $250–300 |
| **Independent certification** | Available | Energy Star; LEED, NAHB, Built Green avail. | LEED; Built Green | Energy Star; LEED; Built Green Canada | Energy Star; NEEM; Earth Advantage | Built Green standard, min.; LEED avail. | Energy Star & American Lung Assoc. Health House |

## A Small, Sustainable Footprint

This 725-square-foot residence's sustainable elements—a small building footprint, living roof, water catchment system, and recycled building materials—combine for high performance and low energy bills. A living roof and spray-foam insulation in the walls minimize energy losses due to air infiltration and conduction through the building frame, while a 1.7 kW PV array provides pollution-free electricity. Well-placed windows allow ample natural light to permeate the home, reducing the need for artificial lighting during daylight hours, while LED lighting fixtures maximize energy efficiency at night. Water-saving fixtures include low-flow showerheads and faucets, and a dual-flush toilet, as well as a greywater recycling system. As a result, the mkLotus exceeds California's GreenPoint rating system, an independent certification sponsored by the nonprofit Build It Green, by 300%.

"I soon realized I would have to start thinking less like an architect and more like a product designer," says Michelle. "I began researching mass production and working on parallel tracks. Although we had used structural insulated panels (SIPs) in our home's construction, I also researched how a factory could make the walls and roof, and how to calculate maximum dimensions for shipping a home module on flatbed trucks."

Michelle's persistence paid off when she found a prefab factory willing to give her a chance. The Kaufmann-Cullen home had taken 14 months to construct at a cost of $197 per square foot. The factory built an identical Glidehouse in less than one-third of that time for $40 less per square foot. Since then, Michelle has built 33 prefab homes for clients ranging from young, urban families to rural retirees. But those aren't the most impressive numbers. She estimates that compared to conventionally constructed homes, these 33 homes together provide an energy savings of 1,934,000 kBtus per year, a water savings of 3,251,920 gallons per year, and annually save 594,000 pounds of carbon dioxide from being emitted.

### Modern Modular Goes Mainstream

Michelle is not alone in her quest to bring modern, green homes to mainstream markets. In the past few years, several architectural firms have started to green their scenes (see "Pushing the Envelope" sidebar).

While their design approaches may vary, the primary goal of green modern prefabs remains the same: reduce a home's environmental impact by maximizing energy efficiency, reducing water use, and using eco-friendly materials, while making it a healthy, comfortable space for its occupants.

"The opportunity to do better seems extraordinary," says Bill Haney, president of the Boston-based prefab design company, Blu Homes. "Other countries do better. The average footprint and the amount of space and energy costs for the average family of the same income in Europe is dramatically lower. Other countries make a lot of their housing in factories, so they are able to use fewer materials and be much more efficient—so they don't have big waste. In Finland, about 70% of the houses are built in factories before they get to the site. In the United States, it's more like 0.7%."

Courtesy John Swain and www.mkd-arc.com (2)

**The Sunset Breezehouse, codesigned by Kaufmann and *Sunset* magazine, blurs the line between inside and outside living.**

# Point & Counterpoint:
# The Cost of Going Green & Prefab

**Does prefabrication make green houses more affordable? BuildingGreen associate editor Allyson Wendt asked this question in 2007 when she was working on a feature article on the topic. Back then, the answer was "not quite yet." Here's what she has to say today.**

More than a year later, the answer still seems to be "not quite yet," at least according to Chad Ludeman, developer of the 100K house in Philadelphia, in an article on the green building blog, www.jetsongreen.com.

He argues that most of the modernist houses could be site-built for less money; that overengineering in the prefab industry makes the less-waste argument specious; that long waiting lists for prefab homes make time savings irrelevant; and the green aspects of prefab rest largely on the "no waste" element.

Ludeman's arguments are good ones, especially as the majority of the industry stands right now. If green features—superinsulation, benign materials and finishes, and energy- and water-efficient appliances and fixtures—aren't standard, prefabrication doesn't offer many cost benefits over site-built homes, since prefabrication depends on volume to realize its claimed benefits. Most companies producing modernist, green, or modernist-green prefabs are still small and don't yet have enough volume to significantly lower material and labor costs. For larger companies, green features mean modifications to their stock plans, which means extra expense.

Ludeman suggests a semi-custom approach with prefabricated components and custom, local finishing—an approach many production builders already use for large developments. Adjusting this approach for infill development would be a great idea. There are several companies out there that mix and match prefabricated components in custom and semi-custom structures.

However, environmentally speaking, the jury is still out, and the potential benefits of prefab green (worker transportation, site impacts, etc.) go far beyond the waste reductions.

Unlike Ludeman, I'm not ready to give up on prefabrication just yet. I still think there's promise in the idea of prefabricated green, especially in the mainstream and affordable housing markets. As for green modernist housing, the benefits of prefabrication may never come through for such a relatively small market.

**As an industry insider in the modular home business, Blu Homes' Maura McCarthy says she agrees that *conventional* prefab companies are not outperforming site-built homes. But, she points out, *smart* prefab companies have the opportunity to do a lot better.**

"If you take the scale efficiencies of manufactured homes, and introduce products like spray foam insulation," says McCarthy, "all of a sudden you are providing spray foam at half the cost of spray foam provided on-site by a skilled subcontractor. This kind of 'scale' logic also holds true for a number of other functions, like the fabrication of countertops made of new, green materials, prefab components like kitchen/bath/utility pods, etc. Moreover, prefab companies have more possibility for innovation given their indoor facilities and opportunity to do research on new technologies."

As for the waste issue, she fully disagrees that the waste in prefab building is comparable to that for site-built homes. "My experience is that most prefab companies produce at least 50% less waste than normal construction. And although you can certainly hire someone to come and haul away the huge garbage bins of waste that you see at every single site-built construction site, the amount of waste in factory versus site-built homes is just not comparable. There are a host of reasons for this, including precise volume purchasing by factories, better storage areas (i.e., not out in the rain) that keep materials protected, and so on. Prefab manufacturers may have gotten a few things wrong, but less waste is not one of them in my opinion."

She thinks that Ludeman makes many of the right points and criticisms of existing prefab companies, but believes these criticisms are of a very nascent industry—that is, the modern prefab homes industry—which needs to break away from its older brother, the modular homes industry.

"With a new U.S. administration that values 'greener' technologies, American consumers who are not only much better educated on the carbon footprint of their homes, but more demanding about the convenience with which their homes are delivered, coupled with the current housing crisis that is wiping out many of the low performers," says McCarthy, "the macro trends toward more green prefab seem positive."

Courtesy JB Spector & www.mkd-arc.com (3)

Courtesy John Swain & www.mkd-arc.com

**Modern prefab designs offer all the desired conveniences with style and efficiency.**

Prefab proponents say that one of the main advantages of prefab over kit, panel, or site-built homes is the amount of work done off-site. Most of the home is factory built, from the shell down to the kitchen cabinetry and even lighting fixtures, allowing predictable time and cost estimates while maintaining quality. By decreasing on-site work and increasing factory assembly, prefab home providers say they have greater control over the quality, schedule, and cost of construction.

## What's in a Name?

Several home-rating programs today are helping consumers cut through the confusion of what is and what isn't green. Most familiar is the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) for Homes. Established in 2007, this program establishes independent, third-party verification that a project meets criteria for a set of stringent green-building standards spread over 35 different categories. According to the USGBC, the benefits of a LEED home include lower energy and water bills; reduced greenhouse gas emissions; and less exposure to mold, mildew and other indoor toxins.

Through a strategic partnership with the National Association of Home Builders, the nonprofit Green Building Initiative has unveiled their Green Globes rating classification as an alternative to the LEED system. This certification program integrates a comprehensive environmental assessment protocol, software tools, and qualified assessors with green building expertise.

Local green building programs can be even more applicable, since they can address regional differences. In California, the nonprofit Build It Green has established their GreenPoint rating system, which grades homes on five categories: energy efficiency, resource conservation, indoor air quality, water conservation, and community.

Because the site work and home construction can happen simultaneously, the overall construction schedule for modular homes can be shortened, and homes can often go up in a hurry. Besides offering potential time-savings, says Kaufmann, building in a factory nearly eliminates the uncertainties of scheduling that often plague traditional building projects, such as delays or damage due to weather.

Blu Homes is focused on making site work quicker and more efficient. "We really feel that customers suffer when they have site-cost overruns," says Blu Homes' Maura McCarthy. "Pier foundations, for instance, can save between $8,000 and $15,000 compared to conventional foundations, and also have positive benefits in terms of the environment, since the site is disturbed less and less material is needed for the foundation." In some cases, McCarthy says, a hydraulic truck can be used instead of a crane to place the modules, which offers both savings and less disruption to the site. Blu Homes is also looking at ways to ship "more house on less truck" to minimize shipping costs and fuel use for transportation.

## Details & Design

Modular homes all meet local and national building codes, but also can exceed them. Because they have to withstand the rigors of shipping and, possibly, being crane-lifted into place, modulars are typically built with more framing and strapping details to maintain their building integrity. According to Kaufmann, the additional materials for that extra strength can be offset many times over by the savings in construction waste achieved by prefabrication. Critics of prefab take issue with the "less waste" argument, considering that, in some areas, waste removal companies are available that will pick up on-site construction materials for recycling, making the comparison moot.

Jason Pelletier, founder of the eco-home improvement site Low Impact Living, says that a distinct advantage of prefab construction is that "hard-to-find green materials can be bought in bulk and used for many projects, minimizing delays and ensuring that no shortcuts are taken due to unavailable materials." He points out that the opportunity for "bulk purchasing and the delivery of a small number of completed modules to the home site can dramatically reduce pollution from transportation to and from the site."

McCarthy says that "there's absolutely no doubt that you get efficiency of scale with large purchases or large products, and having them shipped to a factory," and that using local factories to put together homes "reduces the amount of travel and shipping costs." But, she says, focusing on the home's embodied energy doesn't give a true picture of the more important aspect—its performance over time. "When you look at a home's embodied energy compared to its 50-year life-cycle cost, it's *miniscule.* Over a home's lifetime, the energy it consumes could be *30 to 50 times* its embodied energy."

## Efficiency & Energy

Up-front affordability has always been the bane of modern homes, whether customized or prefab, and, many say, the jury is still out on whether prefab can bring modern to the mainstream (see "Cost of Going Green & Prefab" sidebar). But others argue that the more important consideration is long-term costs.

"If you're the average family, you're figuring out what mortgage payment you can make, and insurance is probably calculated into that mortgage payment, and probably property taxes are calculated into that," says Haney. "Maintenance costs? That's your own nickel. And energy? You're all on your own. We're trying to refocus the questions: What would it take to buy a house? How long will it be on site? What will it cost to operate it?"

Blu Homes puts their prefab designs through off-the-shelf and proprietary modeling software to get detailed estimates on how they will perform in various climates, and works with clients to tailor the envelope—insulation, framing, and window placement—to their specific climate and needs. "Just like you can find out a car's fuel economy before you buy it, we think people should have a sense of 'gas mileage' for their homes before they buy," McCarthy says.

Kaufmann agrees. "To avoid repeating the dire situation so many homeowners are in today, it is critical that our thinking evolve around home costs," she says. "Once we start to equate monthly costs with the true costs of a home, the positive impact will reverberate among homeowners, who will be less likely to find themselves living in homes they cannot afford and more likely to choose green homes, which are often more affordable in the long term."

## Premiums, Prefabs & A Greener Future

In 2005, green homes made up just 2% of the market—but in 2008, they were expected to account for anywhere from 6% to 10%. By 2012, that market share is expected to jump to between 12% and 20%. Yet U.S. builders cite "consumer willingness to pay" as the second largest obstacle affecting green home-building growth, and say that the higher up-front costs of the "green premiums" attached to sustainably designed homes is a barrier to green building's expansion into the mainstream. However, what people are realizing is that, spread out over the terms of a 15- or 30-year mortgage, these higher up-front costs can be easily absorbed and offset by lower utility bills and, to varying degrees, lower maintenance costs and higher tax deductions.

"If we can come up with a system that is more affordable for the average family to live in, is better for the natural world, is more healthful for them and their children—I think that's the kind of thing the average family is looking for," says Haney. "Working with the Massachusetts Institute of Technology and others on energy modeling software has convinced us that it's not that hard to do."

## Access

Managing editor **Claire Anderson** (claire.anderson@homepower.com) spends her spare time poring over green home designs and trying to master SketchUp.

Recommended Reading:

*Prefab Green* by Michelle Kaufmann & Cathy Remick (Gibbs Smith, 2009)

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# SOLAR Stewardship

by John Patterson
& Suzanne Olsen

Driven by her desire to set an example for others and create a healthy environment for her son, Candace Gossen tackled a rehab of her 1924 two-bedroom bungalow in a historic neighborhood in southeast Portland.

"When I bought the house, it had bars on the windows and a chain-link fence around it. It was a very closed-off place," says the 45-year-old mother of one. "I wanted to bring life back to it and make it a healthy home."

Green and blue glass bottles get a second life in a whimsical garden wall.

Shawn Schreiner (2)

Homeowner Candace Gossen at her eco-renovated Portland home.

Shawn Schreiner

Suzanne Olsen

**Above: A large picture window on the south side of the house lets in lots of natural light.**

**Right: The garage apartment features straw-bale insulated walls for improved thermal performance.**

Candace updated the home over the course of 12 years—one project at a time as her budget allowed. She had an edge when it came to the DIY improvements—a bachelor's degree in architecture, a master's degree in building science, and a decade of hands-on practice with sustainable principles. Shortly after purchasing the home, she set up a studio devoted to teaching ecological design. Even with her resources and know-how, she chose to keep the projects simple, doable, and affordable. Her approach followed the life mantra of Buckminster Fuller: *You see what needs to be done and you just do it. Do more with less.*

Candace initially improved the home's energy efficiency through simple upgrades and common-sense measures. She removed the bars and grates from the large south-facing

**Recycled and salvaged materials, as well as renewable energy technologies, come together to create an efficient and comfortable urban oasis.**

Suzanne Olsen

**A model of a living roof serves as a neighborhood education tool.**

Shawn Schreiner

**Left: A 4- by 10-foot solar hot water collector and a 1,540-watt PV array provide heat and power to the home.**

**The drain-down solar hot water system has been working well for years.**

Shawn Schreiner (2)

window in the living room to capitalize on some passive solar gain. In lieu of curtains or blinds, deciduous trees outside the south-facing window provide shading during the warmer months and allow some passive solar gain through in the winter. Energy-efficient lighting and new Energy Star appliances—including a super-efficient 10-cubic-foot refrigerator—rounded out her energy strategy. Lastly, the much-anticipated demise of the home's 40-year-old oil furnace gave Candace the chance to reduce the home's dependency on fossil fuel (see below).

"I wanted the home to show options to homeowners and put the technology in the open—outside—so people passing by could see what we did," she says. "Most people—me included—cannot afford to spend thousands upon thousands of dollars on home improvements for the sake of sustainability and efficiency."

Instead, Candace focused on low-cost, do-it-yourself solutions that "make sense for the average homeowner." To support her sustainable lifestyle and make the community available to others, she eventually converted the finished basement and the garage into two rental apartments.

The house proved to be the perfect demonstration piece for her design studio as well as an ideal classroom for the workshops she teaches through the local community college and university. "It's really important that I give back more than I take," she says. "Using this house to show what can be done and teaching through the various projects seemed like a natural way to be a steward for change."

She used many of the projects to provide her students with hands-on instruction and often invited people in the community to participate. Her home is a favorite on several home tours in the area—including last year's Build it Green! Tour of Homes, where a record number of people turned out to admire their work. Here are a few of the applications that had the crowds stretching on their tiptoes for a second look.

## *Solar Hot Water*

**Cost: $1,000 after $1,500 state tax credit**

In 1997, Candace received approval from her neighborhood advisory board to add a 4-by-10-foot solar hot water collector on the south-facing roof of the garage. In the open-loop drain-down system, potable water is directly heated in the solar thermal collector. During cold weather, when temperatures drop below 40°F, an automatic valve drains the water out of the system and into a rainwater collection system. This drain-down system protects the collector and pipes from freezing. Once the temperature on the collector rises above 40ºF, the valve allows water into the collector. Although thousands of these systems were installed in the 1990s, most were abandoned due to their complexity and common failures during freezing—in favor of closed-loop glycol systems. But Candace's system has worked perfectly through the years.

## Straw Bale At Work

In the back corner of the yard stands a testament to Candace's dedication to both teaching and learning about sustainability. In 1997, she designed a load-bearing straw bale building. She and her students built the 10-by-12-foot structure from renewable and recycled materials as a research project. The goal was to test straw bale construction and other eco-building techniques against the climate conditions in the Pacific Northwest.

Reclaimed concrete from a dump site and old tires helped form the foundation. A layer of decking made from a recycled wood/plastic product, paired with a rubber sealant and 30-pound felt paper, provided a moisture break between the foundation and the 42 straw bales that form the walls.

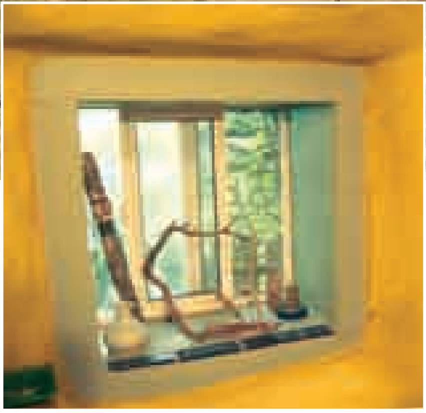
The bales were stacked five high and covered with a box beam of 2- by 6-inch boards and CDX plywood filled with straw flakes for insulation. Seven trusses, formed from 2 by 6s, made up the roof—complete with a built-in trough to catch water in a 180-gallon collection system.

The windows and door openings were wrapped with 30-pound felt paper. The straw bales were covered in coconut fiber, which gave a surface to apply the stucco—a mix of clay, clean soil, cement, fine sand, linseed oil, skim milk (for casein), water, and chopped straw. A thin cement stucco mixed with ochre pigment finished off the exterior. Before plastering, Candace placed 12 manual-read moisture sensors within the bales so she could monitor moisture at various points within the wall structure.

Reclaimed bricks laid over tamped sand make up the interior floor. Beneath that, a layer of recycled nylon sand bags on top of a 3-inch layer of river rock creates 18 inches of thermal mass for the floor.

The success of the project prompted Candace to convert her garage into an eco-friendlier studio by infilling the north and west interior walls with straw bales. Overhead rafters were used as a box beam to attach bamboo pins, and the straw bales were covered with burlap—instead of wire mesh—as an experiment to see how well fibers and plasters would adhere together. Candace brushed three layers of plaster made of earth and lime onto the burlap, and covered the burlap with reed matting. Six moisture sensors monitor moisture in the straw-bale walls. Renewable and recyclable materials complete the décor—bamboo flooring, a ship-bath with dual-flow toilet, interlocking floor mats made from old tires.

The finished garage served as a studio until Candace moved her work space into the straw bale building in the backyard. She renovated the 300-square-foot garage space into a one-bedroom apartment, designing with the principles of efficiency.



Suzanne Olsen (2)

**Tucked into the corner of the yard, the straw bale studio make a cozy office/living space.**

The 120 VAC controller sends energy to the drainback valve and pump independently, based on three temperature sensors. The system has demonstrated a 50% savings over the former electric-only water heater, depending upon weather.

Two fan-assisted hydronic heaters are connected in line with the solar water heating system—one in the garage apartment and another in her son's attic bedroom. Hot water from the solar preheat system and gas backup heater is pumped through a water-to-air heat exchanger, and a fan blows room air across it, providing ample warmth to those well-insulated areas.

Historic district zoning made roof-mounted PV taboo, but ironically, this highly visible, 12-foot pole mount was legit.

Six months of the year, the home's PV system produces more energy than its inhabitants use. During the winter months, the system offsets about 30% of the five residents' usage.

Shawn Schreiner (3)

## *1.5 kW Photovoltaic System*

**Cost: $5,800 after $6,200 Energy Trust credit and $1,500 state tax credit**

In 2004, Candace installed a grid-tied PV system to offset the household's utility electricity use. The roof-mounted design was originally approved by the city, but rejected by the neighborhood advisory board. Their concern? That the array would be too visible from the street-side view of the house and set an unacceptable precedent for future design considerations in the historic neighborhood. The alternative pole-mounted design was, however, given the green light—even though the array in the corner lot's side yard is equally, if not more, visible. The change in plans turned out to be a good thing, as the new site gets better and longer solar exposure.

Candace teamed up with Mr. Sun Solar, the company that also helped install her solar hot water system, to install the solar-electric system—(14) 110-watt BP modules wired in two strings of seven, feeding into a PV Powered 1,800 W inverter. To cut costs, Candace and her student crew did a lot of the grunt work, hand-digging the trenches and the 3-foot-diameter, 9-foot-deep hole for the pole, and pouring the concrete.

The array was mounted on a UniRac rack with an 8-inch-diameter, schedule 40 galvanized steel pole. The pole—with 9 feet underground and 12 feet above ground—was anchored in 2 1/3 cubic yards of concrete, and designed to withstand 100 mph winds.

The energy-aware household—five people living in the three apartments—uses about 5.5 kWh per day during the summer and about 20 kWh in the winter. At 3.95 average daily peak sun-hours, the system averages 4.3 kWh per day.

## *Biodiesel-Fired Furnace*

**Cost: One 1976 Morris Mini Minor**

A walk around the house reveals a shed that houses a water heater and biodiesel burner system for the home's latest addition. In 2007, after the home's diesel furnace gave out, Candace was faced with the decision of how best to provide heating for the house. She wanted to use a renewable energy source for heating, but she wasn't exactly sure how to go about it and whether she could afford to do it. Short on funds, she got creative. She ended up contacting Juaning Higgins from Portland Green Heat to help create a heating system that would use biodiesel as the heat source, but keep the combustion unit separate from the living space. Candace bartered an even exchange—her 1976 Morris Mini Minor (a precursor to BMW's Mini Cooper) for a new furnace.

Biodiesel storage tanks share the laundry room.

Shawn Schreiner

Suzanne Olsen

**The solar hot water system also serves a space-heating function, supplying heat to the hydronic radiators in the house.**

## *Solar Hot Tub*

**Cost: $1,149**

Using a 240-gallon cedar hot tub that she found on Craigslist, Candace and several of her students installed a solar hot tub in the backyard. Mr. Sun Solar handled the technical aspects of the installation.

The finished system relies on a used, 32-square-foot solar thermal collector. The hot glycol from the collector runs through cross-linked polyethylene (PEX) tubing underground into a coil of copper at the bottom of the tub.

The controller from Independent Energies allows the hot tub to reach temperatures up to 109°F before the pump shuts off. Polystyrene spray-foam insulation (R-7 per inch) in the tub's lid, walls, and bottom help keep the tub hot for days in sunny weather. The cost to run the system's pump and supplemental electric heater is about $176 per year.

**The solar-heated hot tub is heated by a 4- by 8-foot solar collector (not shown) through a copper coil, which can be seen at the bottom of the tub.**

Shawn Schreiner

The blower remained in the utility room, and a hydronic radiator coil with 130,000 Btu capacity was installed in the old furnace cavity above the blower. The biodiesel burner was located outside in the shed, along with an expansion tank, biodiesel pump, and pump control box that was modified for B99—99% biodiesel fuel.

The furnace's relay and transformer are managed by a New Vision Pro 8000 touch-screen programmable thermostat, with a remote for upstairs. Two 110-gallon storage tanks in the laundry room hold the B99 fuel. Initially the furnace was burning 3 to 5 gallons of biodiesel fuel per day, but once Candace insulated the shed and wrapped the tank and pipes with insulation, usage dropped to 0.5 to 1 gallon per day. With new insulation added between the floor joists, and blown-in cellulose in the walls, the furnace and hydronic baseboard heaters (which are connected to the solar hot water system) keep the house comfortable.

Shawn Schreiner

Rainwater collection offsets water use and cost, for summertime irrigation.

Art and functionality combine in the bottle-wall, and throughout the property.

Suzanne Olsen

## Rain Collection System

**Cost: $150**

Candace also designed a simple rain collection system—nine 60-gallon barrels along the north side of the house and six 30-gallon barrels along the straw bale structure—to collect rainwater from the roofs. When the first barrel fills, overflow goes into the second barrel. The barrels can store 740 gallons of water for most of the summer garden's needs.

## Wall o' Waste

**Cost: Just her time.**

Nothing goes to waste at Candace's place. Discarded hubcaps, curvy sticks, and broken glass become *objets d'art*. Colored-glass wine bottles—donated by a local recycler and collected from the trash—create a mosaic wall along the front of the house. The project, as Candace says, serves to demonstrate that so-called waste materials don't have to end up in landfills if someone is creative enough to find a use for them.

FYI: Buying "green" is not always a good thing. Green glass, especially that used for green wine bottles, is not highly marketable as a recycled material and often goes to waste.

## Looking Ahead

Even with all of these improvements, says Candace, the house is an "ongoing, ever-evolving" project that may never be truly finished. She keeps busy these days working on her doctoral degree in ecological science, coring lakes on Rapa Nui, and raising a teenage son, but that has not slowed her down any. Her immediate plan is to finish off the biodiesel furnace shed with cob, a wine-bottle mosaic, and a living roof.

"If you're industrious in learning what you need to, willing to put in the sweat effort, and resourceful when finding materials, it all can be affordable—even for a single mom," Candace says. "I'm proof of that."

## Access

John Patterson (john@mrsunsolar.com) is president of Mr. Sun Solar and inventor of the Sol-Reliant solar water heating system. Over the past 28 years, his company has installed more than 2,000 solar energy systems, including PV, solar water heating, and solar pool heating systems.

Suzanne Olsen (suzolsen@integra.net) is a writer and photographer specializing in renewable energy and the environment.

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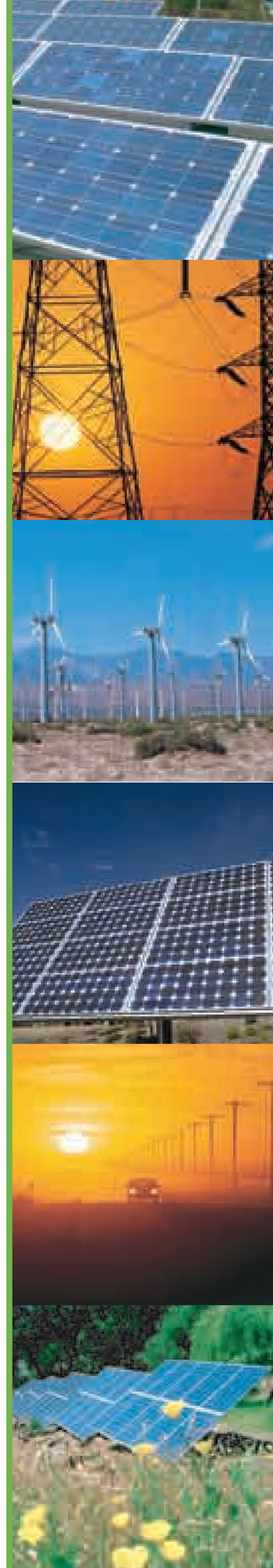

# Get Solarized Now

## Financing Your PV System

by Mo Rousso

When I first started in the residential PV industry, it was as the founder, engineer, salesperson, installer, troubleshooter, purchasing manager, bookkeeper, and janitor of a PV integration company in Southern California. Like most small-business owners, I did it all, and this gave me the opportunity to work with hundreds of customers. Surprisingly, despite the range of people I interacted with, they all had a common thread when it came to buying a system: the bottom line—what's this gonna cost me?

My first sale was to an engaging retiree. She had a doctorate in economics, and kept her mind active by writing and publishing a social responsibility newsletter. She was a staunch environmentalist and wanted to leave a legacy of stewardship for the planet. "Aha!" I thought, "here is an easy sale." Boy, was I wrong! She did end up buying a PV system from me, but only after I demonstrated the added value to her home and the financial impact on her heirs.

Another sale in the early days of my business was to a couple with a strong personal history in environmental and social activism. When we first commissioned their system, the wife burst into tears and said, "I thought I would never live to see this day." Even with all of this personal passion tilting the balance toward the sale, it was still dicey until I could demonstrate a return on investment superior to what they were earning on a bank certificate of deposit.

What I learned in those early days was that even if people wanted to stick it to the utility, gain independence from fossil-fueled electricity, or do their part for the planet, they still wanted to know that the PV system on their home made financial sense.

### Is Financing for You?

In many states, investing in an RE system does make economic sense because of incentives and cash rebates, tax credits, property tax exemption, and increased property value. With all these benefits factored in, it's not difficult to create a compelling financial picture that yields an attractive return on investment.

Once you've made the decision to buy, the next question is *how*. A PV system is a big-ticket item, usually on the order of a new luxury car, swimming pool, or kitchen remodel. Plus, most of us are used to paying monthly for our electricity—paying in advance for years of green electricity is a foreign concept.

The bottom line is that most of us don't have this kind of cash around, or, if we do, are hesitant to part with it. And that's where financing your project can pay off.

### Basic Financing Methods

**Cash Out.** Withdrawing cash from a certificate of deposit (CD), money market account (MMA), or borrowing against a 401(k) may be a good option for homeowners who have accumulated comfortable reserves—and live in an energy market where PV investment returns exceed those yielded by their conventional investments. For example, especially in today's troubled equity markets, a 1-year CD yields 3.5% and an over-$10,000 MMA yields about 2.5%. Compare this to a PV system in California: With the state's high electricity rates, a PV system may yield a return of more than 12% if you can take advantage of all the tax credits.

**Plastic.** Using your credit card is a convenient way to pay for your PV system, provided that you have a high enough credit limit. The downside is that interest rates are high, usually higher than any yield enjoyed by a PV investment, and interest is not tax-deductible.

**First Mortgage & Refinance.** Typical home mortgages are often the very best financing arrangement, since most homeowners are familiar with them and the interest is tax-deductible. A conforming (also known as "conventional") first mortgage takes into account the value of the entire home, including the new solar system, at approved loan-to-value ratios and is paid back over 15 to 40 years. Thirty-year conforming loans are currently available at about 6% and 30-year jumbo loans are just over 7.5%. A jumbo loan or mortgage is a home loan that exceeds the limits set by Fannie Mae and Freddie Mac—the 2007 limit was $417,000 in the continental United States and $625,500 in Alaska, Hawaii, and the U.S. Virgin Islands. Jumbo mortgages generally have a slightly higher interest rate than smaller conventional mortgages.

**Home Equity Line of Credit & Home Equity Loans.** These have traditionally been the mainstay of PV financing. However, due to the current financial crisis, many properties have depreciated in value and the home's equity has evaporated. However, for those homeowners who have built enough equity, home equity-based credit may be attractive.

A home equity line of credit (HELOC) allows you to borrow as needed against the equity in your home. Interest is charged on the amount of money that is actually borrowed. There is no fixed loan period, and the interest rate may vary over the time an outstanding loan balance is carried. Current rates for home equity lines are higher than mortgage rates. The interest may be tax deductible. Typically, there is a fee to set up the HELOC and there may be an annual maintenance fee.

A home equity loan is similar to a line of credit, except these loans are typically for a specific amount, to be paid back over a specified period of time and at a designated interest rate. A home equity loan may include fees and points. Interest may be tax-deductible.

It is interesting to note that a $50,000 HELOC currently has an interest rate of about 4.7%, while a $50,000 home equity loan has an interest rate of about 8%.

The following are guidelines to see if your loan is tax-deductible per the Internal Revenue Service. As with any matter that is tax related, it is prudent to consult with your accountant or tax preparer.

Generally, home mortgage interest is any interest you pay on a loan secured by your home (main home or a second home). The loan may be a mortgage to buy your home, a second mortgage, a line of credit, or a home equity loan.

## Financing Pros & Cons

**+**

- Good for situations where cash is limited
- You are familiar and comfortable with a monthly payment schedule
- Some financing programs include system maintenance, eliminating your risk if equipment should fail
- Some programs offer PV financing rates that are competitive with the rate of historical electric utility tariff increases

**–**

- Traditional financing vehicles, such as loans, may result in a higher total cash outlay due to interest charges
- The fine print in leases and power purchase agreements can be onerous—and these agreements are non-negotiable
- You need a FICO score better than 640
- Going through a credit check and approval process can delay the purchase
- There may be restrictions when selling your home—be sure to read the fine print in any agreement you sign
- Products offered through second-tier companies may have lower credit requirements, but along with this, may have high interest rates, offsetting any financial gains afforded by the PV system

You can deduct home mortgage interest only if you meet all the following conditions:

- You must file Form 1040 and itemize deductions on Schedule A (Form 1040).
- You must be legally liable for the loan. You cannot deduct payments you make for someone else if you are not legally liable to make them. Both you and the lender must intend that the loan be repaid. In addition, there must be a true debtor–creditor relationship between you and the lender.
- The mortgage must be a secured debt on a qualified home in which you have an ownership interest—your main home or your second home. A home includes a house, condominium, cooperative, mobile home, house trailer, boat, or similar property that has sleeping, cooking, and toilet facilities.

**Power Purchase Agreement (PPA).** PPAs are a financial instrument that is moving into the residential market from the commercial PV market. In a PPA, the provider finances, installs, owns, and operates a renewable energy system on your property with no capital investment from you. (See *HP128*, "Financing the Solar Dream.")

During the PPA's term, the installed system generates clean power and you are only billed for the actual electrical output—usually at a discounted price per kWh. In this way, you "buy" electricity from the PPA provider—not from your utility—and are billed for it monthly. At certain milestones during most PPA agreements, you can purchase the PV system at a discount or elect to continue the agreement.

PPA providers assume the operating risks—if the system is not generating electricity, you do not pay them. Most PPA contracts cover a period ranging from 12 to 20 years, so it's in a provider's best interest to use reliable components and contractors to ensure a system's long-term reliability and optimal energy production. Currently, PPAs are not available in most states.

**Bank Secured & Unsecured Loans.** A number of innovative banks have begun offering both secured and unsecured loans for residential PV systems. Most of the secured loans are home equity-based and, as a result, may be tax-deductible if they meet the IRS rules noted previously. Interest incurred from unsecured loans is not tax-deductible. The pioneer in promoting PV loans is New Resource Bank of San Francisco. However, other banks, like ShoreBank, are also very solar-friendly. Mainstream banks, such as Union Bank of California, Bank of America, and Wells Fargo, are also beginning to offer PV system loans.

**Vendor Financing.** Some PV module manufacturers offer financing to their customers, provided through specialty banks and retail outlets. These loans may have attractively lower monthly payments because the payback is spread over 15, 20, or even 30 years. Loans may be fixed, adjustable, or a combination. You may also get deals like no payments for one year, or six months same as cash.

Your interest rate will depend on your credit score. Vendor financing is available through companies like BP Solar, SunPower, and Sharp Solar. In fact, there are a number of PV distributors, like Conergy, Solar Depot, groSolar, SunWize, AEE Solar, and DC Power, that may offer financing. However, financing is not offered on a retail basis. It is offered through their installer network as a value-added service to dealers. As a result, it always pays to ask the dealers from whom you are soliciting proposals if they offer financing—and the terms of that offering.

**Utility & State Loan Programs.** A number of states and utilities have established loan programs to help homeowners purchase PV systems. For example, Sacramento Municipal Utility District's Residential Loan program provides 100% financing to customers who install solar hot water or PV systems. Their 10-year loan currently carries an interest rate of 7.5%.

In Oregon, the Small-Scale Energy Loan Program is administered by the Oregon Department of Energy to finance small-scale, local energy projects. Terms vary with the size and nature of the project.

**Association Financing.** The leader in providing financing products to its contractor members is the Electric & Gas Industries Association (EGIA). EGIA provides financing for energy-efficiency and renewable energy projects through its partnership with GE Money and its GEOSmart Sustainable Financing Solutions program.

**Local Government Loans.** These programs represent one of the most exciting developments in residential PV financing to date. California has passed a unique way to fund the propagation of renewable energy by allowing municipalities to create special tax assessment districts. If you own a home within the district, you can borrow money from the local jurisdiction and pay it back over time through an increase in your property taxes. Berkeley, California, is pioneering this approach with its Financing Initiative for Renewable and Solar Technology (FIRST). The FIRST program will provide financing up to $37,500 per installation for either residential or

## Off-Grid Financing

So, you found that perfect piece of rural property on which to build your dream home and you don't have a lot of cash left for a big RE system. Now what? You still need to have electricity for a number of crucial things, like your well pump, refrigerator, and lights.

If you like the lifestyle, but are not necessarily committed to falling off the grid, you can investigate how much it would cost to run utility electricity to your property. Depending on your distance from existing lines, it may cost between $50,000 and $100,000 (and up)—just for the privilege of buying electricity from the utility for the rest of your years. But $50,000 can buy a lot of renewable energy capacity with no recurring energy bills!

If you are building a new off-grid home, many institutions would be happy to fold the cost of your RE system into the construction loan. If you need to transition to a mortgage at the conclusion of the construction, all home lenders require that the home has sufficient power to properly protect its asset value—a home with no electricity would be difficult to sell.

Make sure that you keep copies of your invoices for the RE system, as well as copies of the approved electrical inspection, to prove to the mortgage company that you have electricity at the property, and to ensure that the appraiser adds an appropriate amount to the value of the home.

If there is existing infrastructure, like an engine generator, that provides electricity, you may still be able to refinance into a new mortgage and access cash for your PV system. Additionally, bank loans may be available. However, they vary on a regional basis, so be sure to talk to your bank—especially if you have a strong credit rating.

Some of the state loan programs will also help finance off-grid PV systems. To see what's available, visit the Database of Incentives for Renewables and Efficiency site at www.dsireusa.org.

## PV System Financing Options

| Type | Down Payment | Interest Rate[1] | Term (Yrs.) | Minimum Credit Score[2] | Provider Selects Materials & Contractor | Assumes Operating Risk & Maintenance |
|---|---|---|---|---|---|---|
| Mortgage or refinance | 5–20% | 6%–7.5% | 15–40 | 640 | No | Homeowner |
| Home equity loan | None | 4.7%–8% | Open | 640 | No | Homeowner |
| PPA | 0–30% | None | 12–25 | 680 | Yes | Provider |
| Bank loan | 0–25% | Varies per credit score | 5–10 | 720, lower if secured | No | Homeowner |
| Vendor financing | 0–20% | Varies by program & credit score | Varies, may be open or revolving | 640 | Yes | Homeowner |
| Utility & state loans | None | 7.5%–10% | 10 | 640 | May need approved contractor | Homeowner |
| Association financing | 0–20% | ≥7.99% | Varies; depends on product | 680 | Need approved contractor | Homeowner |
| Govt. loan program | None | 7.5%–10% | 20 | 640 | No | Homeowner |
| EEM | 0–20% | 6%–8% | 15–40 | 640 | No | Homeowner |
| Lease | 0–25% | None | 7–20 | 720 | Yes | Provider |
| Credit card | None | | Open | N/A | No | Homeowner |
| Cash | None | None | None | None | No | Homeowner |

1. As of 11/1/2008
2. May change, depending on economy and markets

commercial properties—without a down payment. Payments will be made through a special tax on the participant's property tax bill. If the owner moves out of the house during the 20-year repayment period, the property tax assessment and the PV system remain with the property.

**Energy-Efficiency Mortgages.** Homeowners can take advantage of energy-efficiency mortgages (EEMs) to finance a variety of energy-efficiency measures, including solar electricity, in a new or existing home. The U.S. federal government supports these loans by insuring them through Federal Housing Authority or Veterans Affairs programs. This allows borrowers who might otherwise be denied loans to pursue energy-efficiency improvements, and it secures lenders against loan default. Rates and terms are similar to conforming first mortgages.

The federal Energy Star program has a partnership program for lenders whereby lenders who provide EEMs to borrowers may become Energy Star lender partners. Becoming a partner allows lenders to utilize the Energy Star brand to promote themselves.

**Operating Lease.** This method of financing, like PPAs, uses the tax incentives associated with the project to pay for the use of funds. Tax incentives include credits and depreciation expenses. Terms are typically seven to 20 years, and lease payments are matched at or below utility costs. Typically, this type of lease is not performance-based—the homeowner makes the lease payment regardless of system performance. At the end of the lease, the customer can renew the lease or purchase the equipment at fair market value.

The leader in residential PV leasing is SolarCity, which offers lease programs in locations in Oregon, California, and Arizona. They have modified the terms of their lease to guarantee that if your system isn't producing the amount of electricity it is supposed to, they will pay you the difference. They also require very little down payment and structure their lease so that your payments, combined with your net-metered balance of payment to the utility, are less than your average monthly utility bill. However, you'll need a FICO score of at least 720 to qualify. As with any form of financial contract, read the fine print before signing to ensure that you are comfortable with the lease terms, which may stipulate what happens if you sell your home, when your system needs maintenance, and what happens in the case of default.

### Finding Financing That Fits

There are a number of choices available through which to finance your PV system and to realize your green dream. However, it goes without saying that, in today's volatile economy, you need to be comfortable with the payments and the terms. Read the fine print, and make sure you understand what the terms mean and how they impact your specific financial situation.

Generally, and within the context of your financial situation, evaluate financing your PV system in the following order:

1. Liquidate an underperforming asset. In many cases, beating the annual historical electricity tariff rate increase is justification enough for the investment. In California, the historical rate increase is about 7% per year. Not many secure investments can beat that rate in today's market.

2. Use a mortgage or home equity instrument. They offer low interest rates that are tax deductible.
3. If you live where there is property-tax-based financing, this is a very low-risk way to go.
4. If you are looking to minimize your monthly payments and are not interested in assuming the operational risk, then entertain a PPA or a lease.
5. If you are interested in PV ownership and do not have home equity, check out New Resource Bank, ShoreBank, or any other bank that offers financing specifically for PV systems. Also check to see if your state offers low-interest loans.
6. Unsecured loans from any source should be the last resort, since interest rates are higher and the interest usually is not tax-deductible.

## Access

Mo Rousso (mrousso@heliomu.com) engineered and installed his first solar energy project in 1975. In 2001, he founded HelioPower, a leading solar power integration firm based in California. Mo is currently CEO of Helio mU, a PV finance company, that will be rolling out its residential program in spring of 2009. He holds a master of business administration with an emphasis in finance, and a bachelor of science degree in mechanical engineering.

Power Purchase Agreements:

SunRun • www.sunrunhome.com

Helio mU • www.heliomu.com

Bank Loans:

New Resource Bank • www.newresourcebank.com

ShoreBank • www.shorebankcorp.com

Vendor Financing:

SunPower • www.sunpowercorp.com/For-Homes/How-To-Buy/Smart-Financing.aspx

Sharp Solar • 866-667-4916 • www.solar.sharpusa.com

Conergy • www.conergy.us/desktopdefault.aspx/tabid-2013//732_read-5120/

Association Financing:

EGIA/GEOsmart • www.egia.com

Leases:

SolarCity • www.solarcity.com

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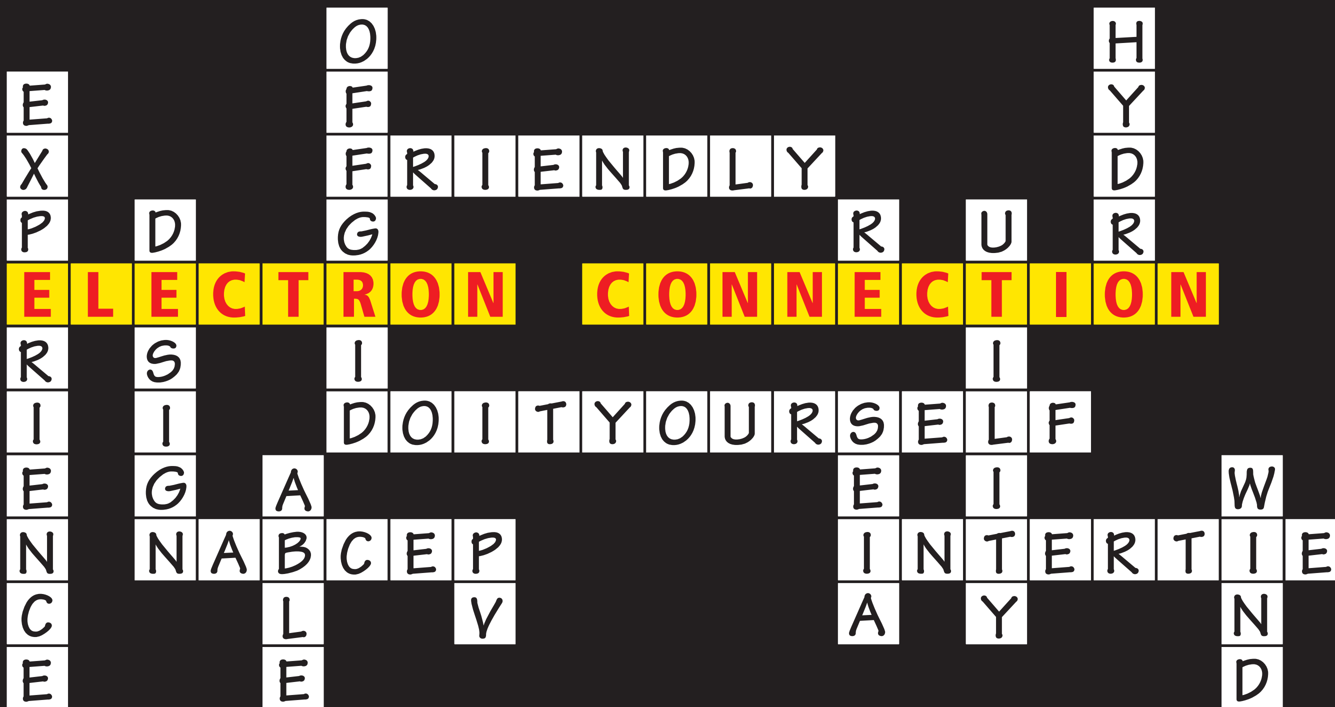


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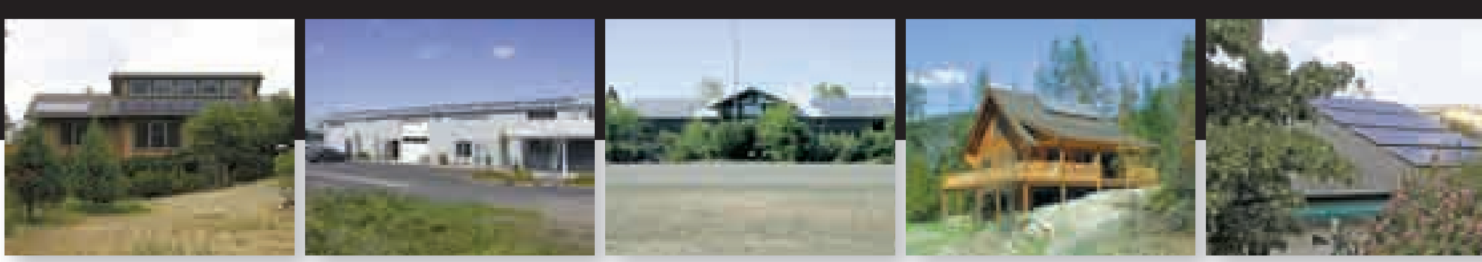

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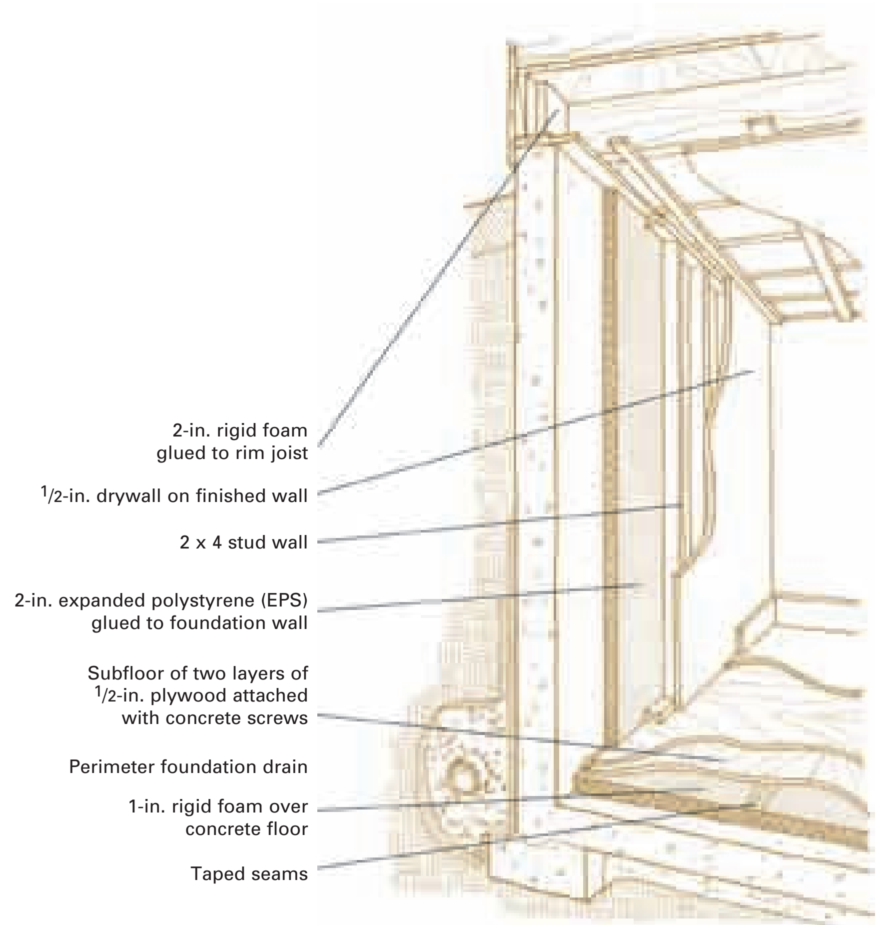
Conventional foundations, while amply strong, have fundamental energy efficiency and sustainability problems—that can be cured. First, conventional foundations are often designed and built without regard to their potential for energy loss (or, looked at the other way, without regard to the contribution they can make to a home's overall energy performance). Second, the concrete they are typically made from has high embodied energy and therefore, a high carbon footprint. Finally, foundations are typically overbuilt, resulting in an unnecessary use of materials.

## REDUCING ENERGY LOSSES

**Basements.** In regions where full basements are the norm, they are often just uninsulated concrete boxes. What's forgotten in all of this is the amount of heat lost through foundation walls, crawl spaces, and concrete slabs. Although foundations are thermally connected to the rest of the house, too often they're not designed as part of the thermal envelope. How much this common oversight actually adds to the cost of heating a house depends on a variety of factors, yet insulation can considerably increase energy savings.

One solution is to insulate the exterior of the foundation wall before backfilling. In most heating climates, 2 inches of closed-cell extruded polystyrene, which is more moisture-resistant than expanded polystyrene, should be the minimum. This should be applied over the moisture proofing on the outside of the foundation wall. The insulation helps to keep the basement at a steady temperature—warmer basement walls minimize condensation and the mold and mildew that go along with it if the basement is made into a finished space.




**Insulating a basement on the inside.**

# GREEN from the Ground Up

by David Johnston & Scott Gibson    illustrations by Martha Garstang Hill

Turning an unfinished basement into living space usually involves adding new interior walls. Builders sometimes use 2 by 4s to build a conventional wall and insulate it with fiberglass batts. A vapor barrier applied to the warm side of the wall, or directly against the foundation, is supposed to keep moisture away from the concrete. But moisture that accumulates inside the wall is trapped, which can lead to mold and decay. A better approach is to attach semipermeable expanded or extruded polystyrene foam panels directly to the foundation wall and tape the joints. This keeps most air and moisture from reaching the concrete and allows the wall to dry to the inside. Gypsum drywall can be applied over furring strips for a finished wall surface, but no impermeable wall finishes should be used.

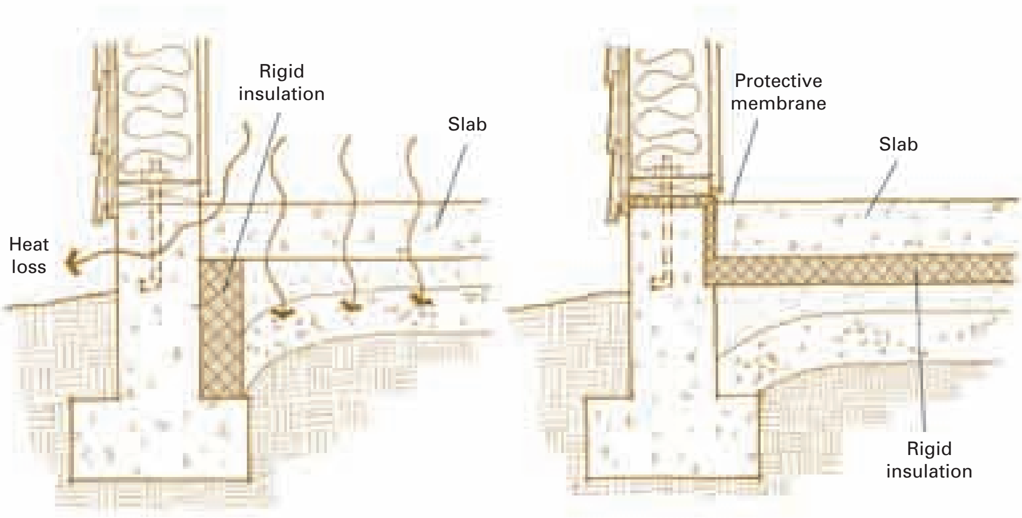
**Insulating the entire slab with rigid foam is a better approach than insulating only the perimeter when using radiant-floor heating.**

**Slabs** are rarely insulated, which means they constantly wick heat or cold to the inside of the house. In areas where the number of cooling degree-days (a quantitative index that reflects the amount of energy needed to cool a building) is very high, heat gain at the edges of a slab foundation can account for as much as 15% of the cooling load. In heating-dominated climates, a lack of insulation often means cold floors in rooms at the perimeter of the house. Edge insulation is an easy answer. It should be installed inside the forms before the concrete is poured. For houses in which radiant floor heating is incorporated in the slab, not only should the edges of the slab be insulated with rigid foam, but also the entire underside of the slab.

The thickness of slab insulation should be determined by climate, but use a minimum of 1 inch of closed-cell rigid foam. When the forms are removed, the insulation sticks to the concrete. When siding is installed over the framing, z-channel flashing can be installed over the foam to protect it. Any foam that's exposed after the foundation has been backfilled can be covered with cement board or a coat of stucco.

## REDUCING WOOD WASTE

Wood form material is one of the largest sources of wood waste from building a house. Dedicated plywood or metal forms for full-basement concrete walls and stem walls can be used many times. But slab-on-grade foundations are often formed with 2 by 12s, which may come from old-growth trees. They may hold up through three or four foundations, depending on how carefully they are removed from the




**Left: Rigid foam insulation on the inside of the footing for a slab foundation doesn't do much to prevent heat loss at the slab perimeter.**

**Right: Adding 2 inches of closed-cell foam insulation beneath the slab and on the interior of the frost wall is a more effective thermal break and reduces heat loss.**

previous slab, but eventually the boards become unusable. By then, they are covered with concrete and permeated with the chemical release agents that keep the concrete from sticking, so they can't be recycled.

Although the initial cost of alternatives such as plywood and metal forms is higher, they save the trouble and expense of replacing forms made from dimensional lumber. They also save good lumber from needless destruction. The release agents themselves are often a petroleum-based product or simply diesel—a waste of oil and a potential environmental hazard. Using a biodegradable vegetable-oil-based form-release agent is better.

## RECYCLED WOOD FOR FOUNDATION FORMS

If you don't like the idea of the plastics that go into many types of insulated concrete forms, consider blocks made from cement-bonded recycled wood-chips—Durisol wall forms are one such product. They can be installed above or below grade, come in several widths, and are available with inserts of mineral wool to boost insulating values.

One advantage of the wood-block forms is their ability to absorb and release high levels of moisture in the air without damage and without supporting the growth of mold. Some or all of the wood fiber used to make them comes from post-industrial waste. From an insulating standpoint, they also perform well, ranging from R-8 for an 8-inch block to R-20 for a 12-inch block with a 3-inch mineral wool insulating insert. Blocks are dry-stacked and then filled with concrete.

## IMPROVING CONCRETE WITH FLY ASH

According to *Environmental Building News*, concrete production produces 8% of global-warming carbon dioxide. One way of reducing this number is to combine concrete with fly ash, a waste product from coal-fired power plants. Using fly ash has a double benefit: It not only provides a way of recycling fly ash but also reduces the amount of portland cement required in the concrete.

Fly ash is a difficult by-product to dispose of. What makes this marriage interesting is that fly ash bonds chemically with cement to make the concrete stronger, more water resistant, and more durable than a batch that uses portland cement alone. Typically, 15% fly ash is added to the mix to yield concrete with a compressive strength of 3,500 pounds per square inch—500 psi greater than a conventional concrete mix. In some parts of the country, fly ash is added to concrete at the ready-mix plant—the builder doesn't even have to ask

### Think Before You Pour

In some parts of the country where full basements have come to be expected, foundation walls are typically 8 inches thick and rest on a 12-inch-wide concrete footing. But like oversized headers and unnecessary framing members, these heavy-duty foundations may simply be a waste of money and resources.

Fernando Pagés Ruiz is one builder who thinks twice about the real value of building conventions and often finds a less expensive, more efficient way of getting the job done. His book, *Building an Affordable House* (The Taunton Press, 2005) details a variety of ways to reduce the cost and complexity of construction. By applying value engineering to foundations, he's found a number of options that are worth exploring:

- Reduce the thickness of concrete walls, at least for some parts of the foundation.
- As soil conditions permit, skip the footing altogether.
- Consider foundation alternatives, such as treated-wood foundations and precast foundations.
- Reduce the thickness of slab foundations.

Some of these alternatives may require soil tests or special engineering, and there's no guarantee that local code officials will embrace them. Yet the effort can pay off handsomely in the form of lower costs and a more efficient use of materials.

**These insulated concrete forms are made with cement-bonded wood fiber and contain no plastics. With 3-inch-thick insulation inserts in the 12-inch blocks, the R-value of the wall is about R-20.**

Courtesy Durisol Building Systems

**An insulated foundation becomes part of the house's thermal envelope, contributing to energy conservation and creating a more comfortable indoor environment.**

Courtesy Ecofutures Building

## Insulated Concrete Forms & Basements

Insulated concrete forms (ICFs) all share a design that combines insulation and concrete to form finished walls. Some types are made with 2 inches of closed-cell extruded polystyrene on both sides of the wall, with spacers in between to hold the form together as the concrete is poured. The spacers do double duty by serving as screw bases for attaching finish wall materials on the inside and outside, to cover the foam. Some ICFs are stacked like blocks, and their internal cavities filled with concrete. In all cases, there is insulation on both sides of the foundation wall that keeps the basement warm and helps make the wall more water-resistant. The exterior surface in contact with the ground should still be coated with a waterproof membrane.

Courtesy Merten Homes

**Insulated concrete forms are an easy way to build rigid foam insulation directly into foundation walls, making for much warmer finished spaces inside. Forms are made from foam or recycled wood waste mixed with cement.**

Courtesy Merten Homes

for it. Some builders in California are experimenting with mixes that contain as much as 50% fly ash and 50% cement, and find they are working very well.

Concrete containing fly ash does have some drawbacks. It sets up slowly, meaning that construction might be delayed a day or two after the pour, depending on weather. That is what makes it more water-resistant, however. In cold weather, it may require other admixtures to accelerate the setup time.

### MAKE CRAWL SPACES GENEROUS

Crawl spaces are common in many parts of the country, and keep the house off the ground enough to allow for the installation of wiring and plumbing. Building codes typically call for a minimum distance between grade and the floor framing of 18 inches. But raising the height of the crawl space to at least 24 inches will keep all the trades happier.

At a minimum, the floor should have as much insulation as the walls. More is always better. Installing insulation between floor joists keeps the floor warm, but it makes the crawl space an unconditioned space. If ductwork runs through an unheated space, heat loss and the risk of condensation and leaks increase. A better method is to insulate the exterior of concrete walls with 2 inches of rigid foam insulation, just as a foundation is insulated. This creates a heated or conditioned crawl space.

Building codes that require vents in a crawl space can be a problem. Here, code hasn't kept up with building science. It's better to keep air and moisture out and make the crawl space part of the insulated envelope, and it's worth having a talk with your local building official if vents are still required. In any case, the ground should be covered with 8- to 10-mil polyethylene and sealed at the perimeter wall. A layer of sand under the poly can keep stones from puncturing this layer. Seams should be sealed with polyethylene tape. If there are piers in the crawl space, plastic should be sealed around them as well. This keeps the moisture out of the air under the house. The only exception to this approach is when a high water table periodically pushes water into the crawl space. In that case, venting will be necessary. Power vents or fans along with a sump pump might also be required.

Scott Gibson, courtesy Fine Homebuilding, ©The Taunton Press

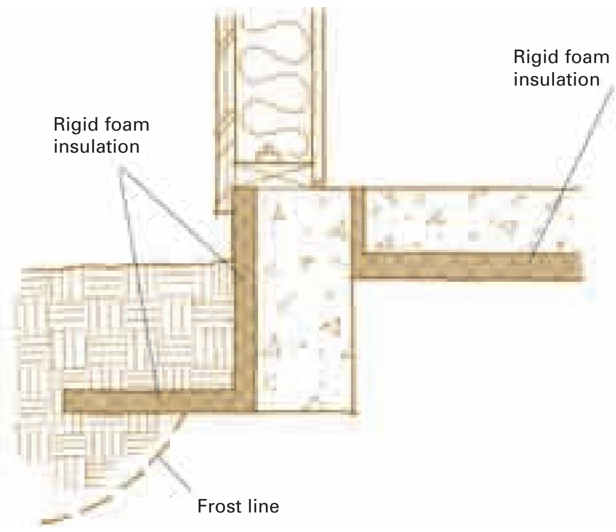
**Building codes may require only 18 inches of clearance in a crawl space, but increasing that to at least 24 inches makes it easier to work in this space. Either the floor or the crawl space walls should be insulated.**

## Shallow Frost-Protected Foundations

The National Association of Home Builders' Research Center has developed a unique way to reduce the amount of concrete in foundations. Rather than pour footings below the frost line in cold climates, researchers placed footings just 2 feet below grade and then insulated the slabs in two ways. Walls were insulated conventionally with 2 inches of rigid closed-cell extruded polystyrene foam. Then, horizontally, a section of rigid foam 2 feet wide was placed around the perimeter of the slab 24 inches below grade.

These added layers of insulation keep frost from being driven deep into the ground where it could crack the slab. Model building codes have recognized frost-protected shallow foundation design principles for more than a decade. In most regions of the continental United States, these foundations can reliably be placed as shallow as 16 inches below grade. Performance has been proven in Europe, and frost-protected foundations have been used in very cold climates in the United States—in North Dakota, for instance—with great results.

It takes a lot less concrete to form one of these slabs when compared to the more conventional approach of placing concrete stem walls below the frost line before the slab is poured. That means savings for the buyer, as well as less energy and material use—all without sacrificing performance.




### BEST PRACTICES

So, you've got your plans, the site is prepped, and you're ready to start building: Remember to keep these tips handy to get your project off to a good start.

- Foundations, including concrete slabs, should be insulated to reduce heating and cooling loads. Insulating the outside of the foundation is better than adding insulation on the inside. If you do insulate inside, use rigid foam instead of fiberglass batts.
- When planning a slab-on-grade house, use a frost-protected shallow foundation design. It uses less concrete and requires less excavation.
- To combine structure and insulation, consider insulated concrete forms.
- Using foundation forms made from dimensional lumber will waste material. Use plywood or metal forms instead.
- Make sure the concrete you order contains fly ash. That makes good use of an abundant industrial by-product, and makes better, more durable concrete.
- Use moisture-proof coatings and perimeter drains to keep moisture out of foundation walls and lower the risk of mold, while making basements more comfortable.
- Raise crawl space height to 24 inches to make access easier and include the crawl space in the conditioned space of the house.
- Engineer the foundation for the loads it will actually carry—and not simply to industry standards—to conserve resources and make the house more affordable.

## Foam Insulation & Insects

When using rigid foam insulation on foundation walls, keep in mind that the foam can provide safe passage for insects—particularly termites—that can make their way into the house without being seen. If termites are a problem in your area, protect the house with a metal termite shield installed between the top of the foundation wall and the mud sill. Check local codes for specific requirements on using foam in contact with the ground.

### ACCESS

**David Johnston's** (david@greenbuilding.com) work in green building has been embraced by homeowners, building professionals, and sustainability advocates in the United States and internationally. In 2007, he was named the International Sustainability Pioneer by the European business community. Johnston's previous book, *Green Remodeling*, has been hailed as the definitive guide to green remodeling.

**Scott Gibson** (scottgibson@securespeed.us) is a contributing editor to *Fine Homebuilding* magazine, and a freelance writer and editor.

This article was adapted from *Green from the Ground Up* (The Taunton Press, 2008).

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# CHARGE CONTROLLER buyer's guide

## Check out the latest developments in charge controllers.

by Justine Sanchez & Brad Burritt

Charge controllers are vital components in battery-based PV systems, keeping the PV array from overcharging the batteries and optimizing charge current. These smart little boxes are placed between the PV array and the battery bank, and allow maximum energy in when the batteries are at a low state of charge (SOC) and reduce incoming energy from the array as the batteries approach full. When the battery reaches 100% SOC, the charge controller reduces the energy flow to a small maintenance (float) charge. Without a charge controller, a battery can be overcharged, resulting in excessive battery gassing and, in chronic cases, damage to the battery, shortening its life span.

Matching the appropriate charge controller to a particular PV system is important for proper system function and for maximizing the amount of solar energy harvested. This guide lists charge controllers 40 amps or above commonly used for whole-house PV systems.

OutBack's FlexMax charge controller.

## Array & MPPT Charge Controller Sizing Example

Calculating the configuration of your array based on your charge controller and calculating the number of controllers needed is not rocket science—just gather the necessary info, then use simple formulas to come up with the results.

**1. Find the maximum Voc per module based at a record low temperature of -29°C (-20°F). (Find your site's record low temp at www.weather.com.)**

### Example Array & Charge Controller Specs

| PV Modules | Spec |
|---|---|
| Number | 24 |
| Peak power (W) | 205 |
| Vpp | 26.6 |
| Ipp | 7.71 |
| Voc | 33.2 |
| Isc | 8.36 |
| Temperature coefficient (V/°C) | -0.12 |
| **PV Array** | |
| Peak size (W) | 4,920 |
| **MPPT Charge Controller** | |
| Max. PV open-circuit voltage (V) | 150 |
| Rated output current (A) | 60 |
| **Battery Bank** | |
| Battery voltage (nominal) | 48 |

Voc per module at STC (25°C) = 33.2 V

Temperature difference between STC & record low = 25°C - (-29°C) = 54°C

Use the module's temperature coefficient specification to find the Voc increase at record low temperature = 54°C x 0.12 V/°C = 6.48 V

Voc/module at record low temperature = 33.2 V + 6.48 V = 39.68 V

**2. Find the maximum number of modules that can be used in series based on the example controller's 150 V maximum Voc.**

Two series modules: Voc = 39.68 V x 2 = 79.36 V = OK

Three series modules: Voc = 39.68 V x 3 = 119.04 V = OK

Four series modules: Voc = 39.68 V x 4 = 158.72 V = Too high!

Three modules in series is the maximum.

**3. Find the number of controllers required and the number of module series strings per controller.**

4,920 W (array peak size) ÷ 46 V (min. battery voltage anticipated) = 107 A

107 A (total max. output current required from MPPT controllers) ÷ 60 A (output per controller) = 1.8 controllers. Two 60 A controllers are needed.

For our total of eight series strings (24 modules at 3 modules per series string = 8 strings), put four strings on each of two 60 A charge controllers. Each charge controller will be wired to 12 modules (4 strings x 3 modules per string).

### The Specs—Using This Guide

**Nominal Battery Voltages**—The nominal, or "name plate" voltage of a battery bank depends on the nominal voltage of the individual batteries and how they are wired together. Most residential-scale battery banks are 12, 24, or 48 volts, with 24 and 48 V most common. Some less common battery banks are 36, 60, or, rarely, 120 V nominal. Many newer charge controllers can be field-adjusted to accommodate any of several different battery bank voltages.

**Rated Output Current**—This is the maximum amperage the charge controller is designed to put out continuously at the rated operating temperature. Above these temperatures, the output will decrease and energy will be wasted. These temperatures may seem high for most climates, but the charge controllers and other associated equipment also produce heat during operation.

**Xantrex's C60 charge controller.**

# Charge Controllers & Specifications

| Manufacturer | Model | Nominal Battery Voltages (V) | Rated Output Current (Amps @ °C) | Maximum PV Open-Circuit Voltage (V) | MPPT | Array-to-Battery Step-Down Option (Max Voc to Nominal V) | Built-In Battery State-of-Charge Meter | Terminals' Wire Size Range (AWG) |
|---|---|---|---|---|---|---|---|---|
| **Apollo Solar** www.apollo-solar.net | T80 TurboCharger | 12, 24, 36, 48 | 80 A @ 45°C | 140 | Yes | 140 Voc to 12–48 V | Yes | 14–1/0 |
| | T100 TurboCharger | 12, 24, 36, 48 | 100 A @ 45°C | 140 | Yes | 140 Voc to 12–48 V | Yes | 14–1/0 |
| | T80HV TurboCharger | 12, 24, 36, 48 | 80 A @ 45°C | 200 | Yes | 200 Voc to 12–48 V | Yes | 14–1/0 |
| **Blue Sky Energy** www.blueskyenergyinc.com | Solar Boost 50DL | 12 or 24 | 50 A @ 40°C | 57 | Yes | 57 Voc to 12–24 V | No | 14–1/0 |
| | Solar Boost 6024HDL | 12 or 24 | 60 A @ 40°C | 140 | Yes | 140 Voc to 12–24 V | No | 14–1/0 |
| **Morningstar Corp.** www.morningstarcorp.com | TriStar TS-45 + display* | 12, 24, 48 | 45 A @ 45°C | 125 | No | — | No | 14–2 |
| | TriStar TS-60 + display* | 12, 24, 48 | 60 A @ 45°C | 125 | No | — | No | 14–2 |
| **OutBack Power Systems** www.outbackpower.com | FlexMax 60 | 12, 24, 36, 48, 60 | 60 A @ 40°C | 150 | Yes | 150 Voc to 12–60 V | No | 14–2 |
| | FlexMax 80 | 12, 24, 36, 48, 60 | 80 A @ 40°C | 150 | Yes | 150 Voc to 12–60 V | No | 14–2 |
| **Xantrex** www.xantrex.com | C40 + display* | 12, 24, 48 | 40 A @ 40°C | 125 | No | — | No | 14–2 |
| | C60 + display* | 12 or 24 | 60 A @ 40°C | 55 | No | — | No | 14–2 |
| | XW SCC | 12, 24, 36, 48, 60 | 60 A @ 45°C | 150 | Yes | 150 Voc to 12–60 V | No | 14–6 |

* Optional display added into suggested retail price

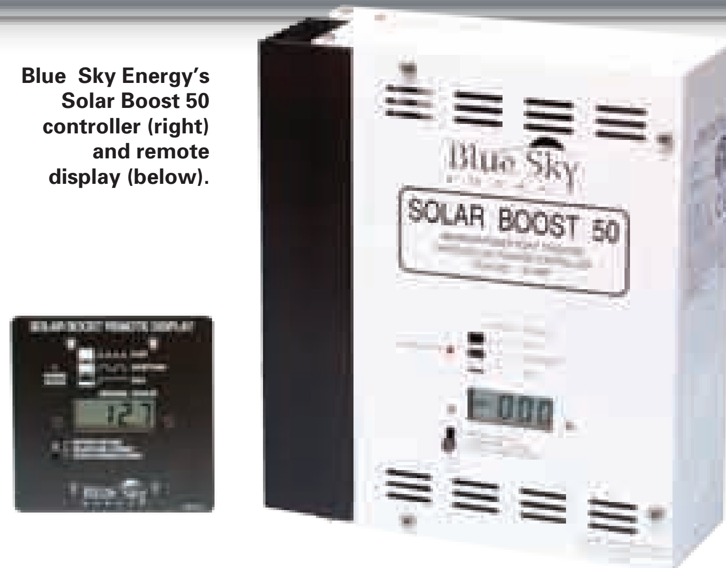
Rated output current is used to determine the size and quantity of controllers needed for an array. For non-MPPT controllers, the output rating of the controller(s) should be at least 125% of the array short-circuit current to allow for higher irradiance conditions. For MPPT controllers, the output current is based on the total array power (in watts) divided by the expected lowest battery voltage (usually the low battery cutout voltage set for the inverter). For matching an MPPT charge controller to a particular array, see the "Array & MPPT Charge Controller Sizing Example" on page 73, as well as controller installation manuals for specifics, which vary by manufacturer.

**Maximum PV Open-Circuit Voltage**—Charge controllers are designed to withstand a specific maximum input voltage. Exceeding this can damage the charge controller and possibly void its warranty. PV array voltage increases with decreasing temperature, i.e. as temperatures drop below 25°C (77°F), module voltage rises.

The controller's maximum open-circuit voltage must exceed the array's Voc. For example, if the array's Voc is 130 VDC, then a charge controller specified for a maximum of 130 VDC should be used. To calculate an array's Voc, use the module's temperature coefficient in conjunction with the site's historic low temperature (see *Code Corner* in this issue).

**Maximum Power Point Tracking (MPPT)**—PV arrays operate most efficiently at voltages higher than battery bank voltage. But because PV array voltage is affected by the load attached to it, batteries can cause the array voltage to drop below the ideal power production point to just above battery voltage, causing some loss of PV array energy. MPPT charge controllers manipulate incoming PV array power by converting excess PV array voltage (when available) to extra amps for filling the batteries.

The overall gain from an MPPT controller depends on temperatures at the site and battery SOC. More voltage is available during cold conditions and less during warm conditions. Additional power is only advantageous if we can absorb or use it. If the charge controller is doing its primary job and actually stopping current from flowing into the batteries because they are already full (high SOC), then this extra power is not harvested. MPPT charge controllers can really shine during the winter months




Blue Sky Energy's Solar Boost 50 controller (right) and remote display (below).

| Battery Temp. Sensor | Warranty (Yrs.) | Suggested Retail Price |
|---|---|---|
| Included | 5 | $849 |
| Included | 5 | 949 |
| Included | 5 | 995 |
| Optional | 3 | 599 |
| Optional | 3 | 599 |
| Optional | 5 | 274 |
| Optional | 5 | 325 |
| Optional | 5 | 699 |
| Optional | 5 | 749 |
| Optional | 2 | 258 |
| Optional | 2 | 298 |
| Included | 5 | 650 |

when cold temperatures increase available PV voltage, and fewer sun-hours lead to increased loads, while less array output tends to keep the battery SOC low. MPPT charge controllers are especially advantageous in battery-based grid-tied systems—when the batteries are full, the extra MPPT-recovered energy can still be sent to the grid.

**Array Voltage Step-Down Options**—MPPT-type charge controllers allow the connection of an array with a higher nominal voltage than the battery bank. Given this step-down feature, nearly any module type or size can be configured into an array to charge any size battery bank, and fewer parallel strings of modules are required for the same power output. This spec gives you the step-down ranges for each controller. For more details on the voltage step-down feature, see "Input Voltage & Controller Efficiency" sidebar.

**Built-in Battery SOC Meter**—This meter reports how full the battery is, eliminating the need to purchase a separate battery state of charge meter. As of this writing, only Apollo charge controllers include this feature. Some manufacturers offer a separate product for this purpose.

**Terminals' Wire Size Range**—Charge controllers have terminals for the wires coming from the PV array and those going out to the battery bank. These terminals accept a range


Apollo Solar's T-80 charge controller and wireless remote.

## Input Voltage & Controller Efficiency

PV arrays are commonly wired for the highest voltage that the controller can handle, as this allows the smallest—and cheapest and easiest—wire size that can be used. Maximum power point tracking (MPPT) charge controllers allow the flexibility to configure a PV array for a range of output voltages.

Having fewer parallel strings in a PV array simplifies the installation and raises the voltage, compared to fewer modules in each string. This reduces costs, as fewer overcurrent protection devices—breakers or fuses—are needed, and a smaller combiner box can often be used. Having smaller and fewer wires speeds up the installation process, reducing costs even more.

But there are trade-offs involved with using higher PV array voltages. Higher array voltage results in a slightly lower operating efficiency for the MPPT controller. Controller efficiency decreases as the step-down ratio (PV array voltage to battery voltage) increases. For example, a system with a 4:1 ratio (96 VDC PV array and 24 VDC battery) will operate at a 0.5% lower efficiency than with a MPPT controller operating at a 3:1 ratio (72 VDC PV array and 24 VDC battery).

Some MPPT controller manufacturers provide information, such as graphs that show the impact on efficiency at various PV array voltages and battery voltages.

On systems with longer wire runs between the PV array and the MPPT controller, the savings achieved by being able to use a smaller wire size can be substantial. Sizing wires somewhat larger than required can reduce a typical array-to-controller wire loss of 2% to 1.5%, for instance. This can make up for the slightly lower conversion efficiency of a greater step-down ratio.

However, on systems with short wire runs, the savings from using a smaller wire size may not be enough to offset the lower MPPT controller efficiency. In these cases, having a lower PV array voltage configuration would be a better choice.

—Christopher Freitas

of wire gauges. Because conductors often need to be up-sized due to voltage drop constraints, having a controller with terminals that can accommodate a wide range of wire sizes can be advantageous.

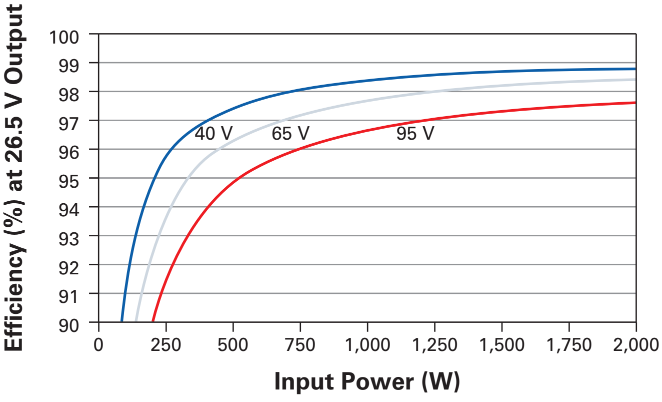
**Battery Temperature Sensor**—All the charge controllers in this guide include temperature compensation functionality, which adjusts charge voltage set points based on battery temperature. Some charge controllers include the battery temperature sensor and others offer it as an option.

**Temperature Compensation**—The internal resistance of a battery fluctuates with battery temperature, so charge controllers are most effective if they adjust their charge termination (voltage) set points to accommodate this changing internal resistance. Understanding how temperature compensation works requires Ohm's law:

**Voltage (V) = Current (I) x Resistance (R)**

When a battery is cold, its internal resistance increases, which causes the voltage to rise (assuming a constant current). Charge controllers use voltage to determine the shutdown point for when the battery is full. Without temperature compensation, a false high-voltage reading means that charging would get shut off too soon, resulting in an undercharged battery. Conversely, high temperature causes a battery's internal resistance to drop. This causes a false low-voltage reading, and thus charging gets terminated too late, causing the battery to be overcharged. Temperature compensation allows a charge controller to

### Typical Charge Controller Efficiency at Different Array Voltages




Charge controllers are designed to withstand a specific maximum input voltage. Exceeding this can damage the charge controller and possibly void its warranty.

increase the charge termination set point for a cold battery and decrease this set point for a warm battery—resulting in an appropriate charging regimen.

**Warranty**—Charge controller warranties range from two to five years. Although having a long warranty to back you up is great, there are other factors to consider, including down-time and service-related expenses. A product with a long history made by a reputable company may save you money (and time) in the long run, regardless of the warranty offered. All the controllers shown are produced by reputable companies that are known to stand by their products.

**Manufacturer Suggested Retail Price (MSRP)**—Each manufacturer lists a suggested retail price. This is typically the highest price distributors will list; some may choose to sell at a lower price.

## Meters & Data Logging

All the units listed in this article include at least basic displays and metering. (If the meters are optional, the prices shown reflect their inclusion.) The displays provide basic voltage and amperage readings necessary for system checks during installation and, later, for monitoring the array for wiring, module, or even shading problems.

All the units listed display battery voltage, and some models (like Apollo) employ a separate wire to take this reading right at the battery bank. MPPT controllers show array voltage and current, as well as output (battery) voltage and current.

Some controllers show array power production in watts, and many have data-logging functions, which can be especially useful for off-grid systems. For example, data logging that includes "time in float mode" helps system owners know the batteries reached full charge for each day the controller dropped to float mode. A number of controllers can be connected to a computer for real-time monitoring and data collection.

## Access

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## Installation & Maintenance Considerations

**Ambient temperature** refers to the temperature of the air in the room or enclosure where the charge controller—and, usually, the inverter and other equipment—is located. Heat from a working charge controller is dissipated with cooling fins convectively, or is pushed out with a fan, adding heat to the space.

Systems with sizable arrays or with the equipment housed in small rooms require that the room be well ventilated, perhaps even actively with an exhaust fan. Too much heat can affect efficiency or damage the controller.

**Equalization** is a controlled overcharge of a battery bank. Battery cells are not precisely equal and will come to have different states of charge. The only way to bring them all back to an equal state is to periodically give the whole bank an overcharge.

Generally, flooded lead-acid batteries require this treatment every five to seven deep discharges (50% or more of capacity), or every two months, whichever comes first. The beginning of winter is a good time to do an equalization, as it will prepare a battery for the deeper cycles normally found at this time of year. Equalization also helps mix the electrolyte after watering the batteries, and helps remove old sulfate crystals from the plates. Some types of batteries (sealed) can be permanently harmed if they receive higher-voltage equalization.

Among the featured controllers, the C series products from Xantrex and all the controllers from Apollo, OutBack, and Morningstar offer both manual and automatic equalization. The other controllers offer only manual equalization.

Effective battery equalization requires a larger array than most systems have, so owners often equalize from an external charge source like a generator or the grid.


**Morningstar's TriStar charge controller (left) and remote display (below).**

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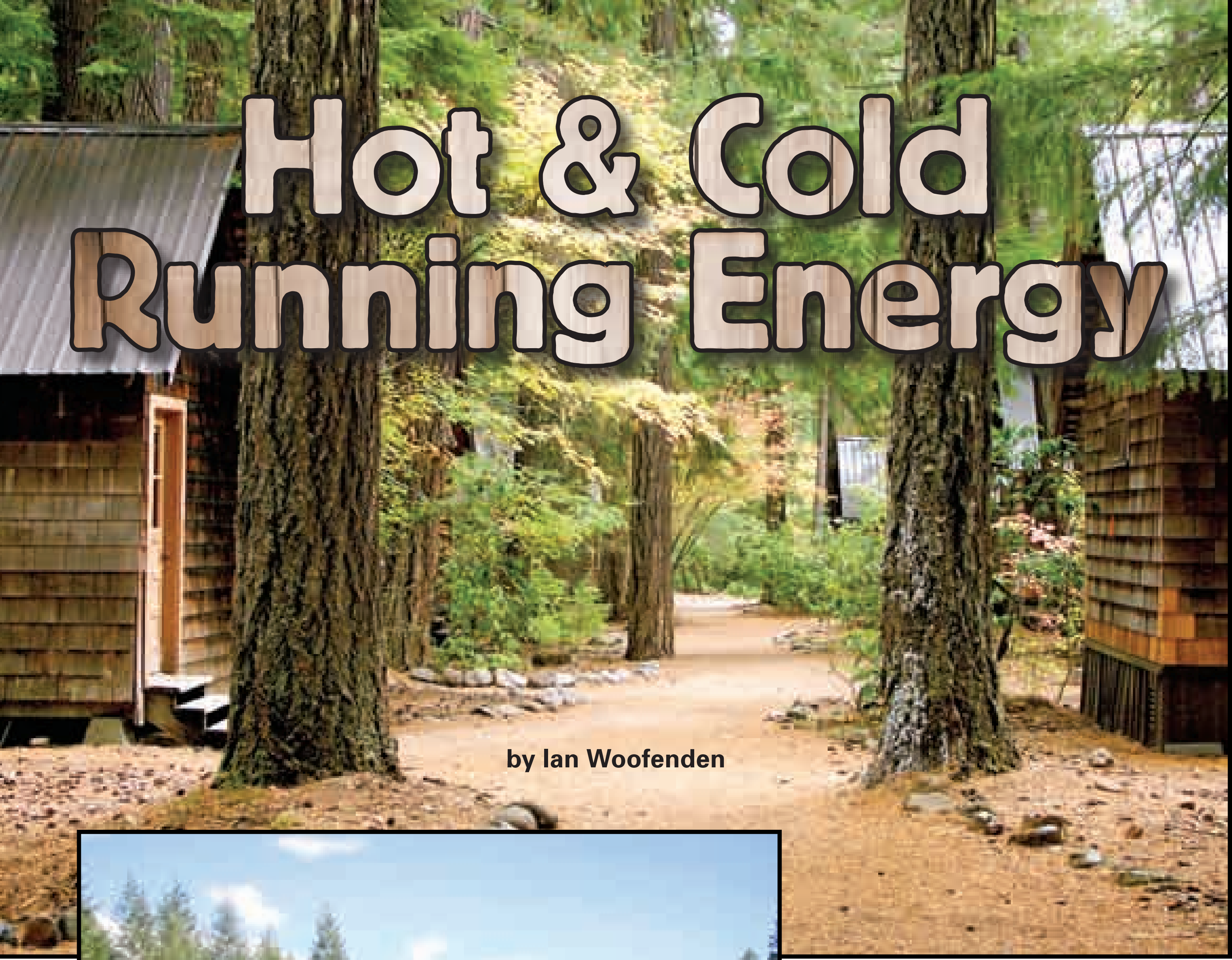
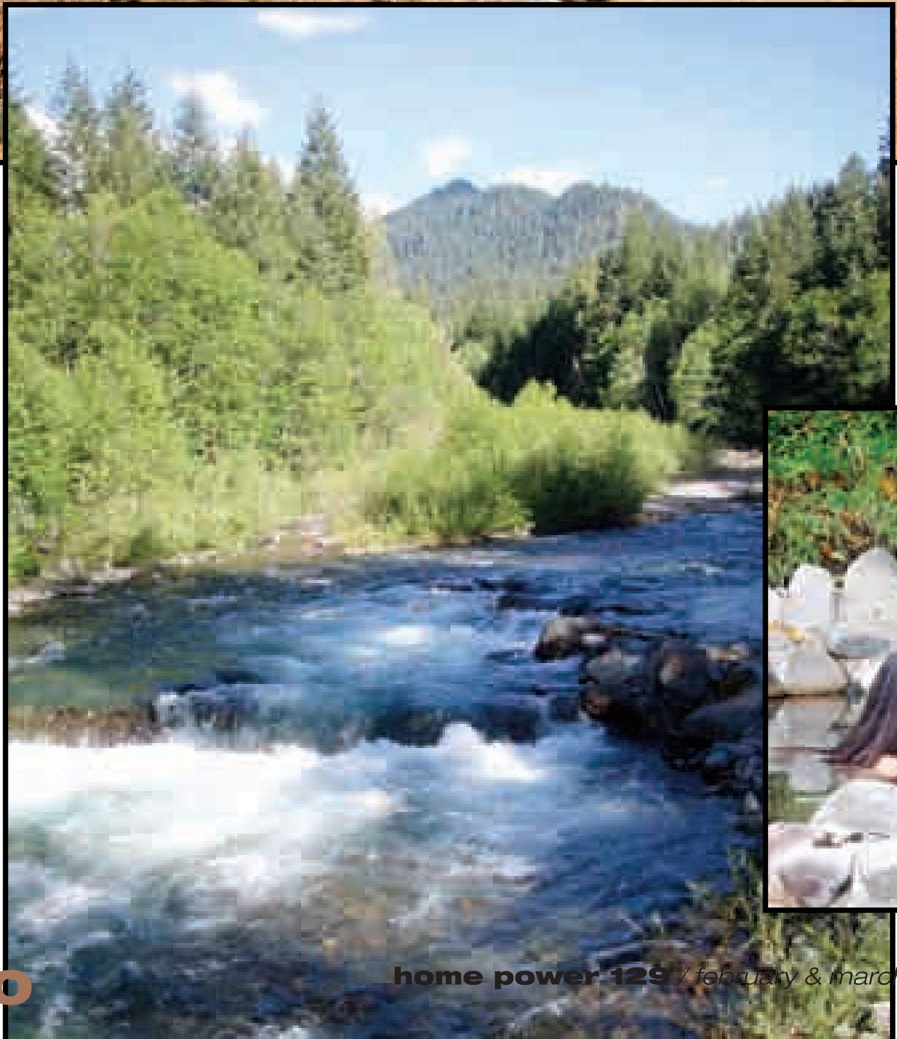
# Hot & Cold Running Energy

by Ian Woofenden





Above: Guest cabins are kept cozy with geothermal hydronic heat.

Left: The mighty Breitenbush River provides electricity to the community.

Below: Soaking pools are heated by natural hot springs and geothermal well water.

Among the ancient trees of the Willamette National Forest sits Breitenbush Hot Springs resort. Sixty-five miles from the nearest large city, it's an inviting place that hosts thousands of visitors who come to soak in the hot springs, enjoy organic food, improve their lives, and just relax. Feeding souls requires energy, and the systems that electrify and warm the 100-plus buildings of the community rely on the flowing water of the Breitenbush River and the natural hot springs below the surface of the community's landscape.

The land that is now Breitenbush Hot Springs Retreat & Conference Center was visited by Hudson Bay fur trappers in the mid-1800s, first homesteaded in 1904, and later developed as a wilderness health spa. The property changed hands a number of times until 1972, when after two devastating floods, the business was closed. In 1977, ecopreneur Alex Beamer bought the land and began building an intentional community to operate a retreat and conference center at the hot springs site.

Breitenbush has grown to include a full-time community of about 60 people who occupy approximately three dozen dwellings on the north side of the river. On the south side of the river, the lodge and 42 guest cabins provide accommodations for up to 135 visitors, and the facility hosts more than 100 workshops each year, including natural healing, dance, personal growth, and more.

## Hydro Power

Operating this extensive facility requires a significant amount of electricity. Several miles off-grid, Breitenbush had to figure out how to make their own. Fortunately, this was easy—the Breitenbush River runs through their 154 acres.

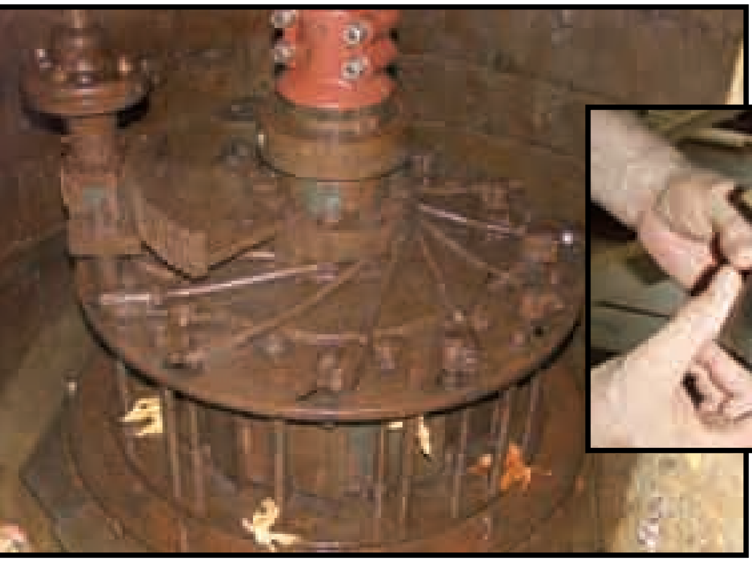
The intake gates that feed the community's hydro-electric system.

The main guest lodge surrounded by natural beauty.

Courtesy Tom Robinson (5)

A very small portion of the fast-flowing river is diverted through a sophisticated intake system, feeding about 35 cubic feet per second (15,700 gpm) into a 42-inch-diameter penstock. The high-density polyethylene (HDPE) penstock runs about 800 feet, and drops 19 feet to the turbine to develop about 8 psi. A recent upgrade of the intake included a fish diversion, level sensors and controls, active screen cleaning, and automated gates.

The turbine is a 22-inch Francis that was originally installed in 1929. It's a James Leffel & Co. "Samson," which was built in Springfield, Ohio, sometime between 1895 and 1927. This model was originally designed for mechanical power in mills, but it's not uncommon for them to be used for electricity production. The runner blades are



Left: The turbine inlet—viewed with the water flow stopped—shows the wicket gates and gate actuator. Inset: An ironwood bearing.

carbon steel, and are cast into an iron hub. In its several decades of operation, the Breitenbush runner has never been rebuilt, while the turbine's wicket gates (that control the flow to the runner) were last rebuilt in 1980. The turbine rides on two wooden bearings, and this isn't just *any* wood. It's *Lignum vitae*—the heartwood of the ironwood tree—the hardest and densest of all woods. The wood contains natural lubricating oils, and the bearings in the Breitenbush turbine typically last three to five years.

The turbine shaft spins at about 312 rpm, and is belted up to 1,800 rpm to drive a 45 kW, three-phase, 208 VAC generator. This output is then stepped up to 480 VAC for distribution in the community.

The penstock terminates at the powerhouse.

In normal water conditions, generator output is between 40 and 42 kW. Because this is an off-grid system with no batteries, the full load of the community needs to stay below this peak output or the diesel generator will start. Since the demand generally is lower than the energy supply, this means that the controls are always diverting or "dumping" a portion of the energy at any given time, and the system must include capability to dump *all* of the production in times when demand is very low. A Thomsen & Howe load-control governor diverts surplus energy to 44 kW of heating elements submerged in a 50-gallon stainless tank with river water constantly running through it to take the heat away. Plans are underway to put this diversion energy to use in a hydronic heating system in the community's shop building.

A 40 kW diesel generator backs up the hydro system during times of high usage, low flow, maintenance, or emergency. But the cost to operate it is more than $200 a day, so it is something the system operators try to avoid. Occasionally, operators will turn off the resident community side's electricity (or have rolling blackouts, turning off half at a time) to maintain electricity to guest facilities. An added benefit after a blackout is that residents become far more conservative with electricity use. To put Breitenbush's power in perspective, consider that the average new home built today is required to have a 200-amp electrical service panel. Such a home is capable of using 48,000 watts. This means that although the Breitenbush hydro system is not capable of maxing out the average house panel, it can serve 200 people in more than 100 buildings, providing electricity for domestic water pumps, irrigation, and septic and geothermal heating pumps, plus computers, a commercial kitchen, and a shop facility.

The hydro plant electrics, metering, and controls.

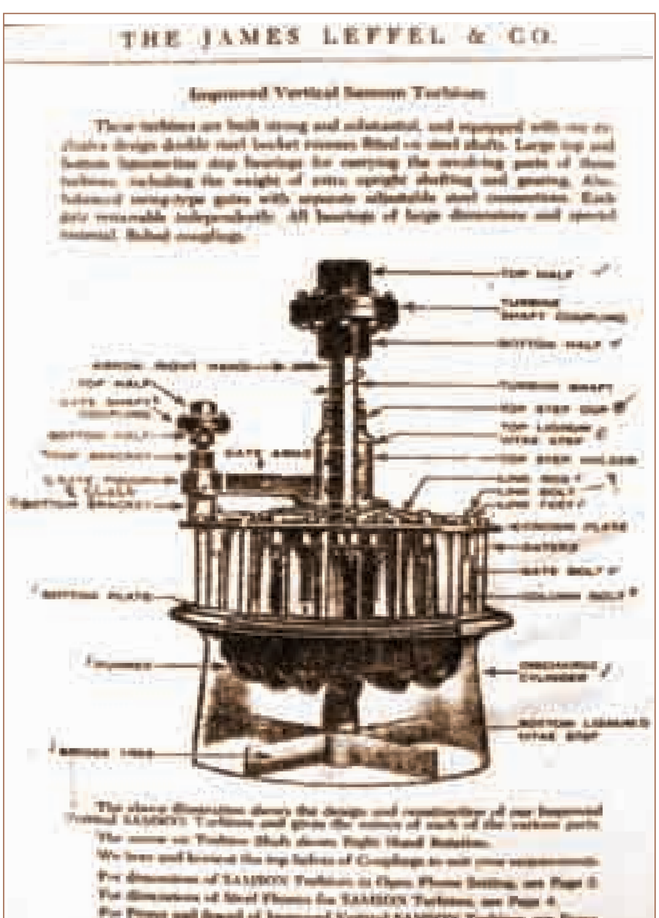
Courtesy Tom Robinson (4)

The dump load, with its 44 kW of water-heating elements wired into place.

A computer display of the monitoring and controls for all the electrical systems.

## Living with the System

Conservation and efficiency play a crucial role in making these systems work for the community. All lighting is compact fluorescent, and appliances are carefully screened before their purchase to make sure that efficiency is high. Residents and guests are not permitted to have toasters, hair dryers, irons, or electric heaters. The following is a quote from the community electrical guidelines, used to encourage a high level of electrical literacy and awareness:



THE JAMES LEFFEL & CO.

Courtesy Tom Robinson (3)

*Please be aware of the power draw of any appliance you own. A watt-meter to measure power draw is available from the Systems Team. If you have questions about any specific appliance, please check with Systems. New community members will be asked to meet with someone from Systems to check their electrical appliances. Any new appliances acquired by existing members must also be approved by Systems.*

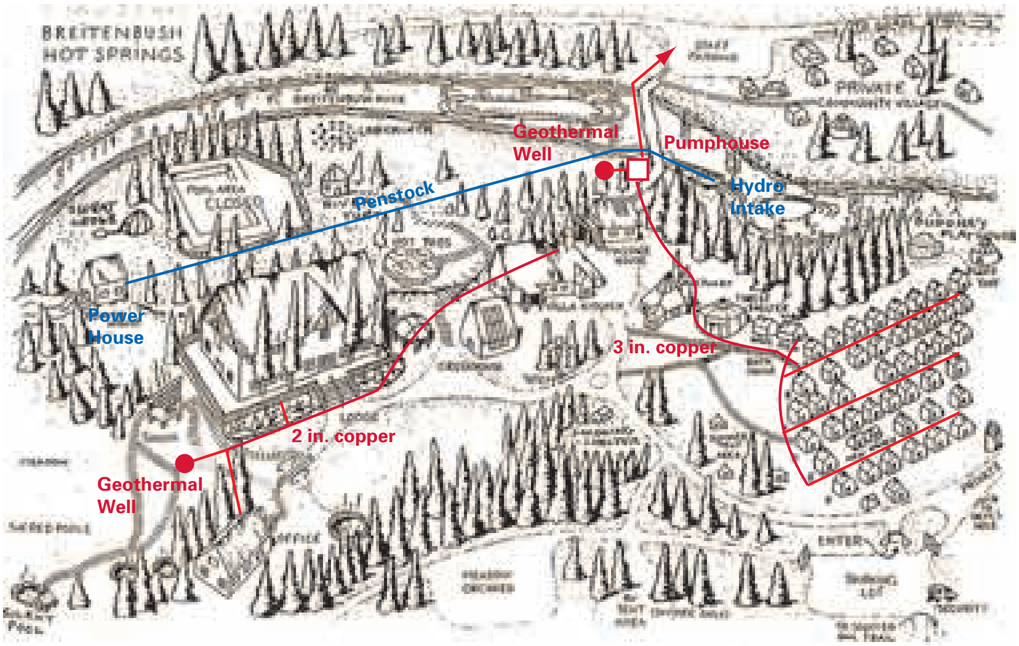
The community facilities include multiple large pumps for geothermal, domestic water, and the septic systems—but the hydro controls have the ability to shed these loads during periods of high demand. This load-control system is generally seamless and automatic, though the system operators are able to manage it manually and can see at any moment how much energy is going to facility loads and to the diversion load.

This wasn't always so: Early energy management came in the form of systems operators, who would walk through the community, turning off lights. And at times of low water, or during the autumn rains, it was not uncommon for community members to manually rake debris from the trash rack in two-hour shifts to increase flow into the system and thus avoid diesel generator use. Today, user education and electronic control has taken over, and the system normally runs very well within its capacity.

Nevertheless, occasionally the diesel generator automatically fires up to cover excess usage, which triggers alarms to the operators' radios. Once a month, the operators test the generator's auto-transfer system to make sure it's ready to go.

## Heat from the Ground

In the late 1970s, the community drilled wells to tap the heat deep in the earth for warming their buildings. At present, they are using two wells—one 500 feet deep and the other 700 feet deep. If the hot water were used directly, the mineral content would precipitate, scale, and plug the interiors of the pipes in a short time. So fresh water is circulated through down-hole, closed-loop heat exchangers, gaining 20°F to 30°F as it passes down into the geothermal well and returns. Typical outlet water temperatures are 200°F to 210°F, and




# Breitenbush Systems Layout*

Hydro System:

Geothermal System:

*Public side of facility shown

return temperatures are 180°F to 190°F. This water heats all the buildings on site, plus the hot tubs. (The natural hot spring pools use surface spring water.)

Two three-phase, 480 V, 3 hp pumps run this system in winter, with only one needed in summer. Cabins and other community buildings use old-fashioned cast-iron radiators, with valves on each radiator to let residents and guests control the heat. The radiators also come in handy for drying clothes and warming toes.

Because of the wide area serviced by the system, it's inevitable that the buildings closer to the wells have more heat available. There is discussion about developing two more existing wells to increase the heat capability for certain parts of the property. The existing wells have roughly a 5 million Btu per hour capacity, while the community is only using about 2 million Btu per hour at most.

Breitenbush Hot Springs is open year-round, and this area can experience several feet of snow during the wintertime—so plentiful, renewable heat is a boon to residents and guests alike.

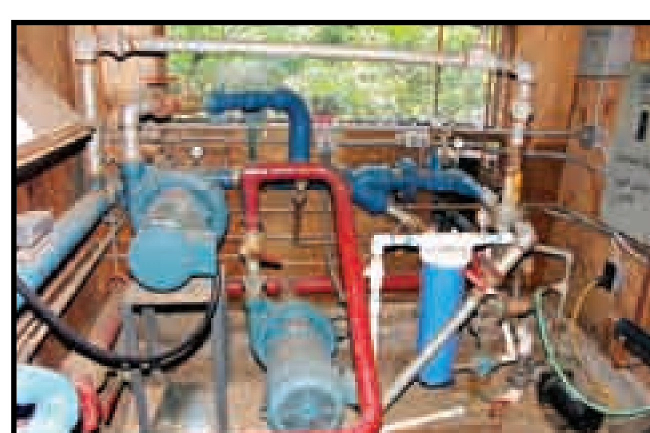
## Beyond Renewables

Breitenbush's efforts toward sustainability go well beyond energy. The many buildings take plenty of care to help them withstand guest use and seasonal changes. In all construction and maintenance, the community tries to use recycled materials as much as possible. They frequently harvest trees that fall in their forests, and either mill them into lumber or use them as natural posts and beams.

**Resident homes (shown here) and guest cabins use traditional cast-iron radiators to distribute geothermal heat.**

Courtesy Tom Robinson (3)

**The pumping system, which pulls hot water from the geothermal heat exchangers and circulates it through the buildings.**



**One of the hot spring pools overlooking the river.**

Composting is a way of life in the community, with centralized composting tanks that are scientifically managed to produce compost quickly. The composting system is one of many projects of the Breitenbush Eco Fund, a nonprofit associated with the community that works to spread the lessons learned at Breitenbush to the outside community.

The resident side of the Breitenbush property includes a large, heavily used community garden. The future may hold development of agriculture for guests as well, since community members are concerned about the impact of their business, and believe strongly in using local resources and building a sustainable example.

Residents are intensely aware of their energy use and impact. They understand that being directly responsible for their energy actions is not necessarily the easy way, but it's worthwhile work. They are conscious of conservation and efficiency. And this awareness extends to how they care for the property they steward, how they care for their bodies, hearts, and minds, and how they care for the thousands of guests who come and go each year.

Breitenbush's influence extends far beyond its acreage, inspiring its thousands of visitors who return home with more knowledge of how to live balanced lives. They may not be blessed at home with the hot and cold running water that fuels Breitenbush's energy scene, but with the principles they see in action in their brief stays, guests can seek out and shepherd the resources on their own stomping grounds, and learn to use them more wisely.

## Access

Ian Woofenden (ian.woofenden@homepower.com) appreciates the hot springs and warm personal connections made at Breitenbush Hot Springs.

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# ELECTRIC VEHICLE Battery Selection

by Shari Prange

## Narrow the field and find the best battery for your EV.


The 6 V golf cart-type battery has a good combination of size, voltage, and capacity for EV use.

The right batteries and design can make or break how your electric vehicle (EV) functions on the open road, in terms of speed, range, reliability, and consistent performance under varying conditions. The trick is finding a battery pack that fits your needs, within the physical limits of your vehicle and the financial constraints of your budget.

### The Right Type

Some batteries offer enough power for excellent acceleration but are limited in range or cycle life, while others offer better range but with high price tags.

Unfortunately, you can't have it all in one battery type, or by mixing different types. A battery pack needs to be made up of identical units—same voltage, same ratings, same chemistry, and even similar age—so that duty cycles and charging profiles match. You don't need to be a battery engineer to choose a battery, but you *do* need to know how batteries work in an EV, and which types will not.

Physical characteristics like size, shape, and terminal type are usually dead giveaways to a battery's intended use. But making the distinction with EV batteries isn't always that easy—they often look alike on the outside. It's what's inside—like number of plates, plate thickness, or chemistry—that makes all the difference in how a battery can be used.

Deep-cycle traction batteries, which are designed to deliver high-current draws and tolerate deep discharges, are the best choice for EVs. Of the different types of traction batteries, a golf cart-type battery offers a good balance of size and capacity for most EV conversions. They come in 6 or 8 volts, and when combined into high-voltage packs can propel a passenger car at 100 mph or faster—*and* provide good range and cycle life. The 8 V versions sacrifice a little amp-hour capacity (affects range) to provide additional voltage (affects speed and power). A number of different chemical reactions can store and release electricity. Only a few, however, are appropriate for EVs.

### Flooded Lead-Acid Batteries

Flooded lead-acid (FLA) batteries—the most common EV battery in use—tend to be long-lived (up to four years) and offer the least cost per amp-hour of the available batteries. Size and weight are the main drawbacks of FLA batteries. With an energy density of 15 to 20 watt-hours (Wh) per pound, FLA packs are heavier and take up more volume to achieve the same amount of range compared to the other battery technologies. The energy density of FLAs is low and their volume per volt is high.

Each cell is comprised of positive and negative plates, usually lead alloyed with antimony, in an electrolyte solution of sulfuric acid and water. During the charging process, a small amount of water in the electrolyte is turned to gas and escapes. In addition to keeping the top and terminals clean and regularly equalizing the pack, you will need to check the electrolyte level and add water as necessary. Though watering does mean regular maintenance, it also means FLA batteries are more forgiving of charging and discharging abuse than sealed batteries.


**Compared to the 6 V version, an 8 V golf cart battery gives higher voltages for more speed and power, but sacrifices total range.**

FLA batteries produce hydrogen gas when charging, so they must be fully enclosed in boxes if they "share the air" with passengers (i.e., in the passenger compartment or hatchback/trunk area). Forced-air ventilation (using a fan and ducting to the outside) is necessary to release the hydrogen gas, which can be flammable in high concentrations. FLA batteries also lose capacity in cold conditions and may need to be insulated.

Because FLA batteries will swell slightly as they age, you need to leave space—about 1/16 of an inch—between the new batteries when positioning them in the pack. Otherwise, when the time comes to replace them, you'll find bloated batteries wedged in place.

In FLA batteries, a battery management system (BMS) is optional but can extend battery life when used properly.

## Sealed Lead-Acid Batteries

Sealed lead-acid (SLA) batteries, also called "VRLA" (valve-regulated lead acid), are available in two technologies: absorbed glass mat (AGM) and gel cell. Instead of free liquid as in a flooded battery, the electrolyte is held either in mats of glass fibers next to the lead plates or in gel form. These spill-proof batteries are more resistant to damage from vibration and physical shock than FLAs, and have a lower energy density, at 8 to 15 Wh per pound.

"Sealed" batteries are sealed only in the sense that you can't add any liquid to them. They are constructed with vents or valves to automatically relieve pressure from gas buildup if they are overcharged or discharged too severely. While sealed batteries are more convenient because they are "maintenance free," they are less forgiving of abuse because there is no way to restore lost electrolyte. Overcharging or discharging too deeply will shorten the battery's cycle life dramatically. A BMS is required for most SLA batteries to better control charge and discharge.

Unlike FLA batteries, in high temperatures, SLA batteries may require cooling airflow from fans since overheating causes a loss of electrolyte that can shorten battery life.

**Custom copper interconnects on these 6 V batteries make for an immaculate installation.**

## Nickel Cadmium (NiCd)

Nickel cadmium batteries are alkaline batteries that use nickel oxide hydroxide and metallic cadmium as electrodes. Delivering 20 to 30 Wh per pound, NiCd batteries offer a higher energy density than lead-acid batteries—in other words, a NiCd battery is smaller and lighter than a comparable lead-acid battery. NiCd batteries also tolerate deep discharging for longer periods.

**Sealed lead-acid batteries have less range per volt than flooded, cost more, and require more careful charging regimens, but are convenient since there is no need to water them.**

# BATTERY SELECTION CRITERIA

**Here's a look at the key characteristics to consider before you buy batteries.**

### Size & Weight

The more voltage, the more speed. Though the minimum for a highway-capable vehicle is 96 V, some systems go to 300 V or more. The physical size of the battery—volume per volt—will determine your top speed, so you'll need to figure out how many volts can fit into the space available and whether that voltage will be enough to reach your desired speed.

Look at volume per volt—how bulky should the pack be to give me the speed I want? Then examine watt-hour (Wh) capacity per pound (a.k.a. "energy density")—how heavy is the pack I need to give me the range I want?

For example, a 96 V pack of 6 V FLA batteries will take up approximately 7.35 cubic feet. A pack of the same voltage (i.e., yielding the same top speed) using 12 V SLA batteries would only take up 2.45 cubic feet. The flooded 6 V pack weighs about 1,072 pounds, while the sealed pack of 12 V units tops out at 350 pounds.

Saving space and shedding pounds may be necessary with smaller vehicles, but consider your range requirements first. The flooded pack has a 23.2 kilowatt-hour capacity compared to only 5.3 kWh for the sealed pack. So while the flooded pack weighs about three times as much and takes up three times as much space, it has almost four and a half times as much range capacity. The sealed pack will require more care in charging and will be almost three times the price for an equivalent amount of kWh, not counting the cost of the battery management system (BMS).

### Interconnection

A battery pack is made up of many batteries interconnected to form one power source. The number of interconnects needed to achieve the series voltage will determine the ease of the job and the pack's overall reliability. Every time you double the number of connections, you quadruple the number of possible failure points.

The type of interconnect used is dictated by the battery terminal style. Clamps are used on round automotive-style terminals, while flat lugs are bolted to flat "L-style" terminals or sometimes directly into the top of the battery. Avoid using lugs over threaded studs sticking up from lead posts—lead is soft and allows the stud to gradually creep upward to relieve the tension of the nut holding the lug. If neglected for too long, this loose connection can melt off the battery terminal or start a fire.

To obtain the desired voltage and amp-hours, batteries can be configured in parallel or in series, or a combination of both.

- In a parallel circuit, positive posts are connected to positive, and negative posts are connected to negative. In this configuration, amp-hour rating is multiplied by the number of batteries and the voltage stays the same as in a single battery.
- In a series circuit (which is most common in an EV), batteries are connected positive to negative. The voltage is multiplied by the number of batteries, and the amp-hour rating stays the same as a single battery.

These two points initially won over some EV enthusiasts, but the technology has proved to be less than ideal for EV conversions, since the batteries are more expensive, harder to find in large formats, have higher self-discharge rates, and, ultimately, are more dangerous to use in traction applications.

If too deeply discharged and then charged too quickly, a reaction can occur in NiCds that generates heat inside the battery until it melts down or catches fire. Because of this risk, many NiCd batteries have been removed from service and replaced with lead-acid batteries.

NiCds also suffer from "memory" problems. If the battery is repeatedly discharged partially and then recharged, it will "remember" that partial level of discharge and act as if that level is its capacity. These batteries need to be fully discharged periodically to prevent this from happening, and require a BMS to properly charge and equalize the pack.

**A lithium-ion battery pack in CalCars' EnergyCS/EDrive-converted plug-in Prius.**

### *Battery Maintenance*

All batteries should be checked periodically for clean and tight connections. In particular, FLAs require regular fluid checks and, when necessary, their electrolyte levels must be topped off with distilled water. FLA packs also need to be "equalized" to keep all the batteries in balance at the same state of charge.

### *Rate & Depth of Discharge*

Battery life is related to two primary factors: (1) the rate of discharge—how quickly energy is drawn out of the battery (measured in amps); and (2) the depth of discharge—how low the voltage can drop before recharging (measured as a percentage). The less severe the rate or depth of discharge, the longer the battery's life cycle.

Some batteries can release large amounts of energy more quickly than others. There are also differences in how deeply they can be discharged without causing damage. If either issue is a high priority for your use, be sure to consider rate or depth of discharge when battery shopping.

### *Balancing & Management Systems*

Imbalances among batteries are typical within battery packs—the same make and model can have small differences in voltages. Over time, these imbalances tend to grow, shortening the life of the pack, so regularly rebalancing or "equalizing" the pack is necessary.

When a battery pack is charging, some batteries reach full charge sooner than others. With equalization, the charging continues until the "weaker" ones catch up with the other batteries. The key is not to overcharge the "stronger" batteries, since overcharging can irreversibly damage or destroy a battery.

Some batteries—typically older, "low-tech" FLA batteries—can be balanced by a standard charger. To ensure safe and effective charging, most batteries require a BMS with a sensor/control for each battery that monitors the voltage and controls the charge going into the battery. More sophisticated systems may have circuits for each battery, while simpler versions have a voltage tap running from each battery to a voltmeter. Some require additional wiring and parts, while others are already built into the battery.

Typically, a BMS adds to the cost of the vehicle and the complexity of the wiring. Expect to spend half the cost of the battery pack, and be sure to allow extra time—and patience—for installation. Follow your battery manufacturer's recommendations for the BMS.

### *Physical Containment & Ventilation*

All batteries must be physically contained, but some require additional measures. Some need to be tightly packed, while others need space between them. Ventilation may be required for carrying away fumes or cooling purposes. Conversely, some batteries may need to be kept warm in cold climates. These packaging considerations affect how many batteries will fit into the vehicle and where they can be placed, as well as the overall cost of the installation.

## Toyota Prius Batteries

The nickel metal hydride (NiMH) batteries used in the Toyota Prius are designed to work in tandem with the factory enclosures and battery management system. While these batteries work wonders in a Prius, they should not be salvaged or adapted for use in EV conversions. These batteries were not designed to be the sole power supply for a vehicle nor to handle deep discharges; they are designed to be discharged a small amount and then sip a little recharge. If packaged improperly or charged at even slightly too high a rate, they could catch fire and possibly explode.

Unlike lead-acid batteries, which need only a little space between them, NiCds need to be firmly compressed to keep the electrolyte covering the plates. Like lead-acids, they need to have their fluid levels checked and topped off as needed, and tops wiped clean of electrolyte mist.

Because NiCds come in 1.2 V cells, they require more interconnects—five to 10 times as many for the same voltage of a 2 V lead-acid bank. This means more work when assembling the pack and less reliability in the long run, since doubling the number of connections quadruples the number of possible failure points.

NiCds do not need the insulation that lead-acid batteries need in cold climates, but they may need cooling ventilation in hot climates. Although NiCds store more energy and perform better in colder climates than lead-acid batteries, they are not recommended for use in conversions today because of the chance of thermal runaway.

**Exotic batteries often come in a variety of physical packages. Pictured here: individual lithium cells from Foxx.**

## Options in the Lithium Market

The first lithium batteries to appear on the EV scene were small, sealed cells much like flashlight batteries. At approximately 3.3 V per cell and a very low amp-hour capacity, it took about 4,000 of these batteries to power a car. That meant hours of welding connections and too many places for potential connection failure.

To simplify the process, A123 Systems offers lithium nanophosphate batteries in a "developer's kit" of six cells with connecting tabs attached. The drawback: Intended for "prototyping," the kits do not come with any technical support.

Other manufacturers are reducing the number of connections by building lithium cells into preconnected batteries. Valence Technologies—the best-known manufacturer of this type of lithium battery—made its batteries available to consumers starting in late 2008. Expect to pay $2,000 for a 12 V, 100 Ah (a 2-hour rate) module with a built-in BMS.

A rising newcomer is the Foxx battery, manufactured by Aten Energy, which can be built up into various-sized units. Expect to pay about $1,250 for a 12 V module.

## Nickel Metal Hydride

In the 1990s, nickel metal hydride (NiMH) batteries were the "next big thing"—all the manufacturers used them in their EVs and hybrids. Not only can they pack the same voltage into a quarter of the volume of FLA batteries, and half to three-quarters of the volume of SLA or NiCd batteries, they also have much greater energy density, at 35 to 40 Wh per pound.

NiMH batteries do not have the memory problems of NiCd batteries nor do they require watering. They do, however, require a BMS for charging. The main drawbacks are that they are not sold at retail level and cost several times as much as lead-acid batteries.

## Lithium-Ion

Lithium-ion (Li) batteries are the "next big thing." Their claim to fame is much the same as NiMH technology, only more so—more capacity in a lighter package, with energy densities ranging from 30 to 95-plus Wh per pound.

Lithium batteries, which have lithium metal or lithium compounds as an anode, are available in different chemistries, but lithium phosphate is the chemistry most widely used in EVs. (See "Options" sidebar.)

Lithium batteries come in two basic shapes: cylindrical or rectangular (a.k.a. "prismatic"). Each shape presents different challenges for physical arrangement, interconnects, and thermal control. For example, the more uniform internal distribution of temperature in prismatic cells increases performance. Cylindrical cells may fit better in a shallow space, whereas prismatic cells stack better into uniform blocks, with less wasted space.

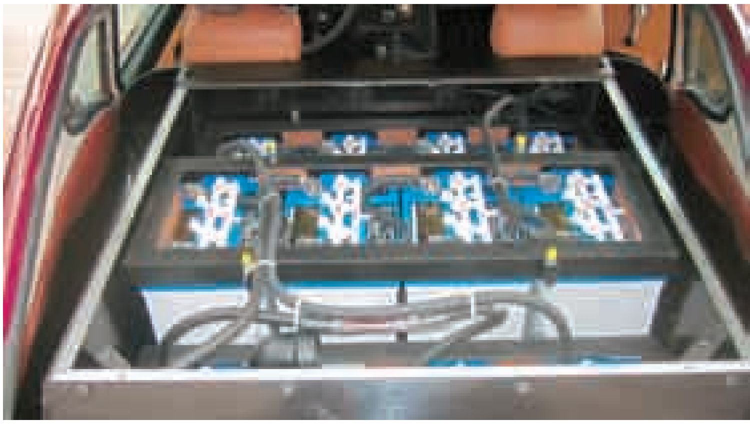
Lithium cells are relatively maintenance free, but they do require a BMS and ventilation for cooling, since high temperatures will degrade the batteries' performance and cycle life. Forced cooling with a fan is the minimum, but liquid cooling (with coolant flowing through tubing or jackets around and through the battery pack) is often recommended.

Despite their higher energy density and a cycle life that's about 2.5 times that of a lead-acid battery, Li batteries have their challenges. Primary is their high cost—about 10 times the price of a lead-acid battery. Even with projected price drops, Li technology is still out of reach for most EV conversions.

Availability for retail sales is very limited and will likely remain so for the foreseeable future—most manufacturers are selling exclusively to vehicle manufacturers and continue to overlook the retail conversion market.

Lithium-based batteries are more sensitive to overcharging or overdischarging than any other chemistry. Under certain conditions, the batteries can catch fire. Manufacturers are,

**A well-designed battery enclosure keeps batteries safe and secure.**




**An amp-hour meter is the EV equivalent of a gasoline tank gauge.**

however, refining the design of the batteries, as well as the charging and battery management systems, to minimize the potential for catastrophic failures.

Because the technology is so new, data for cycle life, usable energy, and other performance specs are based largely on limited laboratory testing and extrapolation. Until these batteries have been on the road for a decade or more, manufacturers' specs are really just guesstimates.

## Comparing Costs

Computing dollars per watt-hour is one way to compare different battery technologies. Take the basic unit in which the battery is sold, whether that's a single-cell or multicell unit, and multiply the voltage by the amp-hour rating to get watt-hours. Then divide the cost-per-unit by the watt-hours.

**Cost ÷ (V x Ah) = Cost per Wh**

As a rule, avoid bargain or store-brand batteries. They may be supplied by multiple manufacturers and relabeled, making it impossible to get a matched, balanced pack. They're no bargain in the long run, since this imbalance will result in poor range and short cycle life.

Prices jump by an order of magnitude from one chemistry to another. Ultimately, you have to decide whether the advantages of a more expensive battery technology are enough to justify the added expense.

## Access

Shari Prange (electro@cruzio.com) is co-author with Michael Brown of the widely referenced book, *Convert It: A Step-by-Step Manual for Converting an Internal Combustion Vehicle to Electric Power*. She has been co-owner of Electro Automotive, a supplier of EV conversion kits, since 1983.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# PV Micromanaging

story & photos by Kathy Swartz & Kris Sutton

After Kathy Swartz and Kris Sutton bought their 5-acre property in Paonia, Colorado, they realized it needed a coop for future chickens—part of their overall plan for providing some of their own food and living as locally as possible. What they didn't realize was that the chickens would also help "grow" their own energy.

When we first looked at our pastured property with wide-open mountain views near the edge of the North Fork of the Gunnison River, there was a little red shed that we thought would make a great chicken coop. Little did we know that the seller was going to take it with him when he moved. Though we were disappointed at its disappearance, constructing a new coop became an opportunity to explore load-bearing straw-bale construction and passive solar design—as well as make room for a second, 1,750-watt grid-tied PV system.

In 2006, we installed a 1,440 W grid-tied PV system—sized to meet our budget at the time and approximately 50% of our electricity usage. But our goal all along was to produce 100% of our own electricity with renewables. The chicken coop, designed with a south-facing roof and nearly shade-free solar access, was a prime spot for the other PV system.

Mounted parallel to the roof plane, which sits at a 15-degree tilt, the second system takes advantage of the region's long, sunny summer days. The pitch is lower than recommended for optimal production, but the system will only suffer a 5% annual production loss as a result, which we find acceptable. However, the shallow pitch does not shed snow very well. In some parts of Colorado, this would be a problem, but since we experience less snowfall, it was less of an issue. After a heavy snow, we sometimes brush off the array with a broom to hasten melting.

## Why Microinverters?

We decided to use ten 175 W SolarWorld modules with Enphase microinverters, one per module. As proponents of buying as locally as possible, it was important to buy U.S.-

**Top to bottom: The PV mounting rails, ready to go; detail of the inverter mounting scheme; inverters appropriately spaced between the PV mounting bolts, with the AC wiring neatly tucked away; the modules in place and connected to their inverters (note the ground wires across the inverters, and behind and attached to the modules).**

made PV products. Both of these companies are in California and just happen to be the closest manufacturers to us.

Kris is typically very cautious about buying equipment from start-up companies. But because the microinverters are so unique—and potentially industry-changing—we were excited to try this product.

Microinverters are fundamentally different from conventional string or central inverters—they have a one-inverter-per-module design. Individual inverters provide maximum power point tracking (MPPT) for each module in the system, resulting in higher system output overall. Though it doesn't apply to our sunny site, with the microinverters, any shading of one module does not influence another module's output. With a larger, central inverter with multiple modules in series, shading of part of one module can decrease the performance of the whole series string. Because of the individual MPPT, modules can be oriented differently or mounted at various tilt angles without affecting one another. Another benefit to a microinverter-based system is that you can put as many modules as you want or can afford in a system—matching module strings to inverters, as required with string or central inverters, is not necessary. Therefore, you can have exactly the number of modules that fit your roof or your budget—increasing the system size in the future is made easy.

Since modules are not connected in series, the DC voltages of the PV array are no higher than one module's open-circuit voltage, reducing (but not eliminating) the shock hazard for PV technicians. As a safety professional in the PV industry, Kris believes that this design is safer to install and service than most conventional PV systems. Plus, eliminating higher-voltage DC circuits meant that we saved approximately $200 and about one hour of installation time, since we did not have to use a high-voltage DC disconnect. Also eliminated are the fused DC combiner boxes required on larger systems with multiple strings in the array. Using microinverters saves wall space and a few hours of installation time by not having to mount a single, large inverter with accompanying disconnects and conduit.

For the size of our small system (and not including communication systems, other balance-of-system components, or installed labor differences), the Enphase microinverters average about $1.14 per watt retail for a 1,750 W system, offering a tiny bit of savings (about $0.02 to $0.16 per watt) compared to a similarly sized central inverter.

However, Enphase microinverters are not without their disadvantages. The biggest one is that they are a new company offering a product with a short track record in the field, even though the microinverters carry a 15-year warranty. They were introduced to the market in the summer of 2008. We don't know what the performance will be like in five or 10 years. And, of course, if the company were to go out of business, product support would disappear along with the company's Web-based data monitoring. But that's a risk that we take with all companies.

If one of the inverters fails, replacing it could be challenging depending on the accessibility to the back of the modules—for instance, if an array is mounted several stories off the ground on a steep roof. For our application, the modules are easily accessible, and this not a concern.

It can get pretty hot under PV modules in the sun and, in general, inverters and other electronics can fail early if they cannot handle the heat. This is also an issue with mounting standard inverters in direct sun or in contained spaces with no airflow. Enphase recommends a minimum gap of 1 inch above the roof for proper heat dissipation.

## Putting the System Together

Our system installation started out like any conventional installation—first figuring out the module layout and then attaching mounting hardware to the roof. However, the step that differed was paying attention to the location of modules on the roof to determine where the microinverters would be mounted so they'd be evenly spaced between the module frames. The inverters must be mounted on the rails, between where the module's frames will lay against the mounting rails.

The inverters were then laid out on the roof to make sure that all of the prewired AC cabling would reach the next inverters' cables. Once their location was determined, we bolted the inverters to the PV mounting rails. The prewired AC quick-connect cables from each inverter were all plugged in together. Once the cables were connected, we secured the extra wire along the mounting rails (see "Installation Tip:

## Tech Specs

### Overview

**System type:** Grid-direct solar-electric

**Location:** Paonia, Colorado

**Solar resource:** 5.85 average daily peak sun-hours

**Record low temperature:** -31°F

**Average high temperature:** 90°F

**Average monthly production:** 205 AC kWh

**Utility electricity offset annually:** 100% (includes existing 1.44 kW system)

### PV System Components

**Modules:** 10 SolarWorld, 175 W STC, 35.8 Vmp, 4.9 Imp, 44.4 Voc, 5.3 Isc

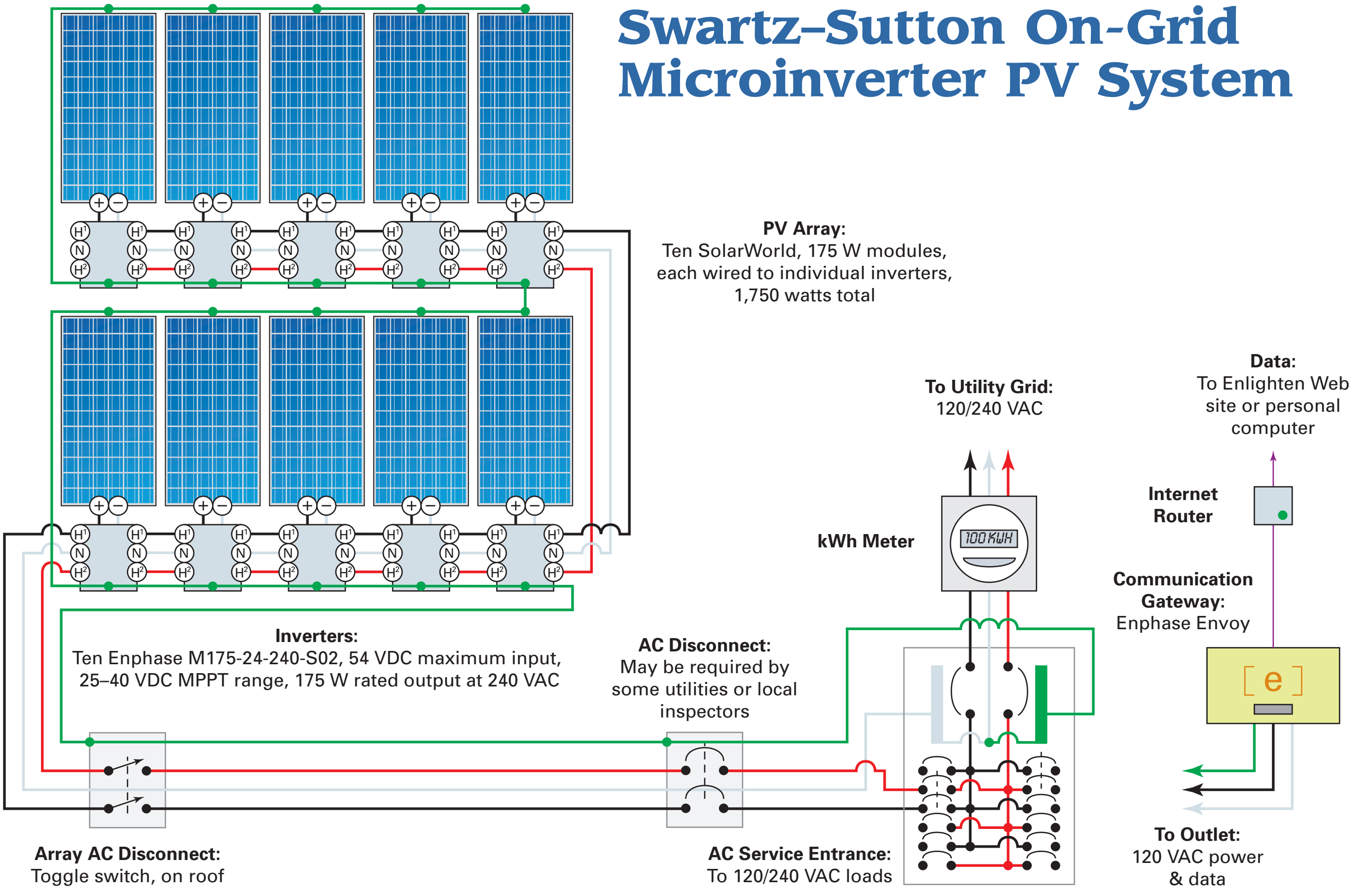
**Array:** 10 modules, 1,750 W STC total

**Array installation:** Direct Power & Water mounts installed on south-facing roof, 15° tilt

**Inverters:** 10 Enphase M175-24-240-S02, 175 W rated output, 54 VDC maximum input, 25–40 VDC MPPT operating range, 240 VAC output

**System performance metering:** Enphase Envoy monitor with Enlighten Web site

## Swartz–Sutton On-Grid Microinverter PV System



## Microinverter System Costs

| Item | Cost |
|---|---|
| 10 SolarWorld PV modules, 175 W | $10,500 |
| 10 Enphase microinverters | 2,000 |
| DP&W PV mounts | 786 |
| Envoy Internet gateway & 1 yr. Web service | 350 |
| Additional 5 yrs. Web service | 650 |
| Utility AC disconnect | 75 |
| Weatherproof box and AC toggle | 30 |
| Misc. wire, connectors, conduit & hardware | 590 |
| **Total** | $14,981 |
| **Less 2008 Federal Tax Credit** | 2,000 |
| **Grand Total** | $12,981 |

Wire Ties" sidebar). After securing all the inverters and wire, the continuous bare copper grounding wire was connected to the grounding clip on the top of every microinverter.

We connected an Enphase AC home-run cable to the last inverter. The cable was terminated with a 240 VAC heavy-duty toggle switch in a weatherproof enclosure, as a roof-mounted AC disconnect to shut down the array when servicing. In this box, we switched from the Enphase cable to THWN-2 wire run in electrical metallic tubing (EMT) conduit from the roof to the ground, and then transitioned to PVC conduit for the underground run to the service panel.

We've found that microinverter systems require a bit more time on the roof than standard PV systems, but can save a significant amount of time, space, and money by not mounting and wiring a DC disconnect, inverter, and AC disconnect on the house. A utility disconnect is sometimes still required by the utility or local jurisdiction.

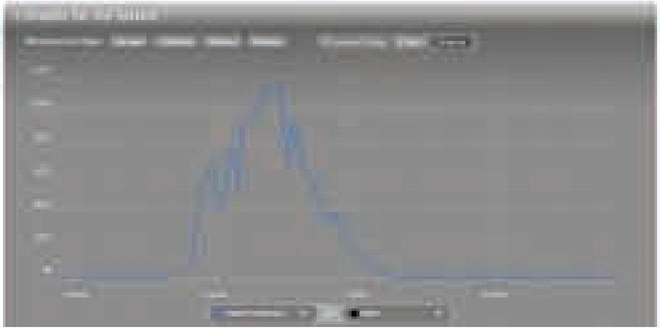
### Data Monitoring

Enphase microinverters have a data monitoring system to follow individual module performance. The inverters communicate via the system's 240 VAC output wires to the service panel. We mounted the Enphase Envoy communications module in the house. It picks up the inverters' communication signals through the AC wall outlet that the module is plugged into and exports the data to our network router. From there, the data communicates to Enphase servers for near real-time display on Enphase's Enlighten Web site. No communication wire is needed to the roof or between inverters, making this the easiest Web-based data monitoring system that we've installed. The Web-monitoring system requires a broadband connection, but the Envoy can also communicate through a LAN and information viewed by typing an IP address into an Internet browser.

The data monitoring system shows information common to most other systems: instantaneous power, daily and monthly

**The Envoy communications gateway receives data through the AC power lines and sends it to Enphase's Enlighten Web site.**


**The Enlighten site provides private Web pages for each subscriber that show specifics for individual PV modules as well as the whole system.**



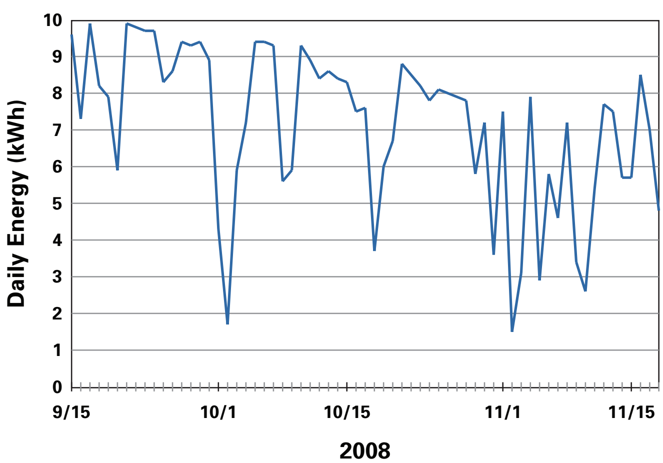
**A graph of the array's performance on a partly cloudy day from the Enlighten Web site.**

**A Web site display quantifying system production.**

cumulative kWh generated, and total cumulative kWh generated. What's unique about Enphase's data monitoring is the ability to keep tabs on per-module production, both instantaneous and cumulative. The Web site's graphical layout depicting module placement adjusts the color of the modules to reflect instantaneous power output, ranging from black (0 W) to light blue (at full inverter output). Besides near real-time monitoring, we can review time-lapse graphic displays of the system's daily and weekly production and, if problems arise, easily pinpoint individual module or inverter malfunctions. The monitoring system automatically alerts us to system failure via e-mail. Setting up the monitoring function entailed making a layout map, marking the serial numbers of the inverters on the map, and then sending the map to Enphase.

This monitoring service costs an additional $350 for the Enphase Envoy Internet gateway (including one year of data monitoring) and $650 for five years of additional service. The Enlighten service also includes "rapid replacement" if there are inverter problems, along with financial reimbursement for lost production.

## Daily System Production




Alternatively, a computer networked directly to the Envoy allows monitoring of the inverters, but without the sophisticated Enlighten Web site and automated e-mail notification. The system will operate normally without an Envoy connected, but there is no way to track individual inverters.

### Maximizing Performance?

After working on PV systems for almost a decade, it amazes us how far the industry has come. Our system is performing well, and we'll be excited to see our first full year of performance in September—and whether or not we truly hit 100% of our energy goal. Comparing our actual system output to the National Renewable Energy Laboratory's PVWatts analysis, our system performed above the monthly projected average for October. So, at this time, meeting our goal seems very likely. And by April, we'll have our first round of chicks, and finally be on our way to eating our own solar-powered omelets.

## Installation Tip: Wire Ties

When thinking about PV installations, which may be producing energy for decades, long-term durability should be your guide, down to the wire ties you choose. Stainless steel wire ties and module clips are highly recommended to secure module wires to the module frames and racks. All wires must be secured to prevent them from touching the roof surface. Wiring that comes in contact with the roof can be damaged due to mechanical abrasion by wind or ice, potentially creating fire and shock hazards. In this installation, the installers added a few layers of electrician's splicing tape under the stainless wire ties to prevent abrasion against the ties' abrupt edges.

### Access

**Kathy Swartz** (kswartz@solarenergy.org) oversees the RE education program at Solar Energy International (SEI). She is looking forward to using her chickens' eggs to bake goodies for the SEI staff.

**Kris Sutton** (kris@suttonsolar.com) has worked in the PV industry since 1999. He currently is a PV instructor at SEI (www.solarenergy.org) and runs a PV consulting business, Sutton Solar Services. He is a NABCEP-certified PV installer, a Certified SEI Affiliated Master PV Trainer through IREC/ISPQ, and on the Board of Directors of CoSEIA.

*Many thanks to Matt Harris, Laura Bartels, Dave Clark, and the students in SEI's straw bale workshop for helping us erect and plaster our coop. We couldn't have done it without you!*

System Components:

Direct Power & Water Corp. • www.directpower.com • PV mount

Enphase Energy • www.enphaseenergy.com • Inverters

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

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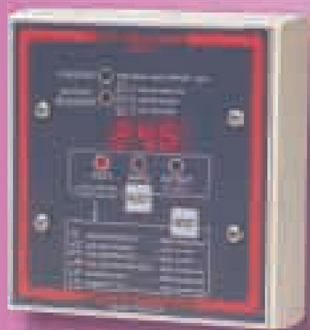

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# Plug In to Greener Computing

by Mike Chin

**In the computer world, the last couple of years have seen many changes in basic technologies, attitudes, and approaches, as well as new organizations and initiatives aimed at greening information technologies. From the consumer point of view, the most important changes are big improvements in energy efficiency of most computer components, and improved documentation of energy consumption.**

But is low power consumption all that's needed for a PC to be green? Well, no, even though most computer product advertising would have you believe it. For example, you cannot ignore simple user factors, such as turning the computer off when it's not in use or using a plug strip to eliminate the phantom loads of many computer products like printers and monitors on standby. The decision to retire an old, less energy-efficient computer and replace it with a newer, faster, more energy-efficient one is not so simple.

The bottom line is that it's impossible to bring a computer's eco-footprint down to zero, which is what green really should mean. We can, however, talk about a green*er* computer.

## Setting the Standard

The U.S. Environmental Protection Agency began certifying computers with its Energy Star label in 1992. The first phase of computer energy standards—v4.0—went into effect in July 2007, with the second phase becoming effective this past January.

By earlier Energy Star standards, a computer could be a total power hog when in use. As long as the power in *standby* mode stayed below target, then it would earn the Energy Star label. The v4.0 criteria include energy-efficiency and power management for computers, and, for the first time, define maximum *idle* power. The v4.0 requirements do not include any new regulations for external monitors. Revisions to the current standards for monitors (last updated in January 2006) and first-of-its-kind criteria for servers are expected this year.

Energy Star-approved computers fall into three different categories based on levels of intended usefulness (see Energy Star v4.0 Categories table on page 103).

## All Ratings Are Not Created Equal

A problem with the new criteria is that each category has different power limits, yet there is only one Energy Star mark. A desktop computer in category A that draws less than 50 W at idle receives the same Energy Star label as one in category B that draws up to 95 W at idle. The lack of distinction can mislead consumers into thinking that all Energy Star computers are equal in their energy savings.

The EPA's Energy Star marking methodology also suggests that a category C computer's efficiency should not be compared to that of a category A computer because it offers better computing performance. Following this logic, a desktop computer with 51 W idle in category A will not earn an Energy Star tag, but a model with 95 W idle in category C will.

Careful consumers can, however, do their homework and find the full details of a product on the Energy Star Web site. A list of certified products is updated periodically and available for free download. The key column

## Beyond Energy Consumption

The amount of water, fossil fuel, and chemicals that go into the production of the average desktop PC and 17-inch CRT monitor is on par with that used to manufacture some automobiles—roughly 1.8 tons. And since computers are usually replaced fairly often, this compounds the embodied energy and toxics problems.

According to *Computers and the Environment* (Springer, 2003) also states that a computer's lifetime energy impact is about the same as a refrigerator—with one critical difference. Ninety-six percent of a refrigerator's typical energy consumption occurs over its lifetime from the grid energy it consumes. For a computer, the situation is reversed: 25% occurs during use, while 75% occurs during production, due largely to its much shorter lifespan (typically two to three years).

Major computer manufacturers have announced initiatives to reduce the toxins in their computers, improve the energy efficiency of their products, and develop more effective reclamation programs. Apple, Hewlett-Packard, Sony, and Lenovo promised to phase out the use of PVC and brominated flame retardants by this year, and some have adopted policies that prohibit their waste from being exported to countries with less stringent environmental regulations.

**This older desktop computer draws 177 W with an LCD monitor. A CRT monitor could bump power consumption to as high as 300 W.**

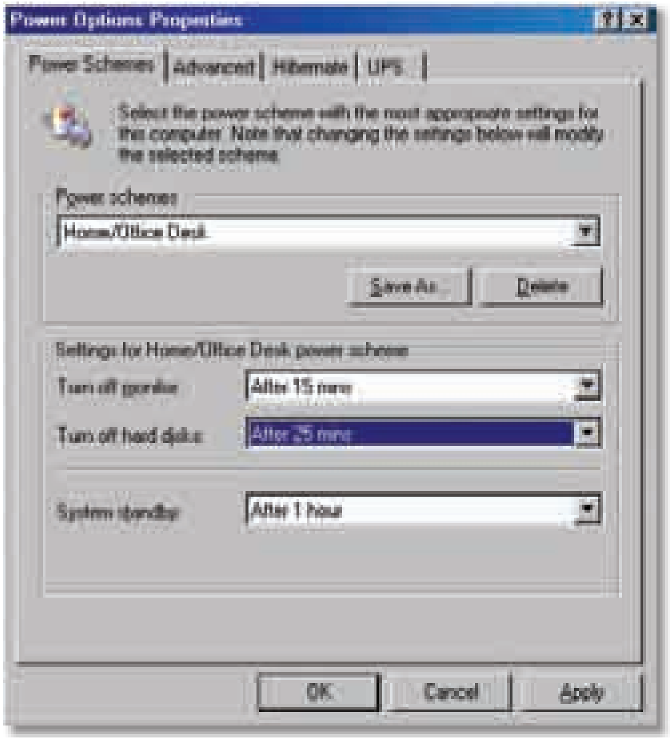
to examine is "Power in Idle" for each category. Many models will fall into multiple categories—several desktops, for example, appear in all three (A, B, and C). This is because many brands offer various components and accessories for a given model (i.e., from budget CPUs to gamer-ready quad-cores; from the most efficient on-board video cards to power-hungry 3-D monsters). If your goal is to reduce your energy use, look for the lowest idle-power PC that will meet your needs.

## Beyond the Star

If you're trying to choose a more eco-friendly computer, then you need to look beyond the Energy Star label and energy consumption. The Green Electronics Council—a nonprofit program of the International Sustainable Development Foundation—created the Electronic Product Environmental Assessment Tool (EPEAT), an online system designed to help consumers compare and select desktop computers, notebooks, and monitors based on their environmental attributes.

EPEAT is a voluntary, self-policing registry that addresses 51 criteria divided into eight categories, including reduction/elimination of toxic materials, product longevity, end-of-life management, and energy conservation. The registry ranks products as bronze, silver, or gold, according to three tiers of environmental performance.

EPEAT standards were established by consensus among various stakeholders, including representatives from every major PC company. While this voluntary participation helps ensure that EPEAT standards encourage manufacturers to compete on environmental points, a self-certification system relying on the manufacturers' word puts the rankings into question. Even though the council performs random reviews, there is no verification of each claim. Adding to the ambiguity of the rankings, some of the criteria on the online registration are indicated by check marks only, rather than detailed explanations or numbers.




**Choosing the right power options can significantly reduce the energy your computer consumes when you aren't using it.**

## Easy Ways Toward Greener Computing

Greener computing is as much about individual choices and behavior as it is about better products. Simple changes can make a big difference.

**Set up your computer to automatically go into standby or sleep mode** after being idle for a period of time (such as 10 minutes). This will reduce its power consumption during periods of inactivity to only a few watts.

**Turn your computer off** if you will not be using it for more than an hour or two. Powering your computer up and down consumes more energy than leaving it on for short periods of time, especially if the computer goes into standby mode. Hibernating and waking your computer can take even less energy (and time) than fully turning it off and on again.

**Dial back the brightness.** Many screens or monitors are brighter at their default setting than they need to be, so conserve energy by using a lower brightness setting. The power difference can be up to 15 W, even with modern 19-inch LCD monitors (which use much less energy than older CRT monitors).

**Tone down the color.** Choose dark-colored images and Web pages for your monitor background, screen saver, and Web home page. Your computer uses more energy to produce the light necessary for bright images.

**Save energy by "Blackling."** If you do a lot of Web searching, set your home page to www.blackle.com. This mostly black search engine obtains the same results as Google, but without all the energy that goes into displaying bright colors.

**Kill the phantom loads.** Electronic devices can consume energy when they're plugged in but not on. Plug your computer and all your peripherals into an energy-saving power strip that turns off everything with one switch. Keep rarely used peripherals, like scanners, on a separate power strip.

**Cut the power.** Power strip or not, turn off any peripherals when not in use. Collectively, printers, scanners, monitors, DSL or cable modems, network routers, and other equipment can draw tens of watts when sitting idle.

**Kick the gaming habit.** Gaming video cards are the worst power hogs among computer components today. Need your gaming fix? Go to Blackle's gaming Web site—www.blacklegames.com—for energy-saving gaming.

Even with its shortcomings, the EPEAT is still the most ambitious resource on the purchasing side of green computing. Since its launch in 2006, the registry has grown to include nearly 1,000 products and has become widely recognized as a tool for institutional purchasing. Although the main database contains products geared for educational, business, and government purposes—often computers with larger hard drives and high-end accessories—there are plans to expand coverage of products for personal and home use.

In the next five years, the EPA estimates that the purchase of EPEAT products will result in the reduction of more than 13 million pounds of hazardous waste and more than 3 million pounds of nonhazardous waste, and save more than 600,000 megawatt-hours of energy.

**Modern laptops provide significant computing power with a fraction of the energy requirements of a desktop computer.**

## Energy Star v4.0 Categories

| Computer Type | Category A | Category B | Category C |
|---|---|---|---|
| **Desktop** Must draw less than 4 W in sleep mode and less than 2 W in standby mode | All computers that do not fit into categories B or C. Usually a minimalist single-core processor with 1 gigabyte (GB) or less of memory, suitable for most tasks except large image and video editing, and 3-D gaming. Maximum idle power must be 50 W. | Typically employs a multicore processor, has more than 1 GB of memory, and a more capable video card. Capable of most PC tasks except extreme 3-D gaming. Maximum idle power cannot exceed 65 W. | Typically has a multicore processor, more than 2 GB of memory, a more capable video card, TV tuner and/or video-capture capability with high definition, and multiple hard disk drives. Maximum idle power must be 95 W. |
| **Notebook/Tablet** Must draw less than 1.7 W in sleep mode and less than 1 W in standby mode | Usually a minimalist single-core processor with 128 megabytes (MB) or less of memory, suitable for most tasks except large image or video editing and 3-D gaming. Maximum idle power must be 14 W. | Typically employs a multicore processor, has more than 128 MB of memory, and a more capable video card. Capable of most PC tasks except extreme 3-D gaming. Maximum idle power must be 22 W. | Not Applicable |

## Example Energy-Efficient Computers

| Personal Computer | Type | Energy Star Categories | Idle Watts | EPEAT Rating | Notes |
|---|---|---|---|---|---|
| Dell Optiplex 740 | Desktop | A, B | 42–52 | Gold | Dual-core AMD CPU; request Energy Star v4.0 when ordering |
| Lenovo ThinkCentre M57 | Desktop | A, B, C | 40–90 | Gold | Dual-core Intel CPU; wide variety of options |
| HP/Compaq 2710p | Laptop | A | 8.5 | Gold | Dual-core Intel CPU, 12 in. display |
| Toshiba Tecra M9 | Laptop | B | 19.1 | Gold | Dual-core Intel CPU, 14.1 in. display |
| Apple MacBook Pro ZOFS | Laptop | A | 5.7 | Silver | Dual-core Intel CPU, 17 in. display |

## When To Upgrade

Before you retire your old computer prematurely, consider all of the energy, chemicals, and waste that goes into manufacturing a new computer and disposing of the old one. Then, implement energy-saving measures until a new computer is absolutely necessary. However, when it comes to monitors, replacing your old CRT monitor with a new LCD one is almost always a good idea—an old-style CRT can easily draw more than 100 watts, while a newer LCD monitor of the same size can draw less than 30 W.

If a new computer is a necessity, then you should approach the selection process with a skeptical eye for details. Start by examining the Gold-rated products in the EPEAT database. Once you've selected some likely candidates, cross-check them in the Energy Star database and choose from the models with the lowest idle power. In general, laptops consume considerably less power and use fewer materials than desktops—but whether they're *greener* is open to debate. Because of the added need for compactness, they are often not as robust as desktop models, nor can they as easily dissipate component-harming heat, so they tend to have shorter life spans.

EPEAT and Energy Star certifications are a good starting point, but you should read about the computer manufacturers and follow their names in the news. Only by understanding their practices and keeping tabs on their environmental record will you feel confident about buying their products. Through an informed purchase, you have the power to shape the marketplace.

## Access

Mike Chin (mikec@silentpcreview.com) is a Canadian tech journalist and founder of Silent PC Review (www.silentpcreview.com), a resource center for quiet computers. He also runs Eco PC Review (www.ecopcreview.com), a Web site dedicated to greener computing.

Green Electronics Council's EPEAT • www.epeat.net

Energy Star • www.energystar.gov

IT & Environment Initiative • www.it-environment.org

*Computers and the Environment: Understanding and Managing their Impacts*, edited by R. Kuehr and E. Williams, 2007, Springer, 300 pages, softcover, ISBN 978-1-4020-1680-6

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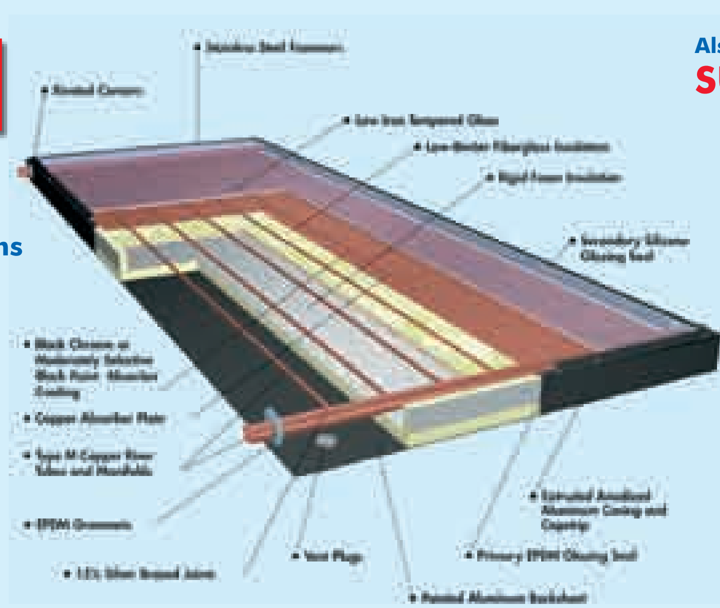

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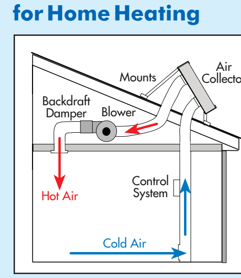


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# DIY Project Profile:

## Improving a SHW System's Efficiency

**by Andrew Goldbaum**

Who: Andrew Goldbaum
What: Drainback solar hot water system
When: August 2008
Where: Warwick, New York
Why: I needed to cut my oil bill

**The guts of Andrew's solar hot water system, now running better with a little automatic—and manual—intervention.**


I considered installing a solar hot water system for many years, but delayed for financial reasons. Then, heating oil approached $4 per gallon, and it finally made economic sense. After considering my family's hot water usage, the federal and state tax credits, and a system payback of just five to six years, it seemed financially irresponsible *not* to install one. I contacted an experienced local solar contractor and had him install a three-collector, 120-gallon antifreeze/drainback system that would preheat water for an existing 50-gallon hot water tank, which is indirectly heated by an oil-fueled hot water boiler.

Even before the installation, I knew my system would have two efficiency issues. The first was that even though the solar hot water tank might be filled with 150°F water, if no hot water was being used, the existing water heater tank would slowly cool as it had always done. This meant that occasionally the boiler would fire just to reheat it a few degrees, despite having a tank of "free" solar-heated water right next to it. When I witnessed my boiler firing up on a hot, sunny, summer day, I became determined to find a solution.

The second inefficiency has to do with heat energy that becomes "trapped" in the drainback tank: At the end of a sunny day when the collector circulator pump shuts down and the


**Left: An X-10 transmitter recognizes 125°F water in the solar storage tank and transmits a signal.**

**Right: The X-10 appliance module receives the signal and energizes the instant hot water circulator.**


solar tank temperature equalizes, the tank water might be 135°F. After filling the bathtub and running a load or two of laundry, the temperature at the bottom of the storage tank might be reduced to 75°F, while the top of it might be 130°F. However, the glycol, just sitting in the drainback tank, might be 140°F. If during the evening, that heat could be transferred into the solar storage tank, it would heat the water in the bottom of the storage tank to about 105°F. This would:

- Lessen or even stop the use of the boiler in the evening during high hot water use.
- Delay the need for backup heating if the following day is not sunny enough to activate the circulator.
- Reduce heat loss, since the solar storage tank is better insulated than the drainback tank.
- Result in higher system efficiency, since collectors operate more efficiently when heating glycol from a lower temperature to a higher one (100°F to 120°F, for example, as opposed to 130°F to 150°F). The next day, more hot water will be available sooner.

## System Description

**Three SunEarth EC32, 8- by 4-foot collectors.** Despite their slightly higher cost, I chose SunEarth's Empire series black chrome collectors for their higher efficiency compared to the more standard, selective-black-painted collectors. The collectors are SRCC approved, which is important for tax credit purposes.

**Two Grundfos UP 26 circulator pumps.** In this system, one circulator alone couldn't pump the glycol the almost-40 feet from the basement to the rooftop collector array, so a second circulator was added in series. This nearly doubles the pressure and head, costing less and using less electricity than a single larger circulator pump.

**One Rheem 120-gallon Solaraide tank.** The Rheem tank with integral heat exchanger is an industry standard for solar hot water storage. The Whirlpool 19-gallon electric water heater, which serves only as the drainback tank—not as a heated backup—was chosen because of its convenient connections. It's fairly well-insulated and holds 9 more gallons of glycol than a typical drainback tank, but costs much less. The extra glycol provides additional heat storage.

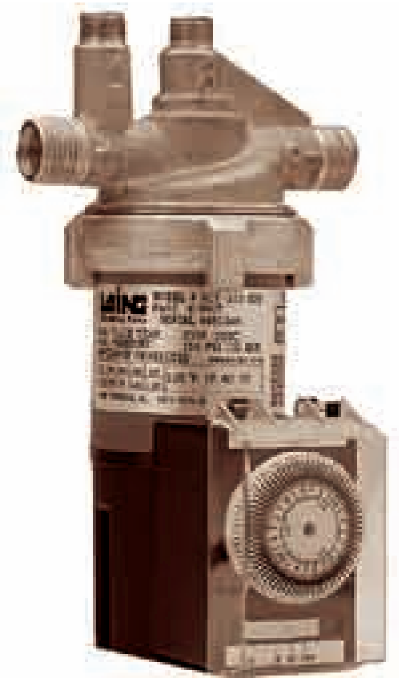
**One SunEarth AECA differential controller.** The controller has three temperature inputs from sensors: T1, at the solar collector output; T2, at the bottom of the storage tank; and T3, at the top of the storage tank. The controller activates the circulator based on the difference between T1 and T2, so that when the collector fluid is hotter than the storage water, the pump comes on. When T1 or T2 is too high, the controller shuts down the pump and the system drains. T3 temperature is for monitoring purposes only, and does not affect pump operation.

## Solution: Reducing Fossil Fuel Use

The solution to my first efficiency problem was to install an instant hot water circulator (IHWC). This eliminates the issue where the boiler turns on to reheat the existing water heater tank despite having plenty of hot water available in the solar storage tank. This device also eliminates the annoyance of waiting for hot water to arrive at the faucet.

An IHWC is installed under the sink that is farthest from the water heater and monitors the temperature of the hot water at the sink. When the temperature drops below an adjustable set point (100°F, in this case), it turns on its circulator pump, which draws hot water from the water heater, keeping hot water at the faucet all the time. If not used in the sink, the water returns to the tank via the cold water line. When the hot water line reaches the required temperature, the IHWC pump shuts off. In this way, hot water is kept very close to all the faucets along the same hot water supply line.

While having on-demand hot water is nice, I wanted to save oil, not use extra by drawing water from the water heater tank during times when solar-heated water of sufficient temperature was not available. I accomplished this by plugging the IHWC into an X-10 appliance module and connecting an X-10 PowerFlash transmitter module to a small thermostatic switch installed at the top of the solar tank.



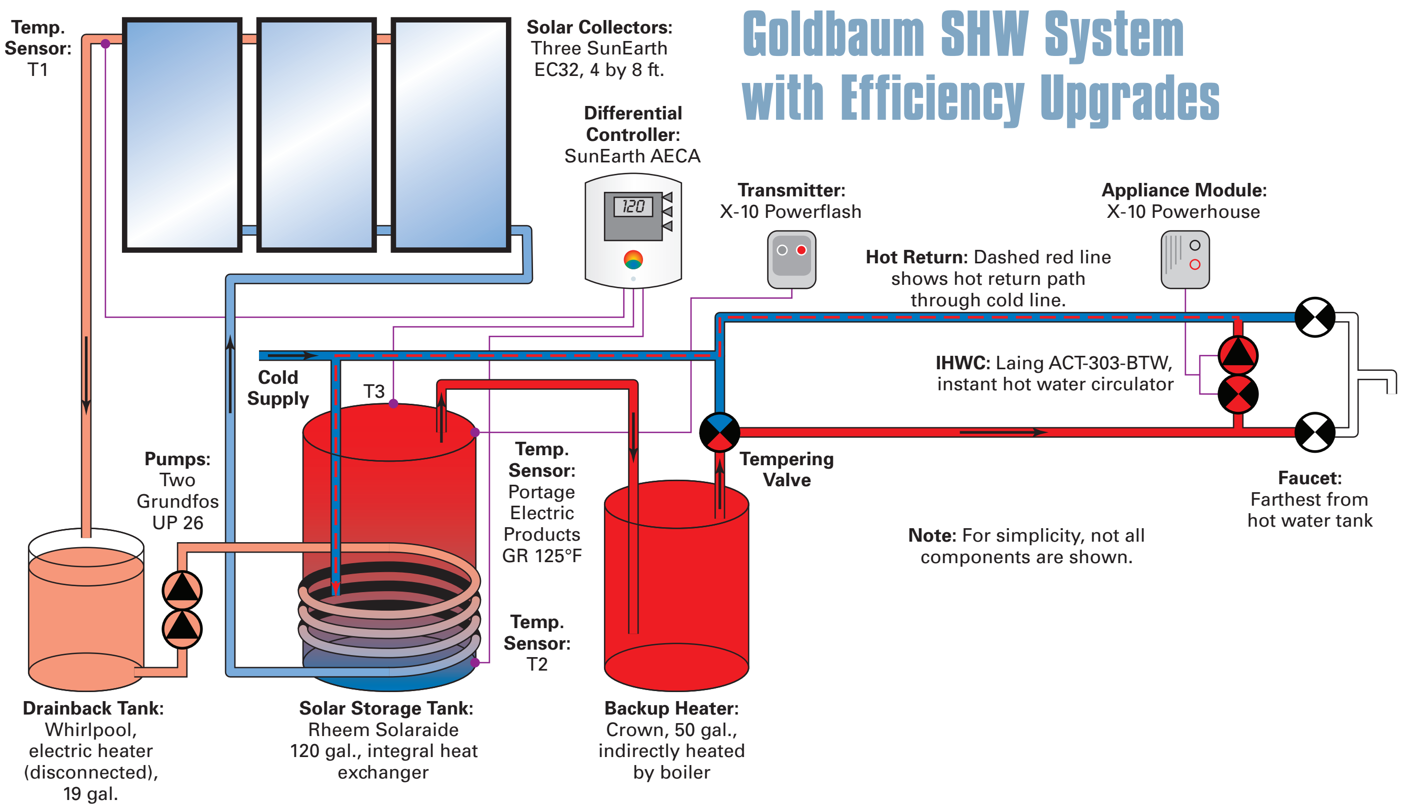
**Only when the instant hot water circulator is powered by the X-10 appliance module and when it senses water temperature below 100°F at the faucet will hot water circulate.**

When the solar tank is at 125°F (5°F higher than the water heater tank's set point), the thermostatic switch closes and causes the X-10 transmitter to send a signal through my home's electrical wiring to the appliance module at the IHWC to power the IHWC's automatic operation. When the temperature in the solar tank drops below 125°F, the thermostatic switch opens, and the transmitter signals the appliance module to turn off the IHWC. This means the IHWC runs only when the tank temperature is more than 125°F and the IHWC temperature at the sink is less than 100°F. With the system properly adjusted, the boiler should stay off as long as sufficiently heated water is available from the solar storage tank. (For homes with 240 V single-phase service split into two 120 V legs, both X-10 modules must be on the same leg to communicate.)

## Solution: Addressing Trapped Heat in the Drainback Tank

The second efficiency issue—where heat becomes "trapped" in the drainback tank—is more complex. Provided a good amount of hot water has been used (cooling the bottom of the storage tank), and it's not too cold outside, the SunEarth controller can be manually set to run the circulator. But if it's too cold outside and glycol is circulating, the cold solar collectors will absorb usable heat from the glycol and begin to cool the solar hot water tank. If it's warm out and the circulator is running, it will quickly heat up the collector until it is hot enough to fool the controller into thinking the sun is shining, keeping the system running. At this point, the controller should be set back to automatic mode. When the solar controller finally shuts off the circulator, the storage tank will be much warmer, having absorbed much of the drainback tank's residual heat. Nineteen gallons of 140°F glycol can raise the bottom third of the 40-gallon tank from 75°F to 105°F. This is more than enough heat to take a hot bath and saves about 0.1 gallons of oil.

## Goldbaum SHW System with Efficiency Upgrades



## Other Alternatives for Making SHW Systems More Efficient

Water heating designs have been pretty solid for decades, but it's always possible to make improvements to the systems. Andrew made some modifications that work for his situation—here are a few others to consider.

Heat loss from a backup water heater can cause unnecessary fossil-fuel usage if the solar storage tank is hot enough to supply the hot water but there is no demand to move the solar-heated water to the water heater. With the tanks normally piped in series, this can happen with intermittent hot water usage. Andrew chose to equalize the two tanks and combine the equalization with a hot water recirculation system (more on that below). Another possibility would be to circulate between the two tanks, rather than throughout the household's water delivery system.

Extra insulation on the water heater can help. Many older water heaters have poor insulation, and wrapping the tank with extra can cut standby heat loss considerably. In areas where hard water isn't a problem, a tankless water heater that will modulate its output with the incoming solar-heated water solves the standby loss.

Gas, propane, and fuel-oil water heaters have an uninsulated flue pipe running up the center of the tank and through a home's roof to dispose of the combustion products, which contributes to heat loss. If your backup water heater is fossil-fuel fired with a conventional flue pipe, consider a highly insulated electric tank as an alternative. At this time, the price of oil is low, but a few months ago the price of propane and fuel oil made electric water heaters attractive. Electric tanks are always a better backup type of tank since they don't have a flue to add to standby heat loss.

Hot water recirculation systems are becoming more popular in upscale residential construction. They've been standard in larger buildings for decades. They provide instant hot water no matter how far the tap is from the water heater, which can reduce the amount of wasted water flowing down the drain while waiting for the water to heat. However, this convenience and water savings has an energy cost. The power that the pump uses is one cost and the heat lost through the pipes as it endlessly circulates through the system is the other cost. Timers and devices like Andrew designed mitigate both of these losses considerably, but it's always a trade-off. Where water is abundant and energy is precious, these systems are of questionable value, except for convenience. In areas where energy is more abundant and water is scarce, the recirculation systems can be beneficial as well as convenient.

Recovering heat from a drainback tank is a novel idea and could be beneficial. However, it would be best not to route the water recovery system through the collectors at night. To keep pumps running as cool as possible, locate them on the cool side of the heat exchanger—where the heat has been pulled out already.

—Chuck Marken, *Home Power* Solar Thermal Editor

Unfortunately, no differential solar controller I'm aware of, including the dual-output models, will allow this process to be automated. What's needed is a special, additional controller that will turn on the circulator for a few minutes when the drainback tank's temperature is a few degrees hotter than the solar tank's bottom (and the collector is not too cold), until the automatic function of the main differential controller takes over. Since no commercial solution appears to be available, I hope to design one myself. (Contact me via e-mail for more information.) For now, the only way to extract the trapped drainback heat is to manually set the controller.

## Performance

Historically, my family used about 550 gallons of oil for heating water, split almost evenly between the nonheating and heating seasons. The solar hot water system should offset 80% to 90% of this during the nonheating season, and about 25%, or 56 gallons of oil, during the heating season. Annually, the system offsets about 250 gallons of oil. At $4 per gallon, that's a savings of about $1,000 per year, which covers most of my loan payments for the system.

Calculating the savings from the IHWC is more complex. During the nonheating season, I estimate my boiler (which burns 3 gallons of oil per hour) fires six times per day to compensate for water heater tank cooling. It fires for about 3 minutes each time, for a total of 18 minutes, burning about 0.9 gallons of oil per day. From June to September, the solar hot water system will supply all our hot water on clear days. According to meteorological statistics, there are likely to be about 32 completely cloudless days in my area for that time period. This means the IHWC and associated components are likely to save a minimum of 28.8 gallons (32 days x 0.9 gallons) of oil per year, recouping costs in about three years.

To calculate the potential savings from my system that extracts heat from the drainback tank, it's necessary to estimate the number of times a cloudy day follows a clear day from June to September. I figure that a cloudy day comes after a clear day for a total of 32 days during that period. Since the drainback tank stores the equivalent of about one-tenth of a gallon of oil (as discussed above), an automatic system would save 3.2 gallons per year. This estimate does not include the reduced losses or increased efficiency savings discussed previously.

## Access

**Andrew Goldbaum** (hmpwr_article@yahoo.com) has an MBA, and is an electrical engineer, programmer, and director of software development for a small New York-based defense contractor.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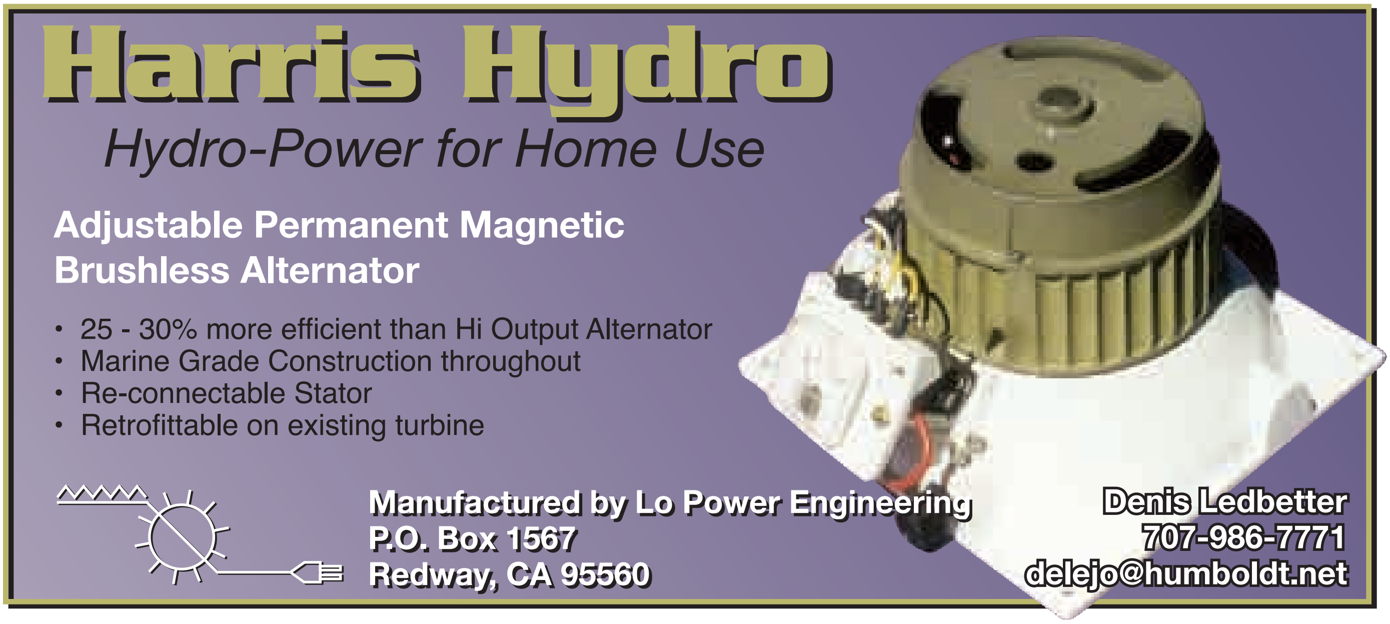
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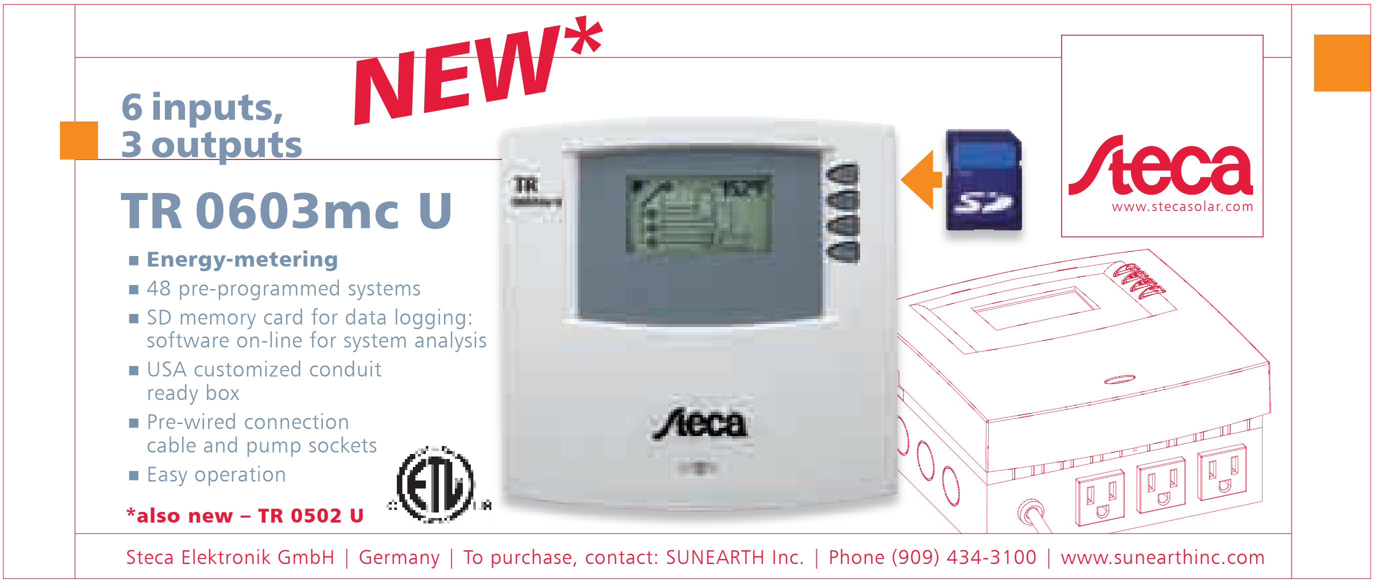
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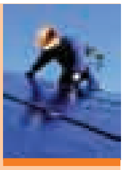

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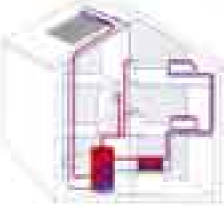

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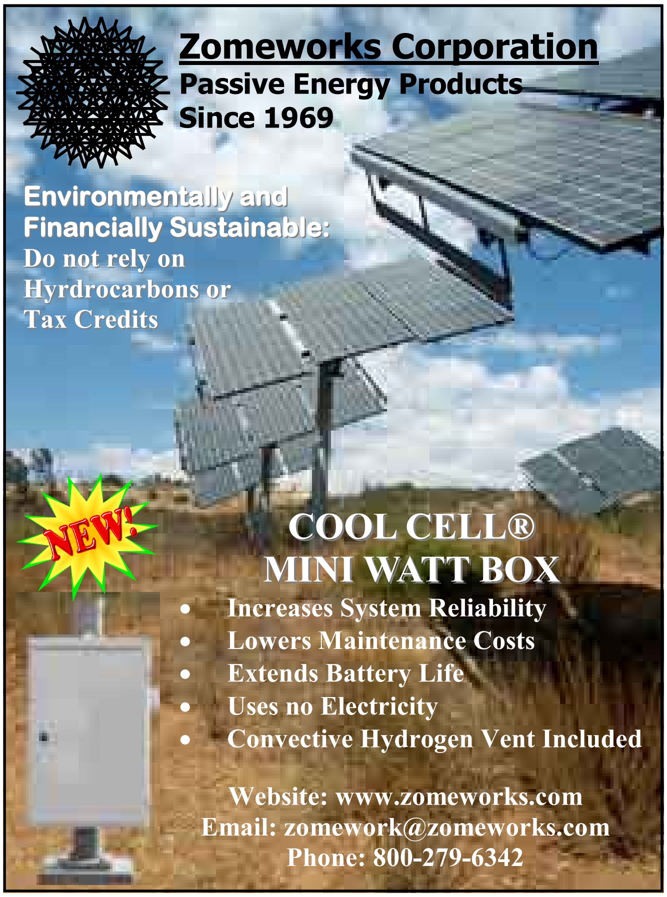
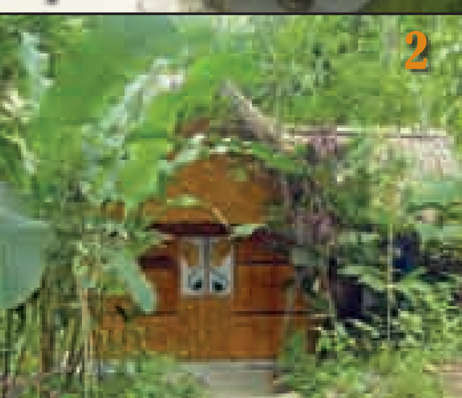


# Farming the Sun





by Laurie Guevara-Stone

photos by Daniel Hagaman & Laurie Guevara-Stone

Just south of the equator on the Ecuadorian Pacific Coast, Rio Muchacho Organic Farm stands in the once-dense rain forest as a model of community development and sustainability. Owners Nicola Mears (an organic horticulturist from New Zealand) and Ecuadorian native Dario Proaño took over the 27-acre farm almost 20 years ago with the goal of helping the land recover from decades of burning, clear-cutting, mono-cropping, and chemical applications.

When Nicola and Dario first started growing food on the land, the region was practically a desert. The tropical rain forest had been so brutally deforested for cattle farming that barely any plant life remained. Nearly two decades later, Nicola and Dario have brought the land back to life through reforestation efforts and sustainable farming practices.

Beyond their reforestation efforts, the couple has used proceeds from agritourism programs—like eco-camps, educational courses, and apprenticeships—to further develop the farm's infrastructure and support community development for the coastal farmers who inhabit and work the land. In addition to growing cash crops of peanuts, corn, coffee, cocoa, and passion fruit, the farm runs a primary school, where local children learn the fundamentals, as well as techniques for sustainable farming, recycling, waste management, and reforestation.

## Getting Involved

Solar Energy International is one of several organizations that has helped the farm develop its infrastructure. Last March, SEI took a group of students—nine Americans and three Ecuadorians—to the farm for a five-day workshop on sustainable agriculture, permaculture, and renewable energy.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1. The author (far left) instructing on module shading and other PV basics.
2. One of the PV-powered cabins.
3. The solar food dehydrator drying coffee, cocoa beans, and herbs.
4. SEI instructor Carol Weis (left) and students wire the controller, inverter, and disconnect boxes.
5. The finished structure, which houses the battery and balance of system components, with the modules on top.
6. One of the hazards of traveling in the rain forest.

7. Mounting the PV modules.
8. The outdoor classroom at the farm.
9. One of the PV-powered bathrooms.
10. Students wire the modules.

A superefficient LED lamp in one of the bathrooms.

## Rio Muchacho Lighting Analysis

| | | LED Bulbs | | CF Bulbs | | Incandescent Bulbs | |
|---|---|---|---|---|---|---|---|
| Lighting | Quantity | Power (W) | Total Watts | Power (W) | Total Watts | Power (W) | Total Watts |
| Overhead | 7 | 2.9 | 20.3 | 18.0 | 126.0 | 60.0 | 420.0 |
| Reading | 10 | 1.8 | 18.0 | 15.0 | 150.0 | 40.0 | 400.0 |
| Path | 1 | 2.9 | 2.9 | 18.0 | 18.0 | 60.0 | 60.0 |
| Bathroom | 3 | 2.9 | 8.7 | 18.0 | 54.0 | 60.0 | 180.0 |
| Totals | | | 49.9 | | 348.0 | | 1,060.0 |

For most participants, the real highlight came on the third day, with the installation of a 100-watt photovoltaic system on the farm—made possible by students' tuition and generous equipment donations. The farm previously installed a small 32 W solar module to charge a battery for radio communications, but the people who live and work on the farm were eager to see solar power applied in a larger format so they could better understand the technology. Due to the unreliability of grid power in the region, which often goes out for days at a time, owners Nicola and Dario have been working with SEI to implement RE solutions for the farm's energy needs, specifically to power all the farm's lights.

### Planning for PV

Prior to traveling to Ecuador, SEI staff collaborated with Nicola and Dario on their needs. Having been to the farm on previous trips, most of the crew were familiar with the layout, which made it easier to plan for the installation.

The farm has several bamboo-thatch cabins to house the growing number of volunteers and guests. Though the amenities are basic, the cabins are equipped with overhead and reading lights that were powered by the grid. The goal was to install a solar-electric system to provide lighting for two cabins, two bathrooms, and one outdoor area—a total of 21 lights.

Working within a small budget, an existing inverter, and limited in-country equipment availability posed a challenge, but the SEI crew hatched a plan that maximized efficiency while minimizing costs. Key to the plan was LED bulbs, which use less than a third of the energy of compact fluorescent bulbs and last up to 30,000 hours. Though more costly than both incandescent and compact fluorescent bulbs, LED bulbs can quickly pay for themselves through energy savings. With the high cost of PV-made energy, the payback is a lot shorter.

By replacing the existing incandescent lightbulbs with LEDs, the crew found that the farm could power twice as many lights with the planned 100 W PV system. Even with the expense of buying new LEDs, the plan was substantially more cost-effective than trying to PV-power the incandescent bulbs.

Weather was the next consideration. Given that five months of the year are completely overcast and subject to

## PV System Cost Comparison

| LED Lighting | | CF Lighting | | Incandescent Lighting | |
|---|---|---|---|---|---|
| Item | Cost (US$) | Item | Cost (US$) | Item | Cost (US$) |
| 2 Kyocera PV modules, 50 W | $550 | 700 W array | $3,850 | 2,100 W array | $11,550 |
| 21 C Crane LED bulbs | 407 | 21 CFLs | 74 | 21 Incandescent bulbs | 42 |
| Millennium battery, 115 Ah | 235 | 700 Ah, 12 V battery bank | 1,410 | 1,050 Ah, 24 V battery bank | 4,230 |
| MidNite Solar DC disconnect | 200 | DC disconnect | 200 | DC disconnect | 295 |
| Steca PR1010 controller, 10 A | 140 | Charge controller, 40 A | 275 | 2 Charge controllers, 60 A | 560 |
| Techman inverter, 600 W | 125 | Inverter, 600 W | 125 | Inverter, 1,500 W | 795 |
| Wire, fuses, hardware, etc. | 110 | Wire, fuses, hardware, etc. | 140 | Wire, fuses, hardware, etc. | 420 |
| DP&W mounting feet | 20 | Roof/ground mount | 400 | Roof/ground mount | 1,200 |
| Total | $1,787 | | $6,474 | | $19,092 |
| % Savings Over Incandescent | 91% | | 66% | | -- |

long cloudy periods, using PV modules as the only power source would not provide the year-round reliability that the farm needed. Since a large battery bank exceeded the budget, the crew decided to take advantage of the cabin's preexisting grid connection and devised a plan that allows the farm to manually switch the power source between the small PV system and the grid. An 115 Ah Millennium battery was used, providing up to three nights of lighting at 50% depth of discharge if the grid goes down.

## Installing the System

Finding a suitable location for the array among the dense tropical flora and fauna proved challenging. The crew settled on a sunny spot not far from the cabins and bathroom buildings—one of the few clearings on the developed portion of the farm. At the equator, the sun is very high in the sky and shading is less likely during midday, so there was less need for a detailed solar site analysis.

In the classroom, Carol Weis of SEI explained to the locals how the power from the PV array goes through the controller to the battery, and then through an inverter to a manual transfer switch. She also illustrated how the grid power comes into the other side of the transfer switch. Following the discussion, the students—including the farm's maintenance workers, who participated in the course and installation—split into three groups and got to work.

**The power center, with each component labeled in Spanish and English.**

## LEDs, Lumens & Performance

According to the U.S. Department of Energy, incandescent lamps typically produce 12 to 15 lumens per watt of electric power. Compact fluorescent lamps (CFLs) produce at least 50 lumens per watt, while currently available high-brightness LEDs can produce about 30 to 35 lumens per watt.

In task-lighting applications, LEDs may be able to provide enough light on the task, even though the total lumens are less than comparable incandescent or fluorescent sources. This is because LEDs emit light in a less diffuse pattern than conventional light sources. In contrast, standard incandescent bulbs and fluorescent lamps emit light in all directions, and much of the light output is absorbed inside the fixture or escapes in an unintended direction.

**Mounting the modules.** The two 50 W modules were mounted on Direct Power & Water feet on a 12-foot bamboo platform, which was high enough to minimize shading from huge umbrella-shaped saman and palm trees.

**Wiring the power center.** The incoming PV array got wired first into a donated MidNite Solar DC disconnect box, where the PV-to-charge-controller circuit breaker is housed. The PV wiring from the DC disconnect was run to the 10 A Steca controller. The charge controller to battery wiring was also completed through its own circuit breaker in the DC disconnect box. Wiring was then run from the battery to a 600 W inverter via a third breaker in the DC disconnect box.

On the AC side, the transfer switch was connected to the output of the inverter, which allows for the manual transfer between grid power and the PV system. Finally, wiring between the transfer switch and the AC loads was completed via an AC disconnect box.

**New wiring to the cabins.** Working in the developing world often means working with pre-existing wiring and equipment that may not be ideal or up to standards. The wiring on the farm was typical of rural Latin America: a jumble of indoor-rated wires running from tree to tree—pretty unsightly and unsafe. Nicola and Dario wanted the wires routed underground in conduit for safety and aesthetic reasons.

## Working with PV

The finished system—which took less than two days to complete—allows the farm to manage their electricity needs by switching between sources. When the sun is shining, energy can be sourced from the PV array. During cloudy weather, or other times, like when the battery charge gets low, the farm can switch over to the grid until the battery is recharged by the PV modules. Likewise, if the grid goes down, the farm can easily switch over to the PV system and still have electricity for lighting. On the rare occasions when the cabins are not being used, the inverter can be turned off and the loads switched over to the grid to avoid unnecessary drains on the battery from the inverter, which uses 3.6 W on standby.

Nicola and two technicians from the farm took part in the class, and Sergio, the main technician, also received additional training in system maintenance and troubleshooting. Taking into account the remote location, the crew left behind extra equipment for unexpected problems—a controller, fuses, and replacement LED lamps.

After the success of the PV lighting system, Nicola and Dario are eager to power the whole farm with renewable energy, including the water pumps for filling the cisterns. Next year, SEI plans to return to the farm to install more PV systems for the cabins, and to build a pedal-powered water pump.

**The truck is free—time to go home.**

## Access

**Laurie Guevara-Stone** (laurie@solarenergy.org) is the international program manager at Solar Energy International, a nonprofit RE educational organization. Laurie, her Ecuadorian husband Anibal, and their son Camilo try to spend as much time as possible near the equator.

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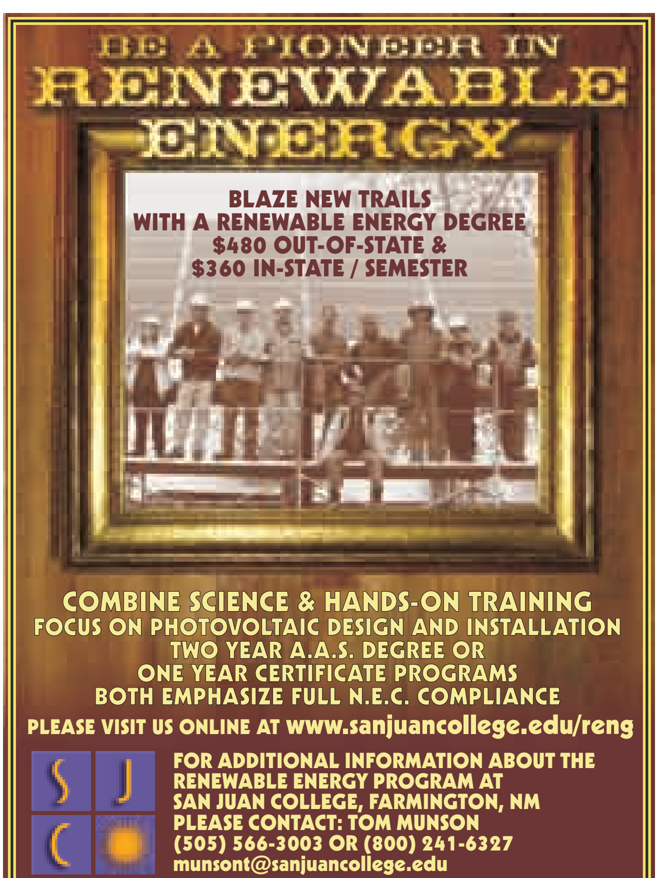



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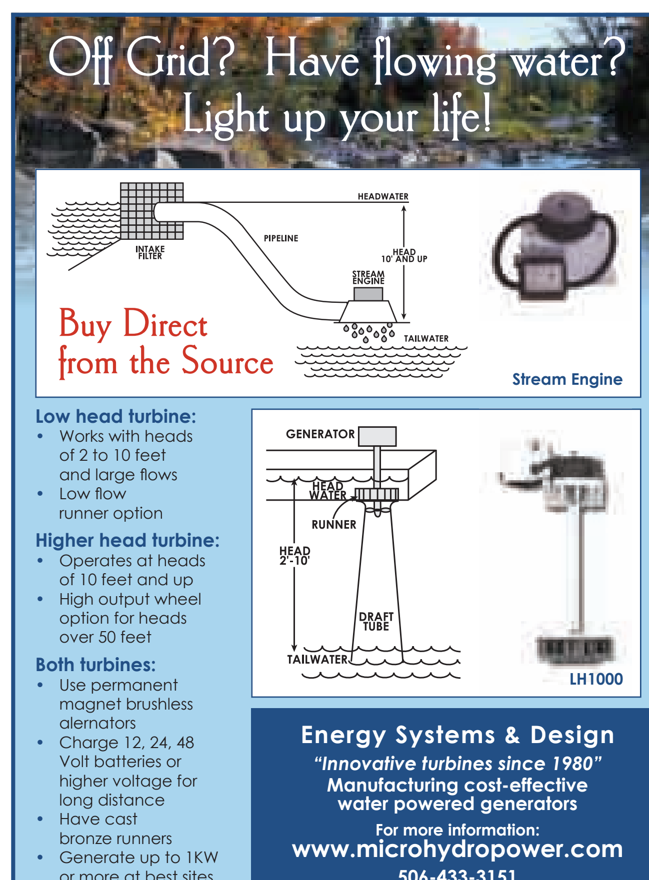
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# Code Calculations

## *for PV Modules*

by John Wiles

A PV module's or string's rated open-circuit voltage (Voc) is measured at a defined temperature, namely 25°C (77°F). But what happens as temperatures fluctuate? As temperature rises, voltage decreases. Conversely, as the temperature drops, voltage increases.

What does this have to do with system design? To avoid damaging equipment, design voltage needs to stay below an inverter's maximum input voltage, as well as the voltage rating of wiring, switch-gear, and overcurrent devices. The expected lowest temperature at the installation needs to be included in the open-circuit voltage calculation, as required by the *National Electrical Code* (*NEC)* Section 690.7. (Since parallel connections of strings do not affect the open-circuit voltage, the number of strings connected in parallel is not involved in this calculation.)

In previous editions of the *NEC*, Table 690.7 could be used to determine a multiplier, which was applied to either the rated Voc of the module or a series string. The *NEC 2008* also allows the table to be used when module temperature coefficient data is not available.

Using the table is easy: All you need to know is the lowest expected temperature at the site. Then, you can look up the corresponding factor from the table (between 1.02 at 24°C and 1.25 at -40°C), and multiply the factor by the rated Voc.

Here's an example: A module has a Voc of 35 V and is going to be installed where the temperature dips to -15°C. The factor from Table 690.7 in the *NEC 2008* is 1.16. So the "cold" temperature Voc for this module is 40.6 V (35 V x 1.16). If 12 modules were going to be connected in series, the string Voc in cold weather would be 487.2 V (12 x 40.6 V). Alternatively, you could also first calculate the string open-circuit voltage and then apply the temperature factor.

### NEC 2008 *Requirements Differ*

Table 690.7 is based on an "average" type of crystalline PV module that has been the most widely used over the last 30 years. However, more accurate values can be determined by using the temperature coefficient data specific to each module. Section 690.7 in the *NEC 2008* requires that when the module manufacturer's temperature coefficient data are available they should be used instead of the table. Temperature coefficients can be obtained from the manufacturer or found in the technical literature of nearly all modules. Unfortunately, different manufacturers present the temperature coefficients in a few different forms. The two most common forms are discussed below.

**Percentage Coefficients.** One way of presenting this data is to specify them as a percentage change. Note that the temperature used in the calculation is a *change* in temperature from the rated 25°C.

For example: The Voc temperature coefficient is given as -0.36% per degree Celsius. If that module has a Voc of 45 V at 25°C (77°F) and is going to be installed where the expected lowest temperature is -10°C (14°F). The change in temperature is 35°C (from 25°C to -10°C). The minus sign in the coefficient can be ignored as long as we remember that the voltage *increases* as the temperature goes *down* and vice versa.

Applying the coefficient, the percentage change in Voc resulting from this temperature change is 12.6% (0.36% / °C x 35°C). This percentage change can now be applied to the rated Voc of 45 V. At -10°C, the Voc will be 50.67 V (1.126 x 45 V).

Eleven of these modules could be connected in series and the cold-weather voltage would be 557.37 V (11 x 50.67 V), less than a 600 V equipment limitation.

**Millivolt Coefficients.** Other PV module manufacturers express the Voc temperature coefficient as a millivolt (0.001 V) coefficient.

A typical module with an open-circuit voltage (at 25°C) of 65 V might have a temperature coefficient expressed as -240 mV per degree Celsius.

If installed where the expected low temperature is -30°C (-22°F), then there is a 55°C degree change in the temperature (from 25°C to -30°C).

Millivolts are converted to volts by dividing the millivolt number by 1,000: 240 mV / 1,000 mV/V = 0.24 V, and the module Voc will increase 13.2 V (0.24 V / °C x 55°C) as the temperature changes from 25°C to -30°C. The module Voc will increase from 65 V at 25°C to 78.2 V (65 V + 13.2 V) at the -30°C temperature.

Let's suppose that the inverter maximum input voltage was listed as 550 V. How many modules could be connected in series and not exceed this voltage? To find out, take the maximum inverter voltage of 550 V and divide it by the module's cold-weather open-circuit voltage of 78.2 V: 550 V ÷ 78.2 V = 7.03 modules. Eight modules could not be used because the open-circuit, cold-weather voltage would exceed 550 V (8 x 78.2 V = 625.6 V).

## PV Math—Module Short-Circuit Current

In most silicon PV modules, the module short-circuit current does increase very slightly as temperature increases, but the increase is negligible at normal module operating temperatures and can normally be ignored.

### *Expected Lowest Temperature?*

Normally, the lowest temperatures occur in the very early morning hours, just before sunrise on cold winter mornings. At this time, the PV modules are sometimes a few degrees colder than the air temperature due to night-sky radiation effects. The illumination at dawn and dusk are sufficient to produce high Voc, even when the sun is not shining directly on the PV array and has not produced any solar heating of the modules.

So how can you find the expected lowest temperature? A conservative approach would be to use weather data that show the record low temperatures and use this. The National Renewable Energy Laboratory maintains data that show the record lows for many locations in the United States (see Access). Local airports and weather stations may have historical data on low temperatures. Weather.com has some of this data available that can be accessed by zip codes (see Access).

### *Access*

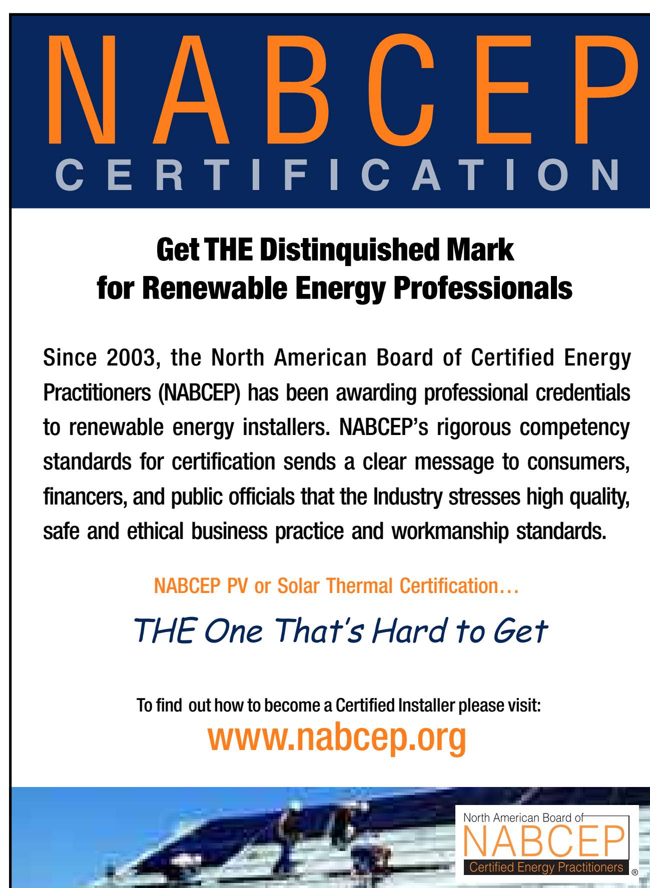
**John Wiles** (jwiles@nmsu.edu) works at the Institute for Energy and the Environment, which provides engineering support to the PV industry and a focal point for code issues related to PV systems. A solar pioneer, he lived for 16 years in a stand-alone PV-powered home—permitted and inspected, of course. He now has a 5 kW grid-tied system with whole-house battery backup. This work was supported by the United States Department of Energy under contract DE-FC 36-05-G015149.

*Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices* by John Wiles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

*PV Systems Inspector/Installer Checklist* and previous *Code Corner* articles •www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html

NREL Insolation Data • http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/redbook/sum2/

Weather Data • www.weather.com/weather/climatology/monthly/ Append zip code to the end of the URL.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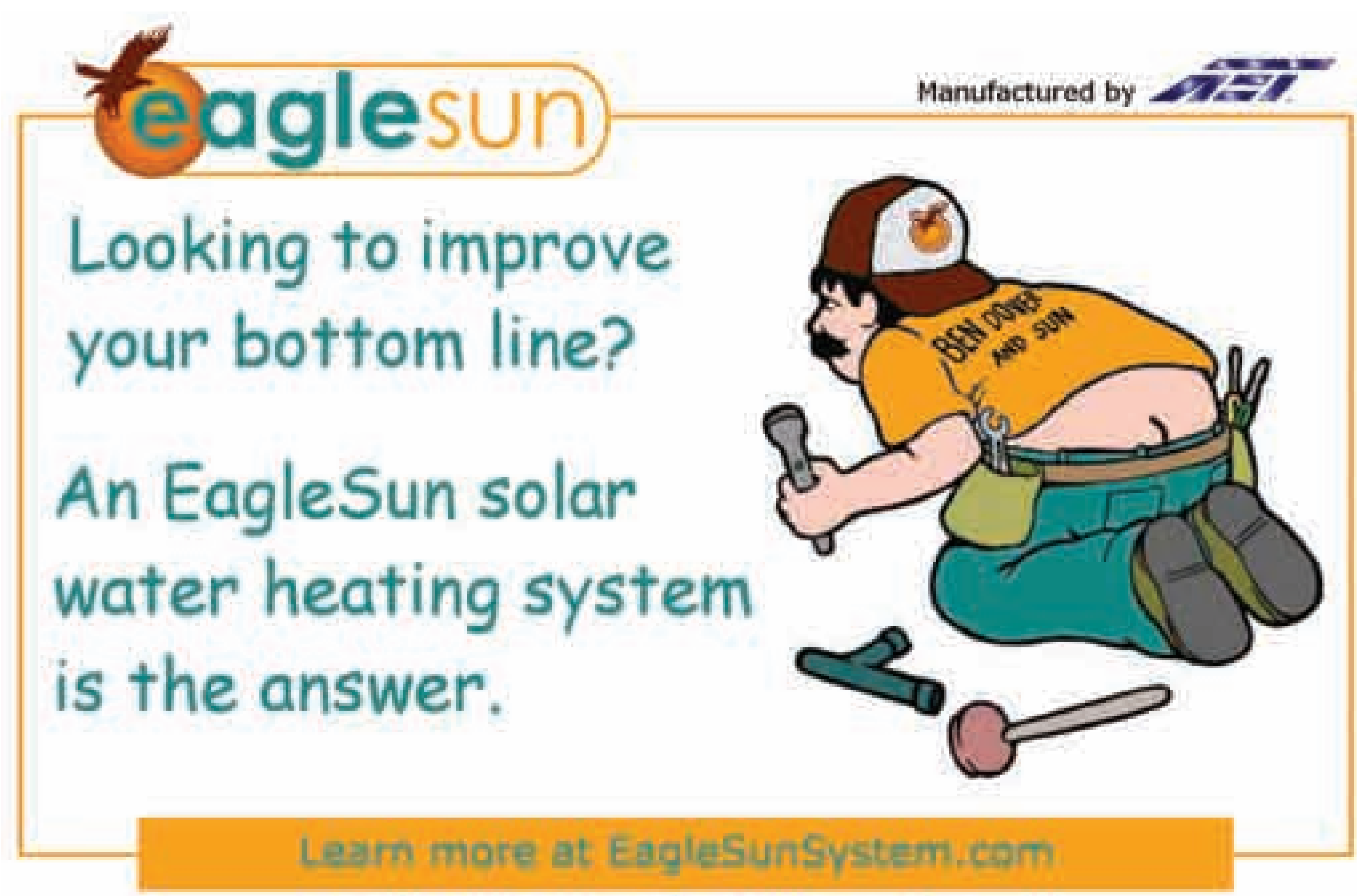
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# Change is Afoot

## Energy Agendas for a New Era

by Michael Welch

Liberals are giddy with the promised "change" that was the hallmark of the Obama presidential campaign, while seasoned energy-watchers and other progressive-minded folks are crossing their fingers and taking a wait-and-see attitude. The president-elect has been in the news almost daily with talk of the promised change—including stimulus for the economy that excludes the unnecessary "pork" that always seems to find its way into the appropriations that Congress places on the treasury (our hard-earned tax dollars).

Obama says that future appropriations bills won't be like those passed and signed this year and in the recent past, inferring that our tax dollars will mostly be made available for getting the United States out of its current economic woes. It is unclear exactly what that means, or where he draws the line on unacceptable pork—but he has made it clear that he wants to stimulate the economy through new jobs in renewable energy and other chosen industries, while at the same time fighting climate change with RE, energy efficiency, and, he says, "clean coal" technology and more nukes.

You can count on the dirtier industries fighting tooth and nail to keep their subsidies and share of the pie. With this more receptive administration, evening out the energy playing field should become much easier: RE advocates will have better access and will likely increase their efforts in their particular areas of interest.

### Climate Change

Global warming is an issue that many interest groups will continue using to bolster efforts for their own particular technologies—some deservedly and some not. The issue does not have its own special interest group fighting for solutions. Instead, hundreds of organizations—from environmental groups to biofuel farmers' organizations, from green business groups to the "clean coal" and nuke industries—are using it as an issue to further their own goals. Here is a look at the new federal agendas of some of these industries.

**Solar.** The solar industry intends to stay its course—it has already been pushing hard on RE issues and has done well considering seemingly overwhelming odds. It will definitely benefit from the changes in Washington, with more environmentally friendly legislators sitting in the House and Senate. As the industry grows, it will be able to exert even further influence. As an indication of the access that is expected, the Solar Energy Industries Association said, "SEIA is very well positioned to work with the transition team for president-elect Obama. We have strong relationships with many of the senior members of the team, in particular the energy and environment team." SEIA's efforts are representative of many other groups' solar efforts and will include:

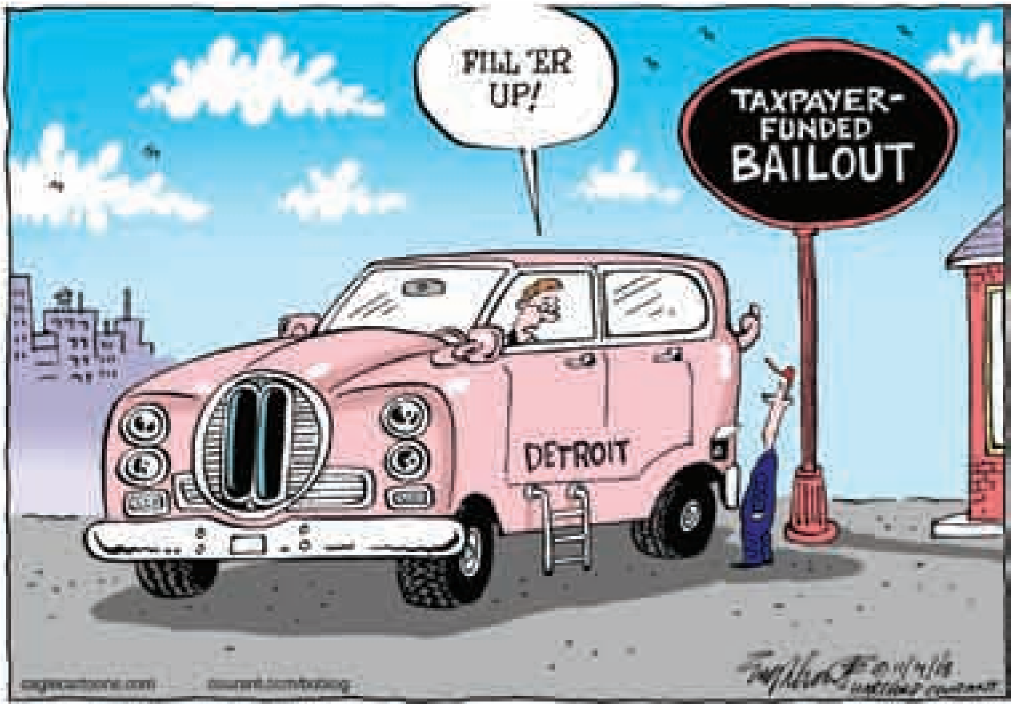
- Federal renewable energy portfolio standards, to set minimum percentages of RE in the makeup of utilities' generation.
- New and improved long-distance transmission, to reliably move RE electricity around the grid.
- Federal interconnection and net-metering standards for RE, to make sure that everyone from any state can connect their own home RE system to the grid.
- Opening up federal lands for solar project development.

**Wind.** The wind-electric industry is slowly catching up to the solar industry in influence—and catching up is their goal. Initially, they want to obtain the same level of support that the solar industry received last year with the financial "bailout" bill. Their agenda is outlined in the document *Wind Energy for a New Era* and includes:

- A national renewable energy portfolio standard.
- A minimum 5-year production tax credit extension.
- New interstate transmission infrastructure to move energy from remote wind farms to customers.
- Further R&D and program funding to help the wind industry grow more quickly.
- Federal agency support for siting wind farms and transmission lines.

**Nuclear Energy.** Obama typically mentions nuclear energy as a partial solution to climate change, even though he has no answer to the waste problem. His campaign contributions from the nuclear utility Exelon make him a pro-nuke suspect, as did his "yes" vote on the 2005 Energy Bill, which is making a "nuclear renaissance" a possibility. But grassroots and larger environmental organizations understand that more nukes are not a reasonable answer to the problem and have been working hard to counter nuke industry efforts. Nuclear waste is the most obvious problem, and the industry and nuclear-related federal agencies have been regularly stymied on that issue. For an excellent read on why nuclear is not an answer for climate change, see *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy* by the Institute for Energy and Environmental Research (www.ieer.org).

**Coal.** The coal industry says that coal is the answer to keeping energy costs down and for obtaining energy independence from foreign oil. But it remains the most polluting source of electricity in the world. Obama has often




touted his support for "clean coal" technology—though how the administration will show their support is a subject of wild speculation. As far as climate change is concerned, "clean coal" technology does nothing for decreasing greenhouse gases. The coal industry is pinning its hopes on undeveloped technologies to scrub carbon dioxide ($CO_2$) from the coal and store it (by underground storage), in efforts to prevent its release into the atmosphere. Expect the powerful coal lobby to continue their campaign to increase coal use. They have been successful on many fronts but have also lost key battles to open new plants. They also are fighting for additional interstate transmission lines to move energy from remote plants to consumers.

There was some controversy in the Obama campaign when vice-presidential candidate Joseph Biden answered an activist's direct question by stating, "No coal plants here in America." The campaign was quick to back off on the statement, fearing the loss of votes in coal-producing states. On this matter, it remains to be seen what the Obama administration will do. An environmental-leaning Congress may make the difference here—with an increase in Democrats and environmentalist legislators well-seated on important committees.

**Transportation.** U.S. automakers and the United Auto Workers have long cited job losses and unwanted additional costs as an excuse for not producing environmentally friendlier vehicles. In reality, no jobs would be lost if they switch production lines to more fuel-efficient and alternative-powered vehicles. In fact, just the opposite happened when U.S. automakers were not ready with hybrid and fuel-efficient vehicles when people demanded them—and they lost business to Japanese automakers that were prepared. Now, U.S. automakers and the UAW are asking the government for billions to make up for their poor planning. In a switch to environmentally friendlier vehicles, there will be additional costs to be passed to consumers, like retooling factories for adding batteries and electric motors for hybrid and plug-in hybrid vehicles—a near-term cost that might as well be undertaken now as later. Hopefully, the government loans that the industry is lobbying for will be tied to retooling for energy-efficient vehicles. Internal combustion vehicles are such a huge greenhouse gas problem that the industry must make changes right away. Transportation accounted for nearly 2 billion metric tons of $CO_2$ in 2006, about a half billion tons greater than $CO_2$ from coal-produced electricity.

On the plus side, the auto industry recently lost one of its most important supporters. In a fight over the powerful House's Committee on Energy and Commerce, Speaker Nancy Pelosi allowed Henry Waxman to take the chairmanship of the committee from veteran Rep. John Dingell. This chair has maintained a position of power for the auto industry, and is key to advancing—or defeating—many other environmental and social issues. Waxman is a progressive leader and has been outspoken about the need to deal with climate change issues. But what this move may also indicate is the level of concern that Pelosi and other leaders have in dealing with environmental issues—especially the reduction of greenhouse gases.

Despite (mostly) promising times, *I* won't make any promises. But at least the stage is set for the next four to eight years' worth of attempts to deal with the all-important issue of human-caused climate change. And, according to many who know more than me, that's about how much time we have to get a good, solid plan in place and implemented.

## Access

Michael Welch (michael.welch@homepower.com) leads a coal- and nuclear-free lifestyle in the Redwood-covered hills of Humboldt County, California.

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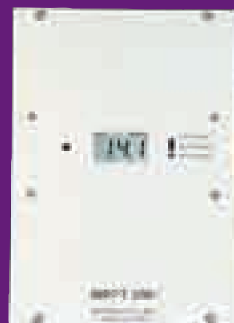

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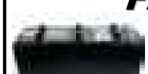

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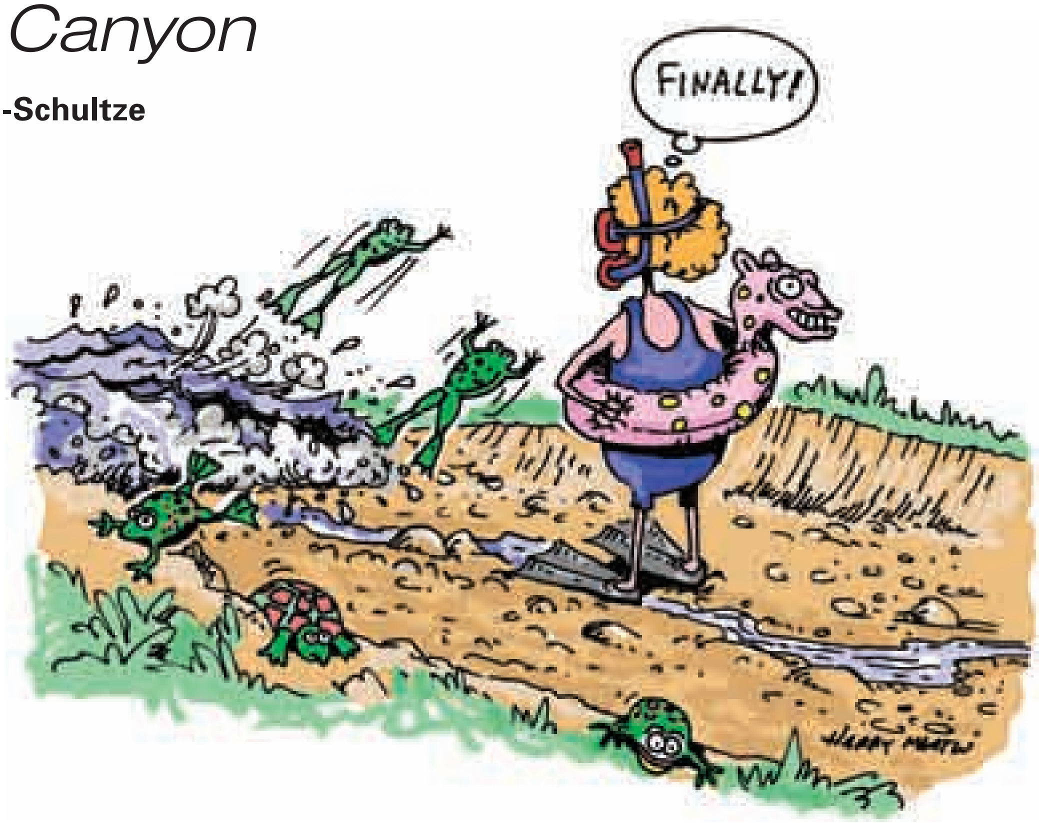
# Up the Creek

## *Down the Canyon*

**by Kathleen Jarschke-Schultze**




Living next to water, you come to know its voices. My husband Bob-O and I used to live next to a river where the song was continuous—it only changed its tune with the increased roar of winter and spring. The last 18 years we have lived next to a seasonal creek, dependent upon its flow for the majority of wintertime power production for our off-grid home.

We live close enough to the creek that we can hear it—when it's running, that is. In the winter, when the mountain at the head of our canyon sheds storm rains or snowmelt, the creek can be big with rushing, brown water—what old miner Teddy Snyderman used to call a "toad strangler." We've had to pull our hydro-electric plant out of the rushing water, and wait for the level and ferocity to recede. We've lost sections of pipe and connections to the creek's storm-driven hydraulic force.

On the flip side of the year, the creek usually dries up. Some seep pools might remain, but not in most years. In the autumn, when the trees lining the creek start to turn orange and yellow, the seep pools get larger. As the trees lose their leaves, the creek starts to flow again, whether we've had rain or not.

Having been anxiously listening for the creek, I rejoice when I first step out on the porch and hear the trickle of running water. I even mark it on the calendar. Along with first rain, first snow, first frost, and such, the calendar also keeps record of how much gasoline we put through our backup generator—only 2.5 gallons since January 2008. If we were able to hold to that through December, it would be a personal best.

### Closing Down

Fall is when our RE power production dwindles. As the days get shorter, our PV array has less time to collect the sun's rays in our small canyon. The weather turns cold with gray skies, but it does not rain and there is not yet enough flow in the creek, so the hydro plant is dormant. Without the sun's warmth to stimulate the thermal flywheel produced by a cold mountain at the head of our canyon and a warm lake 12 miles down-creek, the wind no longer blows steadily every day, and the wind generator's blades are still.

Each year we try to dial back our energy consumption to reduce our fossil fuel use as much as possible, without draining our battery bank too much—so we keep an eye on the creek. As soon as possible, we start the hydro unit with the smallest single nozzle we have. Soon after we hear the creek's first melody, we pick the nozzle, fill the pipe, and begin the at-least daily (often, more) walk up the creek to clean the falling leaves off the hydro intake.

This is not a difficult chore. We use a leaf rake to gather the floating leaves, and sweep them off and past the intake pipe. This year, I made a leaf catcher out of a length of used foam pipe insulation and some old scavenged rope. I strung the rope through the insulation and tied it off to trees on either side of the creek. The foam tube floats at the top of the intake pool and holds back the majority of the leaves. It's easy to clean behind the leaf catcher while cleaning the intake, and my invention appears to be quite effective. Once all the leaves have fallen, I'll remove it.

## Bump Up, Pare Down

This year, Bob-O took down an old tracker with four Mitsubishi 120-watt PV modules on it and put up a brand new tracker with four Evergreen 190s on it. This increased our production by 280 watts, bringing our total PV power capacity to 2,110 W.

Still, when the skies turn gray and the wind is only intermittent, we cannot count on PV energy and the wind turbine for steady power, so we go into a determined conservation mode. When they're not needed, all wall-cube power supplies are unplugged. We limit our appliance and television use. I do all the dishes by hand. We turn on the LED task lights at our desks, while the rest of the house uses compact fluorescents. We always use the timeworn and proven method of one person, one light. If we are in a room at night, the light is on. If we leave that room, we turn off that light and turn on the one in the room we are going to be in. While this may seem overly obvious, it's surprising how much the power savings can add up. Using all these measures and turning off one of our stacked inverters cuts our overnight power consumption by two-thirds.

## Sisyphus, A Screw, Two Washers

In our seemingly never-ending quest to make our ex-cattle ranch cabin more efficient in every way, we recently removed the wood siding on the northwest and southwest sides. Our house is not positioned to the cardinal points; rather it is oriented to the creek's path, so it's not well suited for passive solar gain, and roof-mounted PV modules or SHW collectors would not work well.

*"In the winter, when the mountain at the head of our canyon sheds storm rains or snowmelt, the creek can be big with rushing, brown water—what old miner Teddy Snyderman used to call a 'toad strangler.'"*

Underneath the wood siding, the only insulation (if you could call it that) was a thin layer of Firtex—a stiff, feltlike, wood-fiber material. We removed that and filled the opened walls with fiberglass batts of R-13 insulation, then put the Firtex back into position and covered the whole shebang with a vapor barrier.

The siding we chose was Hardie panels, a cement composite siding with faux wood grain in 4- by 8-foot sheets. Coated with a couple of layers of sage-green paint, it looks great. And we are already noticing the back bedrooms are warmer in the cold weather. The other two sides of the house have some peculiar issues we were not ready to tackle just yet. Soon, though, soon.

Bob-O has always said, "If you don't own a home, you just might have a few coins in your pocket, but if you own a home, your pocket has a screw, two washers, a piece of string or wire, and some plumber's tape." It's like we live in the house of Sisyphus, ever toiling, but never finishing our task.

Despite this, I have to say that there is a very real satisfaction in making our house more efficient. We continue to hone our home and our lives, not only to the betterment of both, but also the Earth.

## Access

**Kathleen Jarschke-Schultze** (kathleen.jarschke-schultze@homepower.com) is using a WWII wool blanket to make a traditional capote at her off-grid home in northernmost California.

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Feb. 16–21 (again Feb. 23–28), '09. Tucson. PV Design & Installation workshop. Hands-on theory, design & installation. Info: See SEI in Colorado listing.

Mar. 6–7, '09. Sustainability & Energy EXP09. Tucson. RE, sustainable construction, water conservation & more. Info: www.tucsonaltenergyexpo.com

## CALIFORNIA

Feb. 18–20, '09. Fontana, CA. Solar hot water workshop. Theory, design & installation. Info: See SEI in Colorado listing.

Feb. 23–27, '09. Fontana, CA. Grid-tied PV workshop. Theory, design & installation. Info: See SEI in Colorado listing.

Jul. 14–16, '09. San Francisco. Intersolar North America. Solar trade exhibition & conference. Market developments & trends, government policies & the latest technology and products. Info: www.intersolar.us

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

Carlsbad, CA. PV installation training for NABCEP certification. Info: www.aptc.edu

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

## COLORADO

Carbondale, CO. Workshops & online courses on PV, water pumping, wind, RE businesses, microhydro, solar hot water, space heating, alternative fuels, straw bale building, green building, women's PV courses & more. Info: Solar Energy Intl. • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

## FLORIDA

Mar. 9–12, '09. West Palm Beach. Green Energy & Climate Conference/Expo. Education & networking for businesses. Info: 561-790-6200 • anitra@palmswest.com

Mar. 28, '09. Marathon, FL. Green Living & Energy Education Expo. Workshops, vendors & speakers on RE, energy efficiency & water conservation. Food & entertainment. Info: GLEE • 305-293-7658 • www.keysglee.com

Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. Info: fleslie@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

## IOWA

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

## MASSACHUSETTS

Mar. 10–12, '09. Boston. BuildingEnergy09. Workshops & sessions on climate change, high-performance buildings, large scale RE, daylighting, net-zero energy, wind & more. Info: www.buildingenergy.nesea.org

May 18–20, '09. Boston. Alternative Energy & Building Efficiency '09. For retailers of RE & building efficiency products. Info: www.alternativeenergyshows.com

Hudson, MA. Workshops: PV, wind & solar thermal. Intro to advanced. Info: The Alternative Energy Store • 877-878-4060 • workshops@altestore.com • http://workshops.altenergystore.com

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## MISSOURI

New Bloomfield, MO. Workshops, monthly energy fairs & other events. Info: Missouri Renewable Energy • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

## MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV, more. Info: Sage Mt. Center • 406-494-9875 • www.sagemountain.org

## NEVADA

Feb. 25–27, '09. Las Vegas. RETECH2009. RE trade show & business conference. Info www.retech2009.com

Mar. 10–12, '09. Las Vegas. RE World Conf. & Expo. Papers, panels & expo for RE businesses on wind, solar, biomass, hydro & more. Info: www.power-gengreen.com

## NEW HAMPSHIRE

Rumney, NH. Green building workshops. Info: D Acres • 603-786-2366 • info@dacres.org • www.dacres.org

## NEW MEXICO

Six NMSEA regional chapters meet monthly, with speakers. Info: NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

## NORTH CAROLINA

Saxapahaw, NC. Solar-powered home workshop. Info: Solar Village Inst. • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

## OREGON

Apr. 28–May 3, '09. Portland. Northwest Solar Expo. Workshops, seminars & exhibits on clean energy. Info: www.nwsolarexpo.com

Jul. 24–26, '09. John Day, OR. SolWest RE Fair. Exhibits, workshops, speakers, music, alternative transportation & Electrathon rally. Info: EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Info: Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

## PENNSYLVANIA

Philadelphia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.net • www.phillysolar.org

## TENNESSEE

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

## TEXAS

Mar. 16–21 (again Mar. 23–28), '09 Austin. PV design & installation workshop. Hands-on theory, design & installation. Info: See SEI in Colorado listing.

El Paso Solar Energy Assoc. Meets 1st Thurs. each month. Info: EPSEA • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston RE Group, quarterly meetings. HREG • hreg@txses.org • www.txses.org/hreg

## UTAH

Mar. 30–Apr. 3, '09. Salt Lake City. Grid-tied PV workshop. Theory, design & installation. Info: See SEI in Colorado listing.

## VERMONT

May 11–16, '09. East Charleston, VT. PV design & installation. Hands-on course, incl. site analysis, design, and a system installation. Info: NorthWoods Stewardship Center • 802-723-6551 x113 • jayson@northwoodscenter.org • www.northwoodscenter.org

## WASHINGTON STATE

Guemes Island, WA. SEI '09 workshops. Mar. 30–Apr. 2: Solar hot water; Apr. 6–11: Wind-electric systems maintenance & repair; Apr. 13–18: Homebuilt wind generators. Info: See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

## WISCONSIN

Jun. 19–21, '09. Custer, WI. RE & Sustainable Living Fair (a.k.a. MREF). Exhibits & workshops on solar, wind, green building, transportation, energy efficiency & more. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: See MREA listing below.

Custer, WI. MREA '09 workshops: Basic, int. & adv. RE; PV site auditor certification test; veg. oil & biodiesel; solar water & space heating; masonry heaters; wind site assessor training & more. Info: 715-592-6595 • info@the-mrea.org • www.the-mrea.org

Amherst, WI. Artha '09 workshops: Intro to Solar Water & Space Heating Systems; Installing a Solar Water Heating System; Living Sustainably & more. Info: 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

# INTERNATIONAL

## AUSTRIA

Feb. 25–27, '09. Wels. World Sustainable Energy Days. Conferences on energy efficiency, green electricity, renewable HVAC & more. Info: www.esv.or.at

## CHINA

Mar. 30–Apr. 1, '09. Shanghai. 4th Asia PV Exhibition. Technical program on PV technology & financing. Info: www.asiasolarexpo.com

May 6–8, '09. Shanghai. Intl. Solar & PV Exhibition and Conf. To strengthen cooperation & exchange between Chinese & intl. markets. Info: www.snec.org.cn

## COSTA RICA

Jan. 31–Feb. 9, '09. Durika. RE for the Developing World. Hands-on workshop. See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

## CUBA

Mar. 8–15, '09. Cuba. RE & Energy Education tour. Meet energy representatives from NGOs, government & educational institutions. Visit RE sites to see that Cuba is a model of sustainable energy development. Info: laurie@solarenergy.org or see SEI in Colorado listing

## HUNGARY

Apr. 16–18, '09. Budapest. REnexpo. Industry conference on RE & EE for central & southeast Europe. Info: www.energy-server.com

## KOREA

Apr. 8–10, '09. Daegu. Int. Green Energy Expo Korea 2009. Conf., seminars, workshops on PV, new products, technologies, policies & market trends. Info: www.energyexpo.co.kr

## MEXICO

Apr. 19–25, '09. Chiapas. Appropriate Technology for the Developing World. Info: See SEI in Colorado listing.


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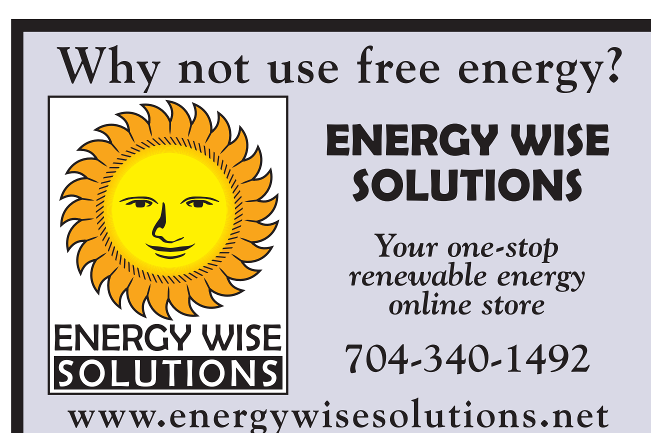
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# Back Page BASICS

# Reading a Battery Monitor

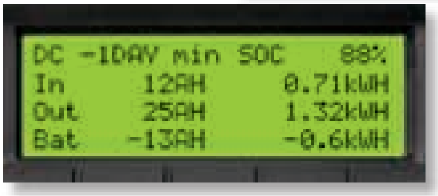
A battery monitor is an important tool in a battery-based renewable energy system. Serving primarily as a "fuel gauge" for your battery, a monitor can also help with system troubleshooting and analysis of energy production and consumption. Equally important as the monitor itself is the ability to interpret the data displayed to maintain battery longevity and trouble-free system operation. The following are common readings displayed on most battery monitors.

## Volts (Example: 24.9 V)

Volts represent the electrical "pressure" or potential within the batteries. It is an instantaneous and constantly changing value that is affected by both charge and discharge. Voltage can be used to help estimate battery state of charge (SOC), though using amp-hours to calculate SOC is more accurate. Voltage can be used as an indicator of battery health. For example, if at-rest voltage is low but the SOC shows full, it's likely that the batteries have lost some capacity.


**Bogart Engineering's TriMetric meter displaying battery voltage.**




**OutBack's FlexNet DC meter allows users to check battery status through a series of displays.**

## Battery % Full (Example: 75.9%)

Also referred to as SOC, "battery % full" keeps track of the net of both energy deposits and withdrawals. This function displays the battery bank balance as a percentage—graphically or numerically—and represents the ratio of energy remaining in the batteries to total battery capacity. For example, a 75.9% reading on an 800 Ah battery bank means there are 607 Ah remaining. Having that much left might provide enough energy to vacuum the house and still keep the bank above the preferred minimum depth of discharge to ensure a long life span for your batteries.

— Khanti Munro


**Xantrex's LinkLite meter, displaying battery state of charge as a percentage and a bar graph.**

## Amps (Example: -1.2 A)

Amps represent the net flow of electrons into and out of the battery bank. Measured by the shunt, this amount is constantly in flux as the battery is charged and discharged. A meter displaying -1.2 A suggests that there is either no incoming charging current and only outgoing discharge current (as shown, above right), or that loads that are on are consuming more power than the output of the charging source. To accurately measure only the charging source or a load, the other variable must be shut off or an additional meter can be used.

## Amp-Hours from Full (Example: -13 Ah)

The amp-hours from full feature (a.k.a. Ah consumed) is essentially the inverse of SOC, keeping track of the net Ah that have been removed from the batteries. If the monitor displays -13 Ah (as shown, above right), you know that your batteries are 13 Ah short of being fully charged.

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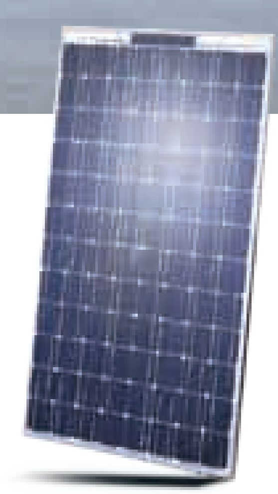

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