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in the Northeast

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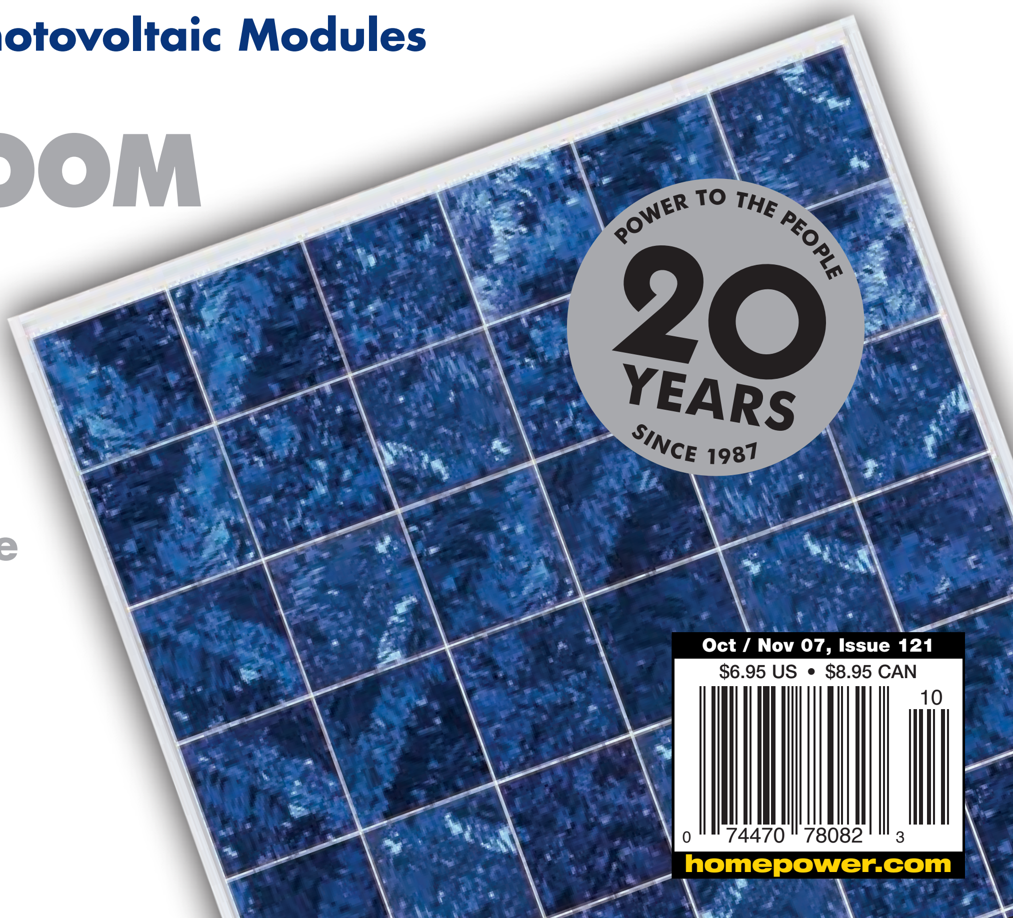

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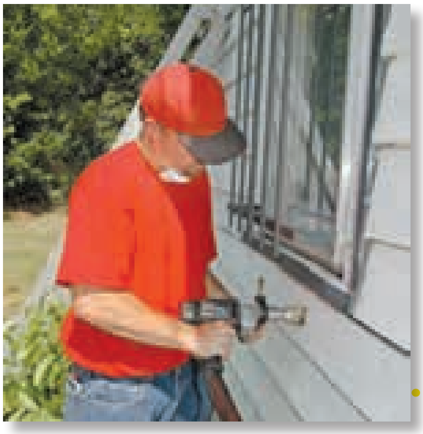
October & November 2007

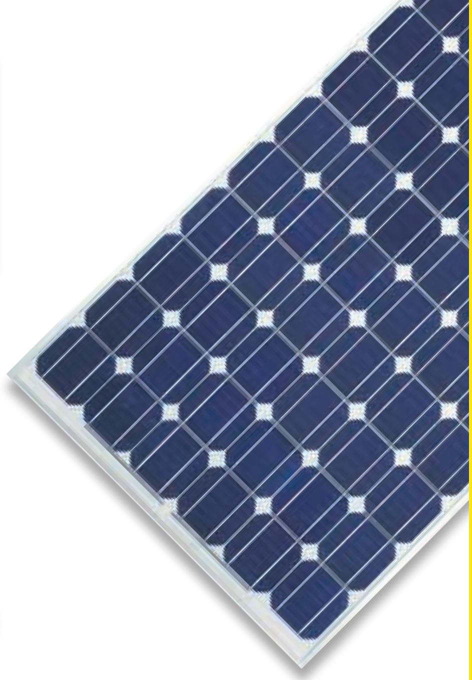


Clockwise from lower left: Courtesy Google.org; courtesy SolarWrights; David Lewis; Richard Hallman; courtesy Solmetric; courtesy Canadian Solar Inc.

On the Cover

Our 2007 PV Buyer's Guide surveys more than 100 solar-electric modules on the market today.

Photos courtesy: Day4Energy; Canadian Solar Inc.; Advent Solar



Regulars

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

from us *to you*

POTENTIAL…

Americans represent 5% of the world's population and consume close to 25% of the global energy supply. You may have heard this statistic a few more times than you've cared to. But instead of assuming this figure is a harbinger of the unavoidable global energy debacle around the corner, I look at it as an opportunity. Then, the questions become: Can we use energy more efficiently and produce more of it with renewables? What resources do we have at our disposal, and how much renewable energy capacity can the grid realistically support?

- In every issue, *Home Power* profiles homes and businesses that consume a *fraction* of the energy required by their inefficient counterparts, while maintaining an equivalent level of comfort and convenience. Using energy intelligently is the foundation of long-term energy security.
- Nations that have implemented well-coordinated programs to increase renewable energy generation have succeeded. In the United States, strong consumer-level support exists for clean energy technologies, and a tangible, bipartisan shift in the collective attitude of our federal representatives is underway.
- Average per capita income in America is among the highest in the world. U.S. consumers and businesses have substantial financial resources, and represent the largest potential market for renewables worldwide. Many countries that already have achieved a high percentage of renewable energy generation have solar and wind resources—and financial resources—that pale in comparison to the United States.
- Variable resources such as the sun and wind account for less than 2% of U.S. electrical generation. In Denmark, wind energy provides more than 20% of the nation's electricity. Since the beginning, American utilities have successfully managed the variable nature of the load side of the grid. There are no insurmountable hurdles to keep them from doing the same on the generation side.

Turning a problem into an opportunity is a learned skill. The energy challenges that face America represent a tremendous opportunity for leadership, technical innovation, job creation, and lifestyles that are comfortable, satisfying, and sustainable.

—Joe Schwartz for the *Home Power* crew

Think About It...

If I were to wish for anything, I should not wish for wealth and power, but for the passionate sense of potential—for the eye which, ever young and ardent, sees the possible. Pleasure disappoints; possibility never.

—Søren Kierkegaard

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Batteryless Hydro

I've heard of large-scale batteryless AC hydro-electric turbines for both on- and off-grid use, but are there any *small* batteryless hydro systems for on-grid applications? Are there batteryless grid-tied inverters that will synchronize a small hydro turbine's output with utility electricity? What does it take to set them up?

James Conklin • Manchester, New Hampshire

Courtesy www.sma-america.com; www.microhydropower.com

Coupling a batteryless inverter with a small hydro turbine in a grid-tied application is definitely doable, but there are some important system design considerations. As with a batteryless inverter using PV for input, you must correctly match the hydro turbine's output voltage to the inverter's input voltage window and maximum DC voltage limit. This can be done with low-head to high-head hydro systems, but is usually easiest with mid- to high-head systems. Low-head hydro systems might require a batteryless inverter with a DC input as low as 48 VDC nominal, which is hard to find these days. For mid- to high-head sites, I usually use an induction turbine configured for high voltage (200–500+ VDC) and 1,200 to 3,600 watts peak output.

The specifics of the turbine are very important, including the diameter of the runner (which affects rpm and voltage), output voltage, and peak output. Unlike a PV system, an important distinction of a hydro system is that it may not be able to handle running without its load. Without protection, this will occur if there is a utility failure, when the batteryless inverter is designed to shut down. In this situation, the rpm of the turbine will increase, and the open circuit voltage (Voc) of the turbine would likely exceed the inverter's maximum DC input voltage and damage the inverter—and possibly the hydro turbine too, due to overspinning.

For high-head situations (200+ feet), having a Voc that is too high for the inverter is a real concern. Fortunately, special diversion loads and controllers are available that will divert the energy fast enough to avoid damaging the inverter, while keeping the turbine electrically loaded. These diversion load/controller combinations are not cheap—they can cost more than $1,500 for 4,000 watts of diversion.

Because these small, batteryless hydro systems are still unusual, I recommend that they be undertaken with the guidance of the turbine and inverter suppliers and manufacturers to ensure optimum performance and reliability.

Jay Peltz • Peltz Power

Peak Sun-Hours

I've read that the Seattle area averages only 3.7 peak sun-hours per day. Maybe that's true in December, but April through October, I'd say it must be more like 10 to 12 hours a day, meaning that the average must be higher than 3.7 hours per day throughout the year. How are peak sun-hours determined?

Jeff Huffman • Brier, Washington

Excellent question! "Peak sun-hours" are not the same as "hours of sunlight." Sunrise to sunset represents hours of sunlight. But peak sun-hours describe how much solar energy is available during a day.

The daily amount of solar radiation striking any location on earth varies from sunrise to sunset due to clouds, the sun's position in the sky, and what's mixed into the atmosphere. Maximum solar radiation occurs at solar noon—the time when the sun is highest in the sky, compared to the rest of the day. Sunlight in the morning and evening does not deliver as much energy to the earth's surface as it does at midday because at low angles more atmosphere filters the sunlight. Besides day-to-day differences, there are also seasonal effects. In midsummer, due to the sun's higher position in the sky, an hour of sunshine packs more energy than the same hour of sunshine in the winter.

(continued on page 16)


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A peak sun-hour is roughly the amount of solar energy striking a 1-square-meter area perpendicular to the sun's location over a 1-hour period straddling solar noon in the summertime. So we can compare apples to apples, the amount of power is standardized at 1,000 watts (1 kilowatt) hitting that 1-square meter surface. By adding up the various amounts of solar irradiation over the course of a day, and counting them as units equivalent to 1 solar-noon midsummer hour (1,000 watts per square meter for 1 hour), we get a useful comparison number—the peak sun-hour.

An analogy might help complete the picture. Imagine that you have to pour sunshine into buckets that are 1 meter square, and each holds 1,000 watt-hours of solar energy. The fastest rate of filling that bucket will occur at solar noon in the summer, when the sunlight is really streaming down. At that time, you could fill a 1,000-watt-hour bucket in 1 hour (1 KWH per hour). At any other time of the day, however, it will take longer than 1 hour to get an equivalent "bucket" of 1 peak sun-hour.

On average, summertime Seattle conditions will net you 4.8 peak sun-hour-equivalents from sunup to sundown. Wintertime sees an average of about 2.5 sun-hours per day. Over the course of a year, the daily average works out to about 3.76 peak sun-hours. For month-by-month solar irradiation information for a variety of cities in the United States, visit http://rredc.nrel.gov/solar/pubs/redbook.

Larry Owens • Shoreline Solar Project

Batteryless or Backup?

I want to install a grid-tied solar-electric system, and I'm having a hard time deciding between a battery-based system and a batteryless system. Can you give me the pros and cons in plain English? Is there any way to have the best of both worlds—the efficiency and economy of a batteryless system paired with the reassurance of always having a reliable source of backup energy?

Joan Beaudet • Milton, Massachusetts

Courtesy www.midnitesolar.com/www.concordebattery.com

Batteryless systems are simpler, more efficient, and less expensive to install and maintain, but during a utility failure, these systems will not provide any electrical backup, even if the sun is shining. A grid-tied, battery-based system is designed to do just that, but uninterruptible power comes at a price. With the same size solar array, a grid-tied, battery-based system will yield about 7% to 10% less energy than its batteryless counterpart. This is primarily due to the inefficiencies involved with battery charging (even when the grid is functioning). And keep in mind that the batteries will need replacement roughly every seven to ten years, which can be a major expense. If you don't experience frequent or long utility failures, you will likely be happier with a batteryless system.

If your grid electricity is unreliable (perhaps you depend on a long rural line in an area that's prone to lightning or ice storms), consider a battery-based system. In battery-based, grid-tied systems, you have to install a separate AC subpanel to separate critical circuits from luxury loads. This ensures that when the system switches to battery backup, the energy stored in the batteries will not be depleted by loads that you can easily live without.

An experienced photovoltaic installer can help you determine which of your electrical appliances can realistically be backed up, and how much battery storage will be required. In almost all cases, it's unrealistic to rely on backup electricity for space or water heating, or for major cooking loads like an electric range, since the energy consumption would be far beyond the capacity of an affordable battery-based photovoltaic system. If your location experiences long utility outages, think about investing in solar heating systems or gas appliances for your heating and cooking needs.

During a utility outage, consider supplying emergency needs with *no* electricity. Store water in a tank. Keep a stack of ice packs in your freezer to increase its holdover period. Keep LED headlamps or flashlights or fluorescent (or gas) lanterns handy. Be ready to ignite your gas stove-top using a spark lighter or matches. Use wood heat, or gas heaters that don't require electricity. If you want battery backup for your computer, Internet connection, radio, or TV, consider purchasing an off-the-shelf uninterruptible power supply (UPS) unit just for that purpose. These preparations will keep you from being overly dependent on electricity when the grid goes down.

Windy Dankoff, founder (retired) • Dankoff Solar Products

Financing Off-Grid Homes

I am writing to you from Vermont where I would like to purchase an off-grid home. I have spoken to a few local banks and have received a lukewarm response to the possibility of taking out a mortgage for a property that is off the grid. How can I find a receptive lender?

Mickel Zuidhoek • Pawlet, Vermont

Courtesy Ed Marue

Financing an off-grid home or property is not entirely different than financing a home in a typical subdivision. There are three major categories that apply to residential real estate financing—income, credit, and collateral.

Collateral is the most important factor in financing an off-grid home, and it is up to an appraiser to address the typical issues and evaluate the property's features for potential underwriters. You'll need to find an appraiser in your area who specializes in out-of-the-ordinary properties, with experience appraising off-grid properties.

Many off-grid homes are near other off-grid homes, which can be used for appraisal comparisons. Have the appraiser prepare an addendum to the property's appraisal that details other nearby off-grid properties and their sales histories. This will help show underwriters that your property is not an anomaly for the area.

Your appraiser will not necessarily be bound by the normal rule of having to use sales comparables within five miles. The lending company Fannie Mae will allow greater distances as long as the appraiser is able to support the necessity for using a sales comparable outside normal guidelines. The appraiser may also search for older sales comparables of off-grid homes to support the value of the home. If you know of any off-grid homes in the area, let the appraiser know—sometimes sales of off-grid homes are private sales and do not show on the multiple listing system, which is how many appraisers find comparables.

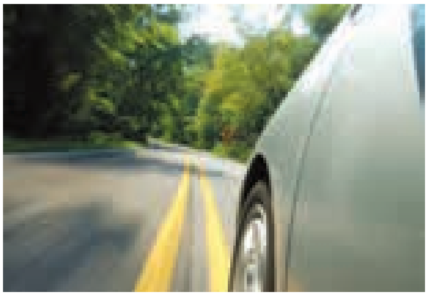
Once an underwriter is able to see how the value of the property is supported with reasonable sales comparables, you will soon be enjoying your off-grid property or home.

Terry Phenicie • First Priority Financial

Wiser Driving

I've heard that the way you drive an electric vehicle (EV) can affect range dramatically. Does the same apply to fuel economy for engine-driven vehicles? Can you give me some basic pointers on how to drive so I use less energy and create less pollution?

James Fallow • Big Pine, California



David Lewis

Many factors affect driving range, but air drag and weight are certainly two of the most important. For an EV moving at less than 30 mph, it's the weight of the vehicle that kills driving range; as speeds increase beyond 35 mph, air drag takes over as the biggest culprit of dragging down fuel economy.

Some idea of air drag's insidious nature can be gained from data for the RAV4 EV—one of the most-studied EVs ever built. At 45 mph, the car can travel almost 150 miles on a single charge; at 60 mph, driving range plummets to about 100 miles (just imagine what happens at 80 mph).

In the case of a conventional internal-combustion-engine (ICE) vehicle, gains in fuel economy are there for the taking—if you're willing to drive at a more leisurely speed. My 1993 Dodge minivan delivers its highest fuel economy—29 mpg—at a constant speed of 45 mph. (For safety reasons, I suggest not driving at this speed on the open highway.) When I dare to keep up with traffic on the Michigan interstate (80+ mph), my minivan's fuel economy drops to about 17 mpg.

Stop-and-go city driving also reduces fuel economy for ICE-based vehicles. This is a consequence of the operating characteristics of typical engines that are designed to operate at higher loads (and, hence, higher driving speeds), and the need for constant acceleration and deceleration. Most hybrid-electric vehicles have circumvented these problems and actually do as well, if not better, in the city as on the highway.

You can improve your city mileage with an ICE-based vehicle if you drive more intelligently. Learn how to coast, rather than braking, into a stop, and time traffic lights so you keep moving at a relatively

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constant speed. These measures will help increase your city fuel economy (as well as increase the time between brake replacements). Likewise, mountain driving offers a number of challenges to fuel economy. Here again, coasting (when possible) and driving slower (when no one is tailing you) will save fuel and reduce pollution.

Another means of saving fuel is to consider carpooling. If you put four people in one car, you'll cut pollution and fuel consumption by about 75 percent compared to four people driving their individual cars. Now that's impressive!

Dominic Crea • Institute for Sustainable Energy & Education

How Tall?

I hear a lot of talk about wind generators needing tall towers. How do I decide what's tall enough? Is there such a thing as too tall?

Jon Powell • Duluth, Minnesota

Although there are several factors that affect tower height, your choice will most likely be a compromise between energy production and economics.

Proper tower height is essential for two reasons: Turbulent wind is not only a poor quality fuel, but it dramatically increases wear and tear on the turbine and tower. To provide the turbine with high quality "fuel," the tower must be tall enough to be well above the turbulence layer created by obstructions such as buildings and vegetation. The wind is stronger up there, and smoother. Ground drag created by obstructions and the ground itself reduces the energy available in the wind. To minimize ground drag, we need altitude. Put simply, wind speed increases with height.

Minimum guidelines for tower height require the turbine rotor to be a minimum of 30 feet higher than obstructions within 500 feet. You should go even taller if the obstructions are young trees that will continue to grow. Finding the average annual wind speed at your site at a given tower height is a bit more difficult, but I would highly recommend trying to determine or at least estimate it, starting with regional wind energy consultants and dealers.

Now for the economics. Once I know the minimum tower height needed to get above the turbulence, I let the turbine and the customer's budget help determine the maximum tower height. I look at the cost of the turbine, its estimated energy production at various tower heights, and the cost of the towers.

The following example uses wind data from my hilltop in western New York, a Bergey Excel-S grid-tie turbine, and three different heights of guyed lattice tower:

Sample Tower Height Economics

Tower Height (Ft.)	Average Wind Speed (MPH)	Production (KWH Per Yr.)	Tower Cost	Annual Energy Value*
80	11.3	9,960	$8,100	$1,793
100	11.9	11,468	9,200	2,064
120	12.6	13,104	10,850	2,359

*At $0.18 per KWH

Why install a $28,000 turbine on a short tower and lose 25% or more of its potential energy production to save $2,750, which is roughly 5% of the overall system cost? Spending that additional $2,750 up front yields an estimated additional 62,880 KWH over a 20-year turbine life span. Here in my neck of the woods, that has a value of $11,318. And that's at our current utility rate of $0.18 per KWH, which I'm pretty sure will increase over time!

A low-cost, small-diameter turbine on a short tower may be a small investment, but it will only yield a small amount of electricity each month. And you won't be any further ahead with a larger turbine installed on a short tower, since you may be sacrificing a large percentage of the turbine's potential energy production, and increasing maintenance costs.

At some point, of course, the law of diminishing returns usually asserts itself and the tower choice becomes clear. And don't forget about zoning or height restrictions, which can be a limiting factor in many areas. Of course, the final factor is the budget for the project. The bottom line for most folks seems to be maximum bang for minimum bucks. So, yes, there is such a thing as too tall a tower, for economic reasons. But other than the money, you'll just keep improving a wind turbine's performance by going higher.

Roy Butler • Four Winds Renewable Energy

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

McMansions

Courtesy Vinod Lobo

I've been an avid reader of *Home Power* for five years. Recently, I heard the derogatory term "McMansion" used on a green blog for the thousandth time. I myself live in what qualifies to some as a McMansion (large subdivision home) in San Diego. Should I feel guilty?

After reading your latest issues, I've found the answer. In our home, we use a gas heater in the early morning for 20 minutes per day (on a timer) about two months each year. We use the air conditioning about five days each year for about two to three hours each day. In one year, our heating and cooling bill is what someone in Montana or Phoenix would likely pay in a week.

Bottom line: We use far less energy in our McMansion than many of the people featured in your magazine. They often have thick jackets on in the photos. Their homes are in either extremely cold places or deserts, and require constant heating or air conditioning. After choosing to live in a very non-green location (from an energy standpoint), they go to extremes to make their living more green, and are then dubbed energy heroes.

It is better to conserve than to generate your way out of large consumption. And the very choice of where we live can be an act of conservation.

By contrast, we coastal southern Californians in our McMansions that people love to judge, just by living here, may end up using less energy at home. Even without solar, wind, or sealing up our houses airtight, we use far less energy per person than those in more severe climates.

Should we feel guilty? Yes, for our swimming pools, SUVs, and hour-long solo commutes to work. But, alas, not for our McMansions. As the magazine writers have said so many times, it is better to conserve than to generate your way out of large consumption. And the very choice of where we live can be an act of conservation. Keep up the great work!

Vinod Lobo • San Diego, California

Courtesy Allan Stellar

Solar Pride

I drove up to our new property last Thursday to take the last walk-through with the former owner and my real estate agent. I got a primer on the solar-electric system, and managed to get the solar-powered well pump working without too much trouble. Greg, the former owner, was gracious enough to let me spend the night in the cabin (and gave me the keys), despite the property not closing until the next day.

So I spent the afternoon playing with the solar-electric system. Turned the lights on. Then off. Then on again. I peeked into the water tank maniacally, watching the slow dribble of water into the tank. I watched with satisfaction as the battery monitor said, "Good," even with the lights on and the pump running.

After an afternoon of playing with the system (can't tell you how much joy it gave me to see it running so perfectly), I drove down to Oroville to get some provisions, called my wife Joni to brag about the solar pumping system actually working, and then drove back up the bumpity 2.2-mile gravel road to the 2.75-acre compound.

I got out my sleeping bag, placed it on the deck, and watched the moon rise. I took it as a good omen that the property was to close on the day of a blue moon. I toasted the moon. Gave a wine offering to the property. Neighbors drove by in their pickup trucks. All of them waved. The neighbor's chickens were quite busy with their clucking. Dogs barked. Generators

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ran. Sound travels well out here. It was a little spooky in the Sierra foothills as night descended, but I slept like a baby on the deck. Woke up to a jackrabbit nibbling on my weeds. "Have at it, fella"—keeps the fire danger down and I won't have to weed-whack it.

In this off-the-grid community, your wealth is measured by the number of solar panels you have, multiplied by the size and flow of your water tank…

Again I played with the solar-electric system. Filled the tank halfway. Battery monitor still said, "Good." Got a drink out of the spigot and washed up with my own solar-pumped water. Kept giggling at my good fortune. Simple pleasure.

Old Bill dropped by. Bill has lived up here for fifteen years. Off the grid with 24 solar-electric modules and a 2,500-gallon water tank. A former Ford factory worker, he proudly stated he raised a family. Had a car. A wife. Children. All supported on his good union job. He sold his house and now is an "off-the-grid, solar Libertarian–Republican." I quickly learned that up here in this off-the-grid community, your wealth is measured by the number of solar panels you have, multiplied by the size and flow of your water tank…

On my way back to Calistoga (in the Napa Valley), I received a message from my real estate agent on my cell phone (which doesn't work at the property). "Congratulations—you now own the property." Called Joni and left a message that all was well. The solar cabin is ours.

Allan Stellar • Concow, California

Wanted: Performance Data

I just read through the twentieth anniversary issue. Such fun, looking at the journey…

Looking at the past prompted me to think of the future. Do you think it is at all likely that you will be doing more equipment reviews? It is nice to read about somebody's personal experiences in setting up a system, especially when it's similar to what I have set up. And seeing that they used some new item that makes the system more efficient is helpful. But those articles, useful as they may be in motivating newbies, do little to help those who are already sold on the idea and need more specific info to aid buying decisions. Or, like me, already have a system and may want to upgrade. We need to know that "X" piece of equipment performs as well as it is advertised, or not. And that among the best-selling brands in a particular category, "A" stands out in one regard and "B" in some other regard...

An example: Several years ago, I decided to upgrade my system, adding 50% to my PV array capacity. I knew I would have to increase the controller capacity over the Trace C-40 I had. So I took a look at MPPT controllers. I was able to get enough information in *Home Power* and elsewhere to determine that this type of controller would increase my system's efficiency. But as to which brand of MPPT controller to use, I found little hard data. Yes, there was some word-of-mouth info, which helped a little. But I needed an outright review with some hard data. I did not find any. I finally selected an OutBack MX60 and have been happy with it. But I may have just been lucky...

Looking at the past prompted me to think of the future: Do you think it is at all likely that you will be doing more equipment reviews?

Much of the new technology I run into comes from the dealers' ads. If it's something I might find useful, I do a Web search for reviews, comparisons, etc., and I usually find very little. And even now, a search for MX60 reviews brings up nothing of substance.

Why am I concerned at this juncture? Well, my system is just over ten years

Renewable energy pro Chris Greacen: Then…and now.

old now. While I don't see any real signs of their coming death, my twelve Trojan L-16 batteries will have to be replaced in the foreseeable future, with the same or perhaps with fewer but larger cells. Also, I don't have a "backup" inverter to my Trace 4024, and supposedly the technology has been improving. At some time I would like to upgrade, while keeping my old inverter as a backup.

What I am saying is that there is a need for hard data on all the various pieces of equipment and, if anyone is in position to provide that data, it is *Home Power.*

John Bertrand • Holualoa, Hawaii

Home Power is ramping up our hardware reviews (see the Solmetric SunEye review on page 88 of this issue), and we're increasing the frequency of our in-depth equipment buyer's guides as well. In addition, we have two additional equipment data collection and review projects in the works. Look for more on this in future issues of *Home Power*, and on www.homepower.com in 2008.

Joe Schwartz • *Home Power*

Overseas RE

It was a pleasure to read the "Clean Energy Pioneers" piece (*HP120*), which hit my mailbox in Bangkok today. I remember helping with a bunch of those articles—seems like yesterday. I was especially tickled to see in your retrospective article a photo of myself as a long-haired 19-year-old in front of the solar oven I built. And now, here I am, twice as old! What a ride!

In a nutshell, here's what I've been up to. In 2004, I finally finished a doctoral degree at UC–Berkeley's Energy and Resources Group, with a dissertation on community microhydro power in

Thailand. In the process, I got diverted by working on various renewable energy projects. Since 2000, I've been living in Bangkok.

In 2003, my wife and I started Palang Thai (www.palangthai.org), an NGO that works to improve conditions for clean, decentralized energy in Thailand and the Mekong region. One success we had was drafting Thailand's net-metering regulations, which are now in place. An upgraded version approved in December 2006 allows RE generators up to 10 megawatts (MW) to net meter and to sell excess electricity at a premium feed-in tariff. More than 280 MW of projects (mostly biomass from sugar cane and rice-husk residues) have been approved under the regulations. Despite some successes, the clean energy community in SE Asia is a tiny minority and for every MW of RE, another 20 or so MW of dirty conventional coal/gas is in the pipeline. In the past few months, nuclear energy is raising its ugly head all over the region, with plans in place in Thailand, Vietnam, and (gasp!) Burma…

Home power technologies and sensibilities are sorely needed over here... We're always looking for talented long-term volunteers! I'm real proud of all that y'all have done over the years. We're now a force to be reckoned with. The forces of light, creativity, logic, and compassion are chipping away at the old, dirty, greasy hegemony.

Chris Greacen • Bangkok, Thailand

Window Tips

I'm about to mention something small but effective. It took me until this year to realize it, after fifty years of solar energy awareness. On sunny autumn, winter, and spring days, when you can use more heat in your home, take off your window screens! Compared to leaving your screens on, it will significantly increase the solar energy input.

Somehow I missed this until I made a PV power meter and checked the output of a module through my new double-pane windows. Then I thought about what would happen to module output through a screen. (PV output is not the same as solar thermal gain, but it reminded me that I'm losing solar potential by leaving my screens on.) And the rest is history, which we need to share, even if everyone says in retrospect, "I know that—it's obvious!"

S. Premena • via e-mail

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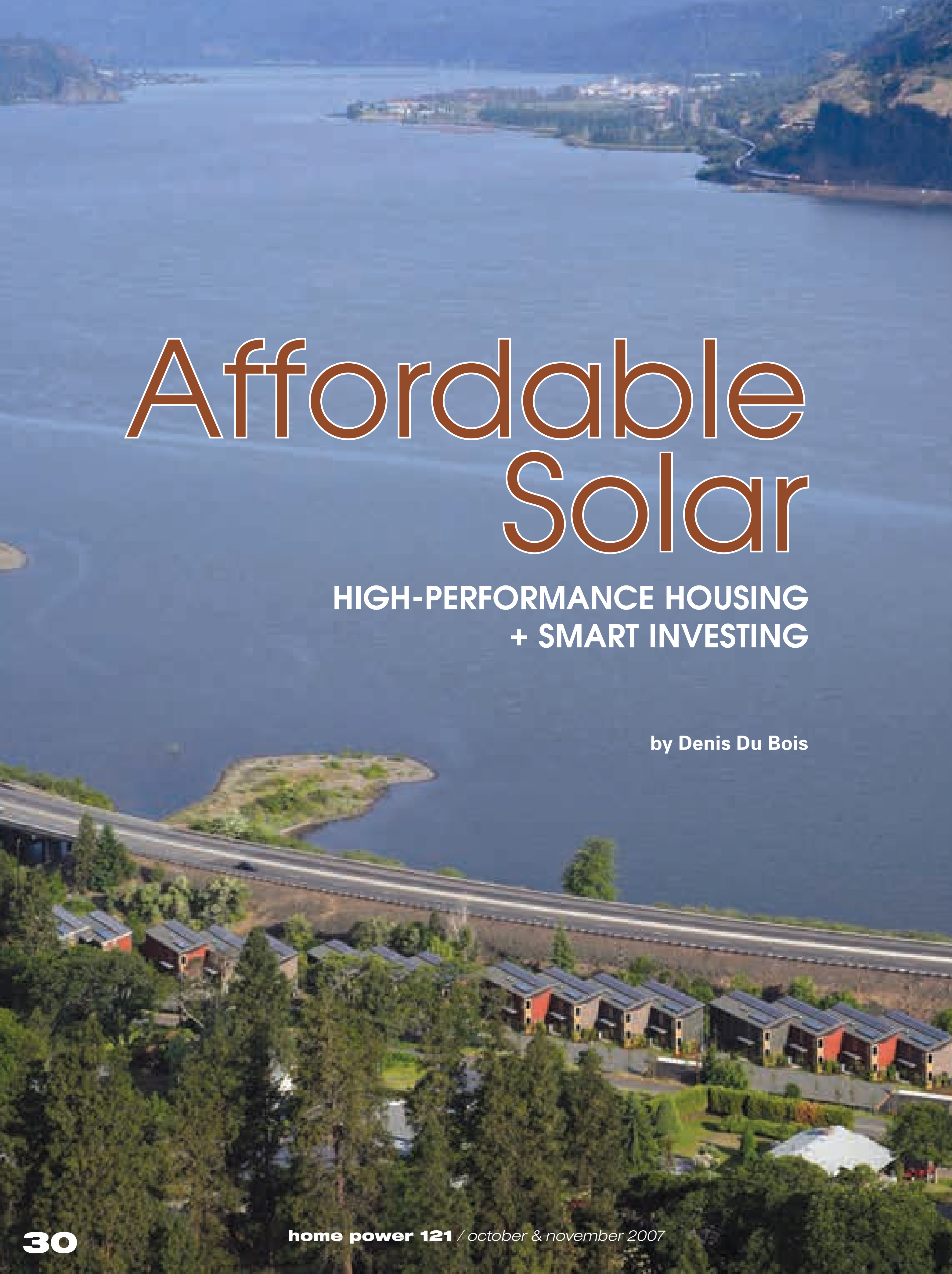


Affordable Solar

HIGH-PERFORMANCE HOUSING + SMART INVESTING

by Denis Du Bois

These modern town houses in northern Oregon are shining examples of building with energy use in mind.

Innovative financing for this Mosier, Oregon, town house development allows investors and homeowners alike to share in the incentives and financial benefits of harnessing solar energy.

Richard Hallman (2)

Would home buyers pay a premium to have renewable energy integrated into their new town homes? Peter Erickson, owner of Urban Fund Inc., a Pacific Northwest development company, was pretty sure of it. "The public is very aware of and concerned about the rising costs of utilities. If a prospective buyer can purchase a home that consumes less energy than a typical home and produce a portion of its own energy," says Erickson, "then it's not a tough business decision."

"The utilities no longer have a monopoly on supplying power. Mosier Creek Solar is doing it, and at lower electric rates."

—Doug Boleyn, Cascade Solar Consulting

So he worked with his architects and a solar consulting firm to integrate photovoltaic and solar hot water systems into his 34-unit development in Mosier, Oregon. After some preliminary number-crunching, he wasn't confident that homeowners would be willing to front the large $28,000 per unit initial expense that the two RE systems would require. But some savvy financial planning saved the day, allowing Erickson to realize his plans to add a strong renewable energy component to high-performance housing.

Making RE a Reality

Erickson tapped into the talents of solar consultant Doug Boleyn of Cascade Solar Consulting, to figure out an attractive financial strategy for incorporating renewables into the development.

In Oregon, financial support for both residential and commercial solar systems is strong. The state offers generous tax credits for both home and business owners of qualifying grid-tied systems, and the nonprofit Energy Trust of Oregon offers additional cash incentives. Adding in federal tax credits for residential and commercial solar energy made the decision to install renewable systems a sound financial move.

Boleyn compared private and commercial solar incentives and laid out two possible scenarios, based on a goal of producing about half of the development's electricity and hot water with solar energy.

One approach was to leverage federal incentives available to private individuals for residential solar installations. Each homeowner would qualify for a maximum $6,000 Oregon state PV tax credit, plus a one-time $2,000 federal solar tax credit. Although this would take care of a chunk of the up-front cost, the combined credits represented less than 30% of the total capital cost of the solar equipment on each home. Plus, Mosier is a vacation destination, with Washington State right across the river. Washington residents who purchased a town house as their second home wouldn't be able to use Oregon's tax credits.

The second option was to arrange for the solar equipment to be commercially owned by a subsidiary of the development company. Business owners of solar installations qualify for much higher incentives than do individuals under both the state and federal programs. With no caps, the state and federal business tax credits have potentially higher value, and businesses can also depreciate the solar equipment, a tax write-off not available to individuals.

In addition to the tax breaks, the Energy Trust of Oregon offers incentives to property developers who install solar-

Richard Hallman (2)

By clustering the 34 residences into eight buildings, Mosier Creek Place devotes half of its 5-acre site to maintaining the existing creek and grasslands.

Large windows admit an abundance of natural light into each townhome's interior, reducing the need for artificial lighting.

electric and solar thermal systems on buildings. The result: The combined business incentives would be enough to offset 70% of the systems' installed costs, a savings Erickson couldn't pass up—and would be able to pass on to the homeowners.

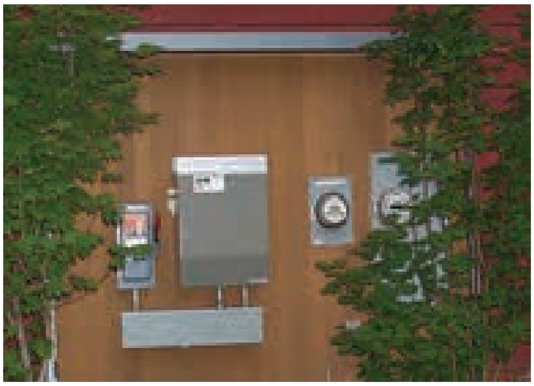
To capitalize on the largest incentives, Erickson formed a subsidiary, Mosier Creek (MC) Solar LLC, to own and operate the systems for a minimum of five years. This third-party investment group bought the solar equipment and took all the utility and tax credit incentives. In addition, they took accelerated depreciation for the improvements over a five-year period.

In effect, MC Solar became its own solar utility, selling the solar electricity generated by the rooftop systems to the homeowners at about 15% less than the local utility's retail rate, a significant savings. Each homeowner has a net-metering agreement with the primary utility (Pacific Power) and can offset with solar up to 100% of their electricity use at the same rate that the utility charges.

The addition of Btu meters would have made it possible to meter the energy produced by the solar water collectors as well, but the investors were satisfied with their return on investment without having to claim the water heating savings. So the

Right: PV modules cover the roofs of this modern town house complex.

Below: PV Powered inverters convert DC electricity from the arrays into typical household AC electricity.



Courtesy Tod LeFevre (2)

approximately 2,500 kilowatt-hours equivalent annual energy from the solar water heating system on each town house is provided to the homeowner at no additional cost.

At the end of five years, homeowners who wish to purchase their rooftop solar systems will be able to buy them at a fraction of their initial cost from MC Solar. Owning the systems will mean that homeowners get low-cost solar energy from their systems, helped by renewable energy credits (green tags) and other available incentives.

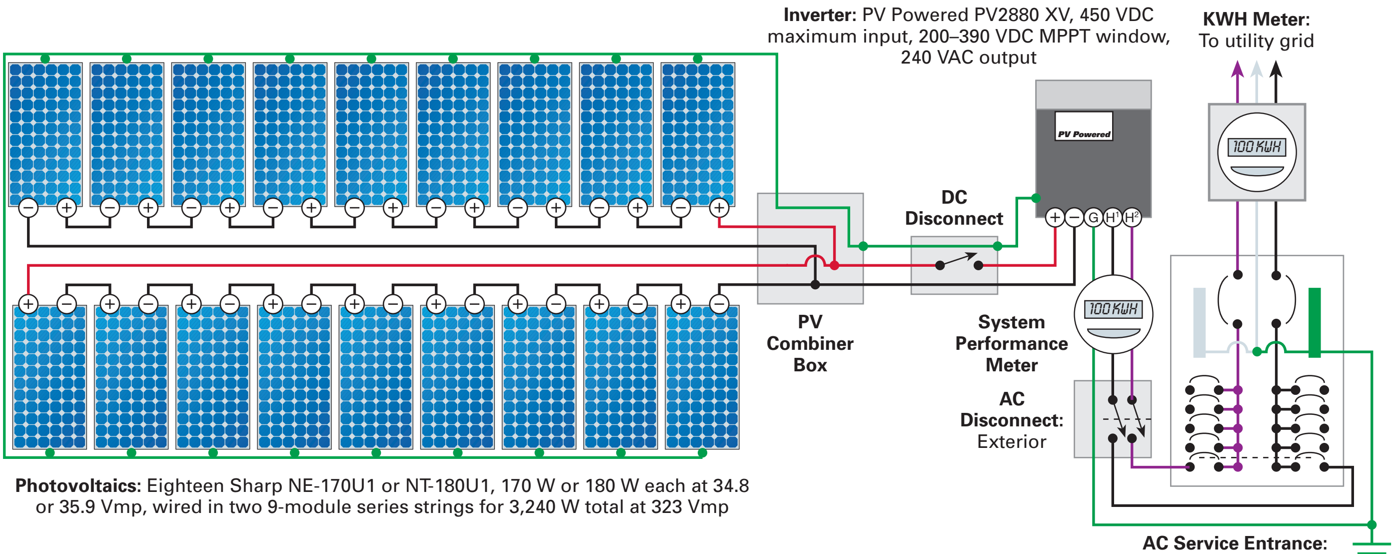
A Model of Success

Erickson and his team, including Cascade Solar, Surround Architecture in Portland, and local green building certification agency Earth Advantage, have broken new ground for renewable energy with Mosier Creek Homes. "This is a first-off model for this sort of arrangement—a developer selling power that's produced right there on the building," says Boleyn. "The utilities no longer have a monopoly on supplying power. Mosier Creek Solar is doing it, and at lower electric rates."

Boleyn says they checked Oregon utility law to make sure that MC Solar would not be considered a public utility and subject to regulation, and acknowledged that the utilities were "quite cooperative in setting everything up, including the net metering agreements."

Erickson is pleased with the outcome and says that high-performance housing offers "distinct marketing advantages

Mosier Creek Homes On-Grid PV System



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

Town House Tech Specs

Location: Mosier, Oregon

Solar resource: 3.9 average daily peak sun-hours

Heating & cooling system: Carrier Performance series, Energy Star-rated heat pump/air conditioning system

Electricity: 3.2 KW grid-tied PV system

Water heating: Solar, with electric backup

Average monthly production, PV system: 366 KWH

Average monthly production, SHW system: 208 KWH

Photovoltaic System Details

Modules: Sharp NE-170U1 or NT-180U1, 170 W or 180 W STC, 34.8 or 35.9 Vmp

Array (per housing unit): Two 9-module series strings, 3,240 W STC total, 323 Vmp

Array installation: UniRac SolarMount, on south-facing roofs, 14-degree tilt

Total PV installed capacity (entire complex): 86.7 KW

Inverters: PV Powered PVP2800 XV, 450 VDC maximum DC input voltage, 200-390 VDC MPPT voltage window, 240 VAC output

Solar Hot Water System

Collector: Sol-Reliant, 56 sq. ft.

Collector installation: Roof mount, south-facing, 14-degree tilt angle

Heat transfer fluid: Propylene glycol

Circulation pump: PV-powered Hartell HEH18

Storage tank: Rheem Solaraide 120-HE/1, 120 gal. (provides SHW storage and backup electric water heating); integrated heat exchanger

that protect the developer in a down-market cycle. In fact, we came online having received our final occupancy permits this past June in the middle of a national slowdown in real estate and have sold ten of our thirty-four units to date."

"The public is very concerned about the rising costs of energy. If a prospective buyer can find a home that is LEED-H certified and produces 50% of its energy needs, then it's an easy decision," says Erickson. "I wouldn't have engaged in the process if it didn't pencil for both us and the home buyer."

Access

Denis Du Bois was hooked on solar energy in 2001 when he installed a PV system at his off-grid summer home. He is CEO of P5 Group Inc., a Seattle firm that helps energy-related companies market successfully. Du Bois founded *Energy Priorities* magazine and hosts the popular "Energy Minute" podcast series.

Cascade Solar Consulting • 503-655-1617 • www.cascadesolar.com • RE planning

(continued on page 37)

Solar Incentives for Better Business

Mosier Creek Solar LLC took advantage of three solar-electric and hot water incentives available to businesses:

- Oregon state tax credit: 35% of system cost, no limit. (This has since been raised to 50%.)
- Federal solar investment tax credit: 30% of system cost, no limit.
- Equipment depreciation: 5-year accelerated.

In addition, the Energy Trust of Oregon kicked in $35,000 (the maximum, per project) through two incentives:

- $1 per watt of rated PV capacity.
- $0.40 per kilowatt-hour of electricity saved for hot water.

The Mosier Creek Homes formula for making PV financially appealing to both developer and buyer:

- Install PV and solar water heating systems on each unit.
- Set up a separate business to own the solar equipment.
- Use business tax incentives and other subsidies to cover as much as 70% of the cost.
- Price the homes at a premium, because of their renewable energy features.
- Sell the solar-generated electricity to the homeowners below retail rates, and let them sell any excess to the utility.
- Consider leasing or selling the equipment to the homeowners, which offers another potential source of profit for developers and investors.

Richard Hallman

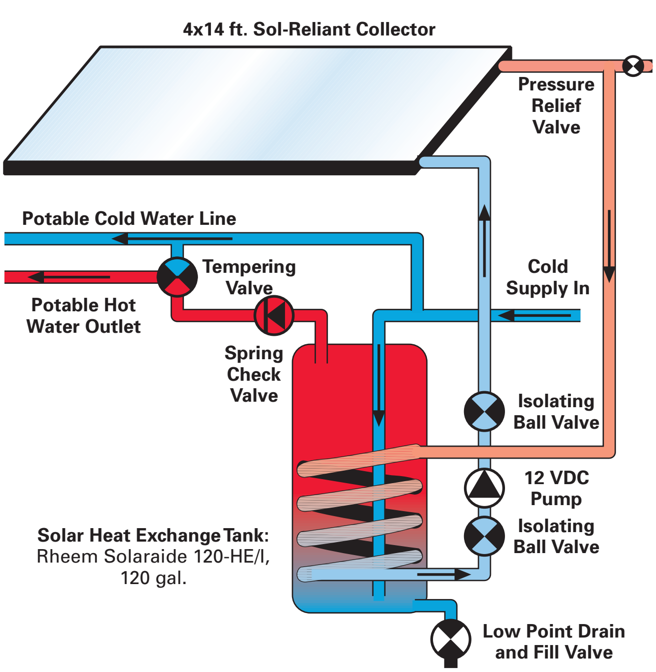
Besides electricity, the sun also provides domestic hot water via solar thermal collectors.

Powerfully Efficient Homes

With an estimated total energy load of 13,560 kilowatt-hours per year for each townhome, the combined output of the 3-kilowatt PV array and a 56-square-foot thermal solar collector is expected to supply a little more than 50% of the residence's energy requirement. Doug Boleyn, consulting engineer for the project, says that's impressive for an all-electric home on Oregon's chilly Columbia River Gorge.

But this shouldn't be surprising, given that the Mosier Creek development was built to the highest energy specification. This LEED-certified project features high-efficiency heat pumps, and Energy Star appliances and lighting. Two-by-six studs framed at 24 inches on center conserve lumber and reduce thermal bridging, and R-21 insulation in walls, R-30 in the floors, R-38 in ceilings, and low-emissivity, high-performance windows throughout help ensure each townhome's excellent thermal performance. The townhomes are sited in an east–west orientation to maximize solar gain. In all, the buildings use 30% less energy than energy-efficient buildings of a decade ago.

Mosier Creek Homes Solar Hot Water System



Single-Tank Solar Hot Water

Manufacturers of the single-tank solar/electric system place a single 240 VAC element about one-third of the way down from the top of the tank. With a 120-gallon tank, this assures at least 40 gallons of standby hot water—even if the sun doesn't shine. The heat in the tall, vertically oriented tank naturally stratifies, with the hottest water at the top. The solar heat exchanger is located in the bottom half of the tank, using the sun's energy to warm the coldest water first.

On a sunny day, the solar gains will exceed the electric element's temperature setting, with solar energy heating the whole tankful of water to 140°F or more. A water heater timer can be used to keep the electric element off during the middle of the day, "prioritizing" solar energy over heating with electricity. (A tempering valve should be installed to ensure that scalding hot, solar-heated water doesn't flow into the hot water service.)

In a single-tank solar-integrated system, solar energy is generally able to achieve temperatures well above the thermostat setting, and the heat lost down to that setting is all solar generated—and all free. The typical standby loss of a two-tank system can be 15 to 20% of the total energy required for the water heating system. In a single tank system, standby losses are about half this amount.

At just under 1,600 square feet, space was at a premium in the two-bedroom townhomes—both inside and on the roof. So the common two-tank solar water heating system—with a solar preheat tank and conventional backup water heater—was abandoned. Instead, a 120-gallon solar tank with built-in heat exchanger and a single upper electric element serves as both the solar preheating tank and backup electric water heater within a single footprint. The tank fits neatly beside the energy-efficient clothes washer and dryer in each townhome's laundry room.

Twenty-eight individual PV systems, with a total installed capacity of 86.7 KW, were installed by Tod LeFevre, P.E., of Hood River, Oregon-based Common Energy LCC. PV Powered inverters, which are manufactured in Bend, Oregon, were specified to synchronize the output of the PV arrays with the utility grid.

On the roof, keeping the solar collectors and PV modules at a low profile was important to the streamlined architecture of the development. The long side-to-side layout of the Sol-Reliant collectors fits nicely with the roof plan and individual PV arrays.

—John Patterson

Common Energy LLC • 541-308-0988 • www.commonenergy.com • PV systems

Mr. Sun Solar • 503-222-2468 • www.mrsunsolar.com • Solar thermal systems

Mosier Creek Homes • www.mosiercreek.com

Surround Architecture • 503-224-6484 • www.surroundinc.com • Architect

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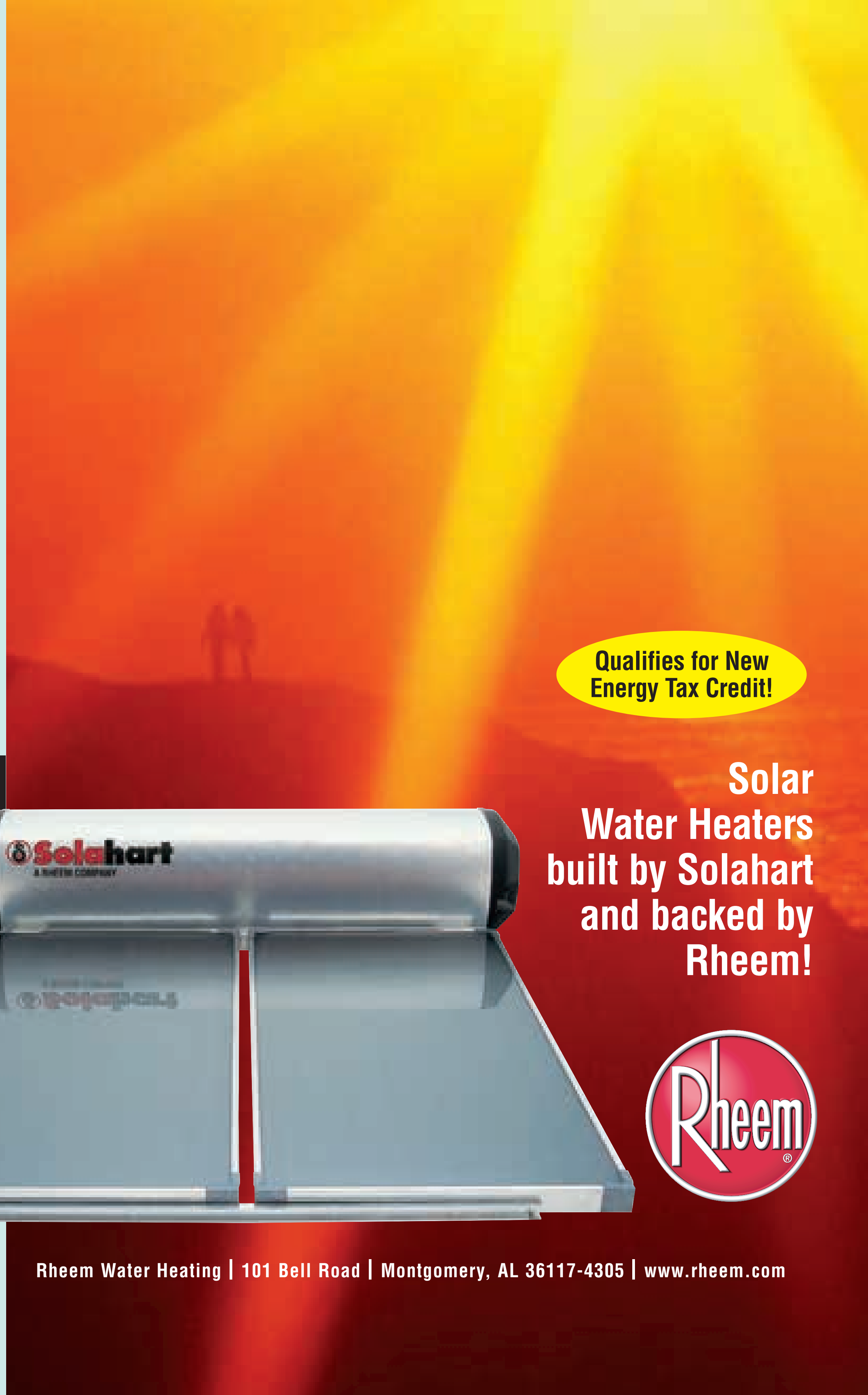

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EFFICIENCY DETAILS

FOR A CLEAN ENERGY CHANGE

If you've been dreaming about lowering your electricity, space or water heating bills, but are daunted by the seemingly high up-front investment in renewable energy equipment, fear no more. Simple, energy-smart strategies can help you reduce both the size and cost of that renewable energy system you've been dreaming about.

by Paul Scheckel

No matter where you live—an uptown loft, a drafty old farmhouse, or a contemporary home—addressing your dwelling's energy efficiency and reducing your household's energy use should be done before you invest in any renewable energy (RE) gear.

You can reduce your use—without giving up modern comforts—by putting technology to work for you. New, energy-efficient appliances and heating equipment, along with advances in building science and awareness of our energy use, allow us to do more in our homes with reduced energy input—the very essence of efficiency. But don't expect technology to do it all. Habits and behaviors greatly influence your energy consumption.

If you're connected to the utility grid, implementing these easy measures translates into lower utility bills. If you're planning an off-grid home, smart appliance and building design choices will both minimize renewable energy equipment costs, and reduce or even eliminate your reliance on a backup engine generator.

INEXPENSIVE ENERGY FIXES

Tip 1: Know Your Loads

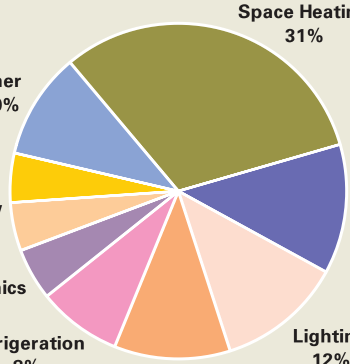
The first step on the renewable path is to get familiar with how much energy your household uses and identify where your energy dollars are going. Take a look at a year's worth of your energy bills. Determine how much energy is used for space and water heating, air conditioning, and other electrical loads.

Depending upon where you live, you may find certain seasonal trends that lead to increased energy consumption. For most of us, space conditioning consumes the most energy and generally warrants the most attention when it comes to efficiency efforts. Water heating is typically the second largest home energy user.

Point-of-use energy monitors allow you to determine which of your appliances are efficient, and which of them aren't. In addition, whole-house electric energy monitors can conveniently report instantaneous and daily kilowatt-hour consumption via a handy display. Both are excellent tools to help put electric use into perspective and will help you track your overall reduction efforts. However, you probably already have a meter provided by the electric company that can also give you useful information (many will display both instantaneous power and total energy)—you just need to read it.

Point-of-use energy monitor.

Typical Household Energy Uses



Courtesy www.eere.energy.gov

Electric appliances also can account for a sizable portion of your overall energy consumption and have a large impact on a renewable electricity system's size and cost. For 120-volt electrical appliances, measuring energy use with a digital power meter, such as the Brand Electronics, Watts Up?, or Kill A Watt, will help you determine actual consumption and prioritize which appliances need to be replaced with more efficient units (see Access).

Tip 2: Adopt RE-Ready Habits

Simply being aware of what appliances are in use, and what needs to be used and when, can help you adjust habits to minimize household energy use. Learn to read your electric meter so that you can see how much power you're using at any given time or how much energy was consumed over a period of time.

The most efficient practices are those that don't require any extra energy input, such as hanging clothes to dry on a clothesline. The next tier of efficiency is to install the most efficient technology and minimize use. For example, wash clothes in a front-loading washer with a high "modified energy factor" rating, dry for only a few minutes (or not at all) in the clothes dryer, and hang until completely dry. Take advantage of passive cooling techniques to minimize or even eliminate the need for air conditioning. In many climates, opening the windows at night and closing windows and shades in the morning to keep the sun out, along with using ceiling or floor fans, can be an effective cooling strategy.

INEXPENSIVE ENERGY FIXES

Tip 3: Take Control

Lowering the thermostat is one sure way to reduce heating costs. On average, you can expect to save about 2% of the energy you use to heat (or cool) your home for every degree you lower (or raise) the temperature setting. Use a programmable thermostat and set it to lower the temperature 10°F when you're sleeping or away from home—or if there's no danger of pipes freezing, you can turn off your furnace completely. (And no, it will not take more energy to reheat the house than you saved by keeping the thermostat turned down.)

Wrap your water heater in an insulating blanket and set the temperature as low as possible. Typically, a 1°F adjustment in your water heater's temperature will result in a 1% change in energy use. You can use a timer to turn an electric water heater off when you don't need it, but you will gain more in efficiency by using conservation strategies such as low-flow showerheads and insulating water heater tank wraps. If you'll be away for more than a few days, simply turn off your water heater entirely.

Timer controls and occupancy sensors work well on lights that tend to get left on, and multiple lighting circuits help put light only where you need it. Switched wall outlets or power strips allow you to turn things off (such as the entire entertainment center or office peripherals) with ease.

Call in the Energy Experts

Expert energy auditors can help you identify the best way to spend your energy improvement dollars. You can find such experts through your state's energy office, the Residential Energy Services Network, or the U.S. EPA's growing Home Performance with Energy Star program (see Access).

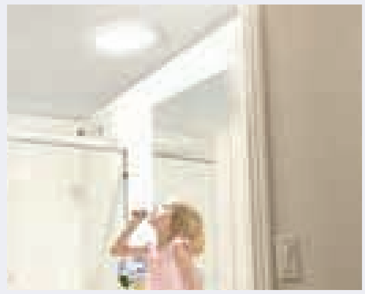
An energy auditor will examine every room in your home, using tools such as an infrared camera to check for insulation voids inside a wall or a "blower door" test to pinpoint air infiltration. A typical audit can take from two to four hours depending upon the tests performed, and auditors may charge a flat rate or by the hour. Always ask what specific tests they will perform, how they charge for services, what the cost will be, and how the results will be presented to you. An average home might save up to 30% on energy costs if all the auditor's recommendations are followed.

GOOD GADGETS & QUICK FIXES

Tip 4: Plug In to Power Strips

A "phantom load" occurs when an appliance that appears to be off still consumes some electricity. Examples include appliances with clocks or indicator lights, remote controls, and plug-in power adapters. Although a few watts of standby energy use per appliance may sound like small potatoes, the combined energy use of these small loads adds up fast. Phantom loads in a typical American household use about 1.2 kilowatt-hours per day—the equivalent of some superefficient off-grid whole-house PV systems! Make efficiency easy to practice by using switched outlets or power strips to control these loads and make the switch on the strip easily accessible.

Tip 5: Bright Lighting



Courtesy Solatube

Wherever you can, replace incandescent bulbs with compact fluorescents (CFs). CFs provide the same level of lighting, at about one-quarter of the energy use of incandescents. Although their up-front cost is higher, their reduced energy use paired with their longevity translates into long-term energy and cost savings. Use compact fluorescent bulbs everywhere except inside your fridge, where the cold temperature, short on-times, and frequent on-and-off cycling will reduce the lifetime of the bulb and offer little savings. In the fridge, remove the 40-watt bulbs it probably came with and replace them with a single 15-watt (or lower) incandescent bulb.

For electricity-free lighting during the day in windowless or dark rooms, consider installing light tubes, which bring in natural light. (Skylights can serve the same function but may also bring in unwanted heat during certain seasons.) In areas where excess heat is not a concern, clear roofing panels can provide a fairly inexpensive solution to provide additional daylighting. My (unheated) garage, porch, and chicken coop each have a few clear roofing panels that really brighten these areas during the day.

gwmullis

Tip 6: Seal Leaks & Deal with Ducts

Similar to appliances and electricity, the tighter your home, the less fuel you'll need to keep it warm. Start by identifying and sealing air leaks, which can be found around chimneys, window frames, the top of the foundation walls where wood meets concrete, and plumbing and electrical chases. Sealing your home against air leaks is the most cost-effective improvement you can make to reduce heating and cooling consumption while increasing your home's comfort.

Unless they are properly designed, sealed against leaks, and well insulated, heating and cooling ducts can account for tremendous energy loss to the unconditioned spaces through which they travel, like attics and basements. If you have forced-air heating or cooling, be sure to seal and insulate ducts everywhere you can.

Tip 7: Go Low-Flow to Save on Heating

In most homes, heating water is second only to space conditioning in energy use. Low-flow showerheads and faucet aerators can help lower your household water consumption and water-heating demand. So can using only cold water for clothes washing and laundering only full loads. If you have a private water system, conserving water will also reduce your pumping energy requirements and the load on your septic system.

Wagner Furlan

INVEST IN ENERGY EFFICIENCY

Tip 8: Improve Insulation

Take a look in your attic. Depending upon your climate, if there is less than 1 foot of insulation, it will be worthwhile to add more. Walls are a bit harder to examine. One trick to inspect wall insulation is to either find or make a small hole in the wall, and then poke a wooden skewer into the hole. By wiggling the skewer, you might be able to pull out a few fibers of insulation. This is also a quick way to determine the depth of the walls and, therefore, the thickness of the insulation.

Insulation won't work well if it's not properly installed. Avoid gaps and compressions, especially around plumbing pipes and electrical wiring, and be sure the insulation material is in contact with all sides of the cavity into which it is installed. The best time to add insulation to walls is when you're making other improvements or renovations. Make sure air leaks are sealed before adding insulation.

David Lewis

Courtesy Pella.com

Tip 9: Get New Views

Replacing older, single-pane windows with new double- or triple-glazed units can save energy if they are installed to include air-leakage control around the frame. However, you can get almost as much savings by adding storm windows as you can with new double-glazed windows, at a fraction of the cost. Again, pay close attention to air-sealing when improving older windows. When it comes time to buy new windows, pay more for more efficient units. Over the long-term, the up-front cost will pay for itself in efficiency gains and reduced energy use.

On Your Way to Renewables

With renewable energy, a little advanced planning can add up to significant savings. Here are two quick tips to get you on the right track:

✔ **Design right.** Whether you're building a new home or remodeling an old one, proper design and planning can offer savings once you're ready to install your RE systems. Orient additions or new buildings to true south and reconsider rooflines and gables that interfere with solar access. Provide an unobstructed south-facing roof surface that allows plenty of solar collection area.

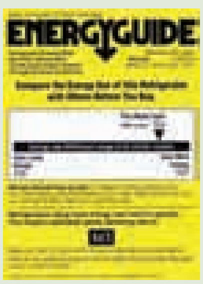
If you're planning to install a PV or SHW system, consider incorporating a chase between the roof and the basement to allow easy access and plenty of space for running cables and insulated plumbing. And don't forget to construct your roof to handle the additional weight of collectors, if necessary. Purchase a long-lasting roofing material too, and then, if you know what equipment you're planning to use, consider pre-installing rack stanchions before the new roof goes on.

✔ **Double up.** If you identify what you want ahead of time, you can piggyback projects with little or no extra cost. When we had some driveway work done, I had the backhoe and crew already on site dig trenches for conduit between my house and a future wind turbine site, as well as for piping between rain collection barrels. It took less than an hour of backhoe time for all that work and now I'm a step ahead on two future projects.

Tip 10: Seek the Star

Energy Star labels indicate a generally high level of efficiency for different classes of appliances, from dishwashers and refrigerators to furnaces and air conditioners. Qualifying products are compared to minimum federal efficiency standards, and savings vary by product. For example, Energy Star-labeled refrigerators must use at least 15% less energy than the current federal maximum allows.

While the Energy Star label helps you instantly identify more efficient products, be sure to compare energy use among labeled products by reviewing the yellow Energy Guide tag and choose the appliance that uses the least amount of energy in its class.



Courtesy www.eere.energy.gov

Access

Paul Scheckel is a senior energy analyst for the Vermont Energy Investment Corporation and author of *The Home Energy Diet* (New Society Publishers, 2005, www.nrgrev.com).

Digital Power Meters:
Brand Electronics • www.brandelectronics.com

Kill A Watt • www.p3international.com

Watts Up? • www.doubleed.com

Energy Efficiency & RE Incentive Information:
Database of State Incentives for Renewables & Efficiency • www.dsireusa.org

Energy Star • www.energystar.gov • Information on household energy efficiency and energy-efficient household appliances

Residential Energy Services Network (RESNET) • www.natresnet.org • Professional home energy raters directory

Tax Incentives Assistance Project (TIAP) • www.energytaxincentives.org

Cashing In on Renewable Energy

Many federal and state tax credits, rebates, and utility incentives are available for residential and commercial renewable energy projects. To better the bottom line and find the best financial fit for your project, here are your best Web bets for discovering—and cashing in on—your own RE returns!

▶ **Estimate Energy Production & Costs.** Before investigating incentives for your project, you'll need an accurate estimate of your energy use and potential savings from RE or from energy-efficient upgrades. FindSolar's "My Solar Estimator" (www.findsolar.com/index.php?page=rightforme) is a handy resource for both home and business owners interested in investing in solar electricity. The online calculator can quickly give you an idea what a photovoltaic (PV), solar hot water, or solar swimming pool system will cost, and estimate the financial and environmental benefits. Plug in your location and some info from your utility bills, and the estimator will display available incentives, and also give a rough estimate of your system's cost and return on investment (ROI).

▶ Unsure how much energy a PV system will generate at your site? Use the PVWatts performance calculator to find out (http://rredc.nrel.gov/solar/codes_algs/PVWATTS). This calculator estimates electricity production based on the peak sun-hours at your location. Arm yourself with this information to ensure that your economic analysis is founded on accurate production figures.

▶ **Tap into Incentives.** Once you get an idea of system sizes and costs, check out your incentive options at the Database of State Incentives for Renewables & Efficiency (www.dsireusa.org), which offers the most comprehensive compilation of federal, state, and utility incentives for RE systems and building efficiency upgrades. Click on your state on the interactive map to find out what's available, or peruse the summary tables to see incentives broken down by category.

▶ If you're thinking about investing in PV, read OnGrid Solar's *Payback and Other Financial Tests for Solar Electric Systems* (www.ongrid.net/papers/PaybackOnSolarSERG.pdf) to acquaint yourself with the nitty-gritty of PV payback, then check with your state's energy office, utilities, or energy commission for any public information or guides. If need be, consult a tax professional to best apply any available incentives. For businesses, the Solar Energy Industries Association's federal tax manual (www.seia.org/manualdownload.php) will help you and your accountant more easily understand and navigate the new federal incentives.


Alex Mathers

▶ **Finance an RE System.** Buying or building an energy-efficient home, or making an existing home more efficient can call for a larger-than-normal initial cash outlay. Fortunately, financing, both through government-insured and conventional loan programs, is now available to support your efforts. In many cases, lenders can approve a larger mortgage payment based on the projected savings on monthly utility bills, or roll the costs of proposed improvements into the mortgage. Use this site to find qualified lenders and a certified home energy rater in your area: www.natresnet.org/consumer.

—Resource recommendations by Andy Black • andy@ongrid.net; written by Erin Moore Bean • erinmoorebean@gmail.com

Solar Success in the Northeast

by Jon Sharp, Ray Furse & Robert Chew

If you're thinking that only Californians and Southwesterners can reap the rewards of solar energy, it's time to think again. Progressive and workable incentive programs, strong net-metering support, increasing utility rates, and ample year-round solar resources are giving home and business owners in several Northeast states plenty of opportunities to plug into affordable renewable energy.

Courtesy SolarWrights

After California and New Jersey—states with longer histories of support for renewable energy—the Northeast has become the third-largest market for photovoltaic systems in the United States. Solar thermal technologies have enjoyed a parallel surge in popularity—in particular, rooftop collectors for domestic hot water or radiant heating.

SolarWrights, our Rhode Island-based renewable energy company with offices in Connecticut, Massachusetts, New York, and Vermont, has seen an annual sales volume increase from less than $100,000 in 2000 to more than $5 million and is experiencing continued rapid expansion. Jim Grundy, president of Elemental Energy in East Montpelier, Vermont, reports, "We've had a five-fold growth in sales since 1999." In New York alone, the number of applications for PV system incentives has increased by a factor of 3.5 during the past three years.

So what's behind the northeastern rush to renewables? Favorable economics, says Jonathan Klein, a consultant specializing in emerging technology trends. Klein says that "solar energy still requires substantial subsidies" to compete with subsidized fossil-fuel generated electricity, and "stretching subsidy dollars means focusing on the customers who require the least amount to make solar power a profitable investment." These customers, he says, are the "small" utility customers—homeowners and small businesses—who end up paying the highest rates for utility electricity.

And in the Northeast, it's these small customers who pay some of the highest retail electricity rates in the nation. Paired with progressive incentives, solar-generated electricity quickly becomes an economically viable energy solution for these customers. In fact, when states are ranked in order of the subsidies required to make solar energy break even with utility electricity costs, six northeastern states—Massachusetts, New Hampshire, New York, Rhode Island, Connecticut, and Maine—appear in the top eight, the other two being California (No. 1) and Nevada (No. 3).

Solar electricity is particularly helpful to the notoriously creaky Northeastern electrical grid. As more and more PV systems are installed, the combined generation capacity will help stabilize the utility infrastructure, and reduce brownouts and blackouts during summertime peak loads.

Tech Trends

Mary and Jack Brennan had eyes for the future when they had a 9.7-kilowatt grid-tied PV system installed at their Guilderland, New York, home. "We strongly believe in preserving the earth for future generations, and 'going green' is a portion of what we can do to help the environment," says Jack. "Plus, our already-high electric rates will probably go even higher…[so] our PV system will reduce the amount of utility electricity we need to purchase and eventually reduce our dollars spent." According to the Energy Information Administration, average retail rates for electricity in New York have risen about 22% in the past four years—from 13.5 to 16.6 cents per kilowatt-hour.

Consumers are experiencing similar trends in other northeastern states. Connecticut Light & Power Company recently requested a 4.6% hike in retail electricity rates starting in 2008—this in a state whose residents have suffered a whopping 90% increase in rates over the past seven years.

Thankfully, these states also have initiated renewable energy goals—of which solar comprises a varying share—as well as differing funding solutions, paperwork, and procedures for installation oversight. SolarWright's founder Robert Chew, who has both written and advised on subsidy program legislation, feels that Connecticut's incentive program for photovoltaics is a good model for the Northeast. Its performance-based approach takes into account the PTC (PV USA test conditions) rating of modules and inverter efficiency, which better reflects real-world PV system production.

By requiring that approved PV installation professionals install systems that are receiving financial incentives, the Connecticut Clean Energy Fund is balancing the necessary increase in installation capacity to handle this fast-growing market with maintaining high installation standards. In

Solar Energy in Any State

How will solar work for you and what might the payback be? Before calling an installer, you can get some preliminary information using one of several online calculators. (See "Cashing In on Renewable Energy" on page 48 for Web site resources.)

Consumers are advised to independently research the support that is available in their own state and to keep that in mind when discussing energy solutions with contractors. For the most up-to-date information about RE incentives, visit www.dsireusa.org.

PV System Comparison: New York vs. California

Area	PV System Size (KWp)	AC Output (KWH Per Year)	Average Utility Rate ($ Per KWH)	Electricity Value ($ Per Year)
Capitol region of New York	5.0	5,839	$0.159	$930
Southern California	3.9	5,839	$0.140	$817
Ratio of CA : NY	78.0%	100.0%	87.9%	87.8%

The system size advantage goes to the smaller system in California, but the energy value in dollars is greater in New York, making the point that solar electricity is not only effective in the sunniest parts of the United States, but also in the Northeast due to high retail electricity rates.

Rhode Island, the utility National Grid has worked closely with industry leaders to develop a streamlined and effective interconnection application process that may also serve as a valuable model.

Solar Support

It hasn't escaped the notice of savvy politicians that solar technology is simply good business: It is one of the most labor-intensive fields in the energy industry, and is on track to create more than 30,000 new jobs in the United States by 2015. These are not low-wage temporary positions, but quality careers in manufacturing, engineering, and installation. According to a Solar Energy Industries Association report, "each megawatt of installed systems supports 32 jobs, a quarter of which are local installation and sales positions."

The success that solar is seeing in the Northeast should put to rest any doubts about its effectiveness and value. The region receives more sunshine than Germany, which boasts the most installed PV of any country in recent years. Solar installers and energy professionals agree that, unlike the "boom and bust" environment created by quickly established—and quickly snuffed—subsidy programs in the '70s and '80s, interest and investment in renewable energy is here to stay.

Although occasional predictions of "breakthroughs" in module efficiency appear in the press regularly, it is unlikely that this will result in significantly decreased consumer prices in the near term. More likely, increased manufacturing capacity will bring down the price of tried-and-true silicon-based modules. Many industry experts are forecasting continued equipment-cost reductions in the years ahead. As the installed cost per watt of PV declines, financial incentives will likely be scaled back and ultimately eliminated. But that is not necessarily a bad thing: It would simply mean that solar technology is finally coming into its own as an economically viable, clean energy choice.

RE on the East Coast

Owner Name: Robert & Lisbeth Chew
Location: Bristol, Rhode Island
Average Peak Sun-Hours: 4.46
System Type: Grid-tied PV
System Size: 4 KW
Average Annual Production: 4,960 KWH

To respect the traditional aesthetics of their historic neighborhood, Lisbeth and Bob Chew installed an unobtrusive rooftop PV system that followed their home's roof lines.

Although this hundred-year-old home in Bristol is not governed by the stricter rules of the historical district that begins one block to the west, its new owners wanted to respect traditional aesthetics while installing a modern PV system. The steep pitch of the south-facing roof threatened to make a typical PV installation stand out, so careful array design and module selection was key. The Chews opted for a rectangular design that followed the home's roof lines, and chose SunPower SPR-200 modules, with their less obtrusive flat-black appearance.

Twenty modules feed into two SunPower SPR-2000 inverters. During its first twelve months of operation, the system produced just over 4,960 kilowatt-hours. This has delighted Robert and Lisbeth, as it has effectively freed them from paying a monthly utility bill. Rhode Island's net-metering regulation zeros out excess PV production annually, which means the Chews can build up credits during the sunnier months, and then use them in the winter. The Chews say the array has the added benefit of shading the roof, making their upstairs office cooler in the summer, reducing the use of a window-mounted air conditioner and further decreasing their need for electricity.

Owner Name: Pine Point School
Location: Stonington, Connecticut
Average Peak Sun-Hours: 4.46
System Type: Grid-tied PV
System Size: 72.6 KW
Average Annual Production: 80,000 KWH

At Pine Point School, children learn the *four* R's: reading, 'riting, 'rithmetic—and renewables—with a 72.6-kilowatt rooftop solar-electric array that provides 40% of the school's electricity needs. The system was funded in part through a special grant from Connecticut's On-Site Renewable Energy Generation program, with the balance of costs funded through the solar developer. The school purchases the solar electricity at a reduced rate through a green power purchase agreement with the system owner.

Under this agreement, common for large commercial projects, the system developer owns the PV system and sells renewable energy to the host at a reduced rate, adjusted annually depending on the cost of electricity provided by the local utility. This allows Pine Point School to avoid budgeting the large cost of purchasing the system. As retail rates for utility electricity continue to climb, the school will benefit by having reduced its grid usage.

"This is the first small-scale project in Connecticut to incorporate a creative power purchase agreement between the system developer and the host site," says Lise Dondy, chief operating director of the Connecticut Clean Energy Fund.

Courtesy John Koulbanis, SunPublishing Co. (2)

Pine Point students are proud of their solar-electric school.

"Pine Point wants to reduce its carbon footprint," says Pine Point head of school Paul Geise. "In doing so, it hopes to serve as a model for other schools in Connecticut and throughout the country. There's no doubt that in the last year there has been a sea of change in the public's perception of the environment, most notably regarding the topic of global warming. Pine Point is committed to being a good steward of the environment, both institutionally and through its work with students. That spirit and commitment have been most tangibly demonstrated with the installation of a photovoltaic system that will supply well over a third of the school's electricity."

Owner Name: Mark & Lisa Nelson
Location: Westerly, Rhode Island
Average Peak Sun-Hours: 4.64
System: Evacuated tube solar hot water
System Size: Viessman V300, 30-tube collector
Average Annual Production: 9.0 MBtu (2,638 KWH)

Courtesy SolarWrights (4)

Homeowners Lisa and Mark Nelson installed a Viessman collector on their home's rooftop to provide hot water for their household.

The Nelsons chose a solar hot water system to offset their use of an oil-fueled boiler that provides both space heating and domestic water heating. With two children and frequent guests, their boiler was running much of the time, which was especially annoying in the summer months. By switching to a solar hot water system, the boiler rarely needs to run to heat water for their household.

The Nelsons' roof, which faces 40 degrees west of true south, offered a particular design challenge for a typical flat-plate solar hot water system. Finally, it was decided that an evacuated tube system would be a better match because it is easier to rotate the tubes toward the south for maximum solar exposure. A 20-watt PV module powers the system's circulation pump. Because of this, the system can continue to function in the event of power outages. At 80 gallons of 120°F water per day, their hot water use is a bit higher than the 62 gallons typically used by a family of four. But the effect of installing the system has been that they rarely rely on using their oil-fueled boiler in the summer—the system provides about 70% of their yearly hot water needs.

Owner Name: Cheryl Wheeler & Cathleen Joyce
Location: Swansea, Massachusetts
Average Peak Sun-Hours: 4.51
System: Solar pool heater
System Size: 9 Aquatherm 1500, 4 x 8 ft. collectors
Average Daily Production: 0.2 MBtu per day during summer (58.6 KWH)

Courtesy SolarWrights (3)

Cathleen Joyce and Cheryl Wheeler enjoy sunny days for more than just one reason: a solar pool heating system (above) extends their swimming season and a solar hot water system (below right) heats household water.

Installing in the Northeast

PV and solar thermal system siting, design, and performance issues in the Northeast can vary greatly by location, as the terrain includes coastal plains in the east, and the Appalachian range and foothills in the west. PV mount design should take into account high coastal winds and special wind regions: canyons through which wind may be funneled at high speeds, and the upper reaches of isolated hills and ridges.

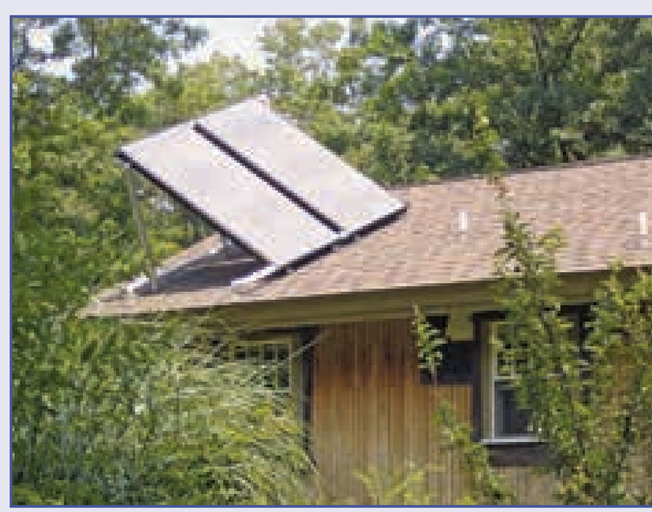
Heavy snow loads typical in higher altitudes or caused by lake-effect snows will require consideration. Roof-mounted systems installed at very low tilt angles may need to be hand-cleared, or will suffer decreased output until the snow melts. In snowy regions, pole-mounted systems should be designed to keep the lowest modules out of the snow.

As with other structures, ground-mounted systems must take into consideration the depth of the frost lines to avoid frost heave. And the subsoil rocky ledge of western New England may require "pinning" or other special installation methods for pole and ground mounts.

Finally, all PV systems must use durable materials that can withstand the elements for 25 years or more, especially the corrosive effects of salt air near the coast. Your local installers and the manufacturers of system components are excellent resources for dealing with special considerations in your climate.

When folk singer Cheryl Wheeler and her partner Cathleen Joyce built an in-ground saltwater swimming pool, they wanted to heat it with solar energy and extend their swimming season. But they had already filled the south roof of their barn with a 4-kilowatt PV array, and no other south-facing roof space was available. That called for innovative problem-solving from the installers. The barn's shallow-pitched north-facing roof offered a solution. The unglazed collectors were mounted at a low pitch on the roof, and still produce a significant amount of hot water for pool heating. The pool's filter pump circulates pool water to the collectors, where it is heated before its return trip to the pool.

Over the years, Cheryl and Cathleen have become strong proponents of renewable energy and often promote its concepts to concert audiences. At home, both walk the walk by driving Toyota Priuses, and relying on a PV array for electricity and a solar thermal system for water heating. Cathleen says that "the pool heating system has met all of our goals," with the pool easily reaching the preset temperature of 88°F on sunny days. Although the temperature drops on cool mornings after the cover is taken off, water coming from the collectors arrives 8°F to 10°F hotter than when it leaves the pool, allowing them to extend the swimming season by eight to twelve weeks each year.



Jon Sharp and **Ray Furse** are regional managers for SolarWrights, in Saratoga Springs, New York, and Litchfield, Connecticut, respectively. **Robert Chew** is the founder and president of their employee-owned RE firm, based in Bristol, Rhode Island.

plug-in

HYBRIDS

Courtesy General Motors Corp.

Fueling the Future

by Sherry Boschert

Last summer, Google.org (the philanthropic arm of the Internet giant) launched a plug-in hybrid car project and Web site called RechargeIT.org, proclaiming, "Recharge your car. Recharge the grid. Recharge the planet." It could just as well have added, "Recharge your home."

Plug-in cars, some that rely solely on electricity and some that marry an electric motor with a gasoline motor for better mileage and fewer emissions (plug-in hybrid-electric vehicles or PHEVs), are slowly making their way into the mainstream.

And it's not just because they replace most or all of the gasoline used to fuel the typical car with cleaner, cheaper, domestic electricity. The ability of electricity to flow into a car's batteries and also to be pulled back out and returned to the electrical grid has caught the imagination of consumers and environmentalists alike. That return trip—commonly called vehicle-to-grid (V2G) technology—could power some of a home's electrical appliances during a grid outage, or could be used by the electrical grid in ways that will increase the storage of and our access to clean, renewable energy.

An Electric Evolution

The story of plug-in hybrids has been unfolding within the past two decades or so, beginning with the battle over modern all-electric vehicles (EVs). General Motors unveiled an electric car in 1990, inspiring California's clean-air regulators to demand that all the major car companies start producing zero-emission vehicles. Thousands of leased electric cars hit the roads, but a weakening of the clean-air mandate in 2003 allowed automakers to cancel the leases and destroy the cars, as documented in the 2006 film, *Who Killed the Electric Car?*

EVs are powered solely by an electric motor and a large bank of batteries—not by a gasoline engine. When the driver steps on the accelerator pedal, a controller sends electricity from the batteries to the motor, making the vehicle move. Regenerative braking systems use the electric motor to convert some of the car's kinetic energy into electricity that gets fed back into the batteries as the vehicle slows down.

The plug is the best thing—and the worst thing—about EVs: On one hand, you *get* to plug them in (which is generally a cheaper and lower-emissions source of energy than gasoline), and on the other hand you *have* to plug them in to recharge their batteries after 30 to 200 miles of driving, depending on the car, driving conditions, and the battery type and size.

While the car companies were making EVs, they also began building hybrid gas-electric vehicles like the Toyota Prius,

Opposite: General Motors' concept plug-in hybrid electric vehicle, the Chevrolet Volt.

Honda Civic, and the Ford Escape. Hybrids are gasoline-dependent vehicles with internal combustion engines that also have an electric motor and a small bank of batteries. The electric-drive components work with the engine, providing boosts of power or increasing the overall fuel efficiency of the vehicle. The most popular hybrid, the Toyota Prius, typically gets 45 to 55 miles per gallon.

Hybrids on the market today aren't designed to be plugged in. Instead they use the gas engine and, to a much lesser degree, the drive motor via regenerative braking, to recharge the batteries. Depending on a hybrid's design, the gasoline engine may shut down when the electric motor can meet propulsion needs—saving energy and reducing emissions—and automatically restarts when more power is demanded. The fuel efficiency of hybrids depends on whether they are "full" hybrids that include all the hybrid features, or "hollow" hybrids that claim the name but incorporate minimal features, such as stopping the engine while idling but not using regenerative braking. Hollow hybrids may add merely 1 mpg in efficiency, and are often more about increased power than increased fuel efficiency.

Plug-In Promises

People are realizing that hybrids can be improved by adding more batteries and an AC charger that can be plugged into the grid. With overnight grid charging, a plug-in hybrid like the Prius can travel 100 miles on 1 gallon of gasoline and about 33 kilowatt-hours (KWH) of electricity. And PHEV drivers still don't need to think about finding someplace to recharge the car if they want to drive long distances. If the owner forgets to plug in overnight, it's no big deal—a plug-in hybrid then operates just like a conventional hybrid.

Plug-In Pioneers

A few dozen Prius owners, eager for the benefits that plug-in hybrids offer and tired of waiting for auto manufacturers to produce them, have converted their hybrids into PHEVs, even though the modifications may void parts of the cars' warranties. Felix Kramer of Redwood City, California, did it. So did Ryan Fulcher of Seattle, Todd Dore of Chicago, and Ron Gremban of Corte Madera, California, among others. Google's RechargeIT.org site shows a map of vehicles that have been converted to PHEVs, and they are popping up all over the country.

These plug-in pioneers modified their cars for more than their own benefit. They did it to make a point: If they could make a plug-in hybrid, the major car companies could too—and should.

Kramer, Gremban, and a cadre of volunteers formed the California Cars Initiative (CalCars.org) and in 2004 converted Gremban's Prius to a plug-in hybrid, doing the work in his garage. They added inexpensive lead-acid batteries and some innovative software to fool the car's computerized controls into using more of the energy stored in the batteries instead of using the engine, dramatically increasing fuel efficiency. Several small companies like EnergyCS in Southern California and Hymotion in Canada have started doing small numbers of conversions for fleets and government agencies, using longer-lasting, more energy-dense lithium-ion batteries.

Kramer hired EnergyCS to convert his Prius as a test case, and has reported on a typical day traveling 51 miles, mostly on the highway. At fuel efficiencies of 1 gallon of gasoline and 15.3 KWH of electricity expended to travel 124 miles (the equivalent of about two to four cents per mile for electricity, depending on local retail rates), his plug-in hybrid used 61% less gasoline and cut the vehicle's greenhouse emissions in half. The total fuel cost? $1.76 instead of the $3.17 the car would have required on gasoline alone.

CalCars.org and the national Electric Auto Association have created an open-source "Wiki" Web site with instructions for do-it-yourselfers who want to convert their own hybrids to plug-ins. They hope to put together a video and eventually sell a package of components for individuals wanting to convert their hybrids. (See www.eaa-phev.org.)

CalCars founder Felix Kramer's Prius, converted by EnergyCS, was one of the first consumer-owned PHEVs to hit the road.

Courtesy CalCars.org

Courtesy Google.org

Larry Brilliant, Google.org executive director, recharges the RechargeIT car.

Improved Efficiency. At an average fuel efficiency of 20 mpg, a conventional gasoline car needs 5 gallons of gas to travel 100 miles. The Toyota Prius hybrid needs about 2 gallons to go that distance. In comparison, Toyota's RAV4-EV all-electric SUV goes 30% farther—about 130 miles—on the energy equivalent of just 1 gallon of gasoline (34 KWH). That's half the energy required by a conventional Prius hybrid and one-fifth of the energy required by a standard gas-engine car. So how do PHEVs pencil out?

Using the average price for residential off-peak electricity in the United States—about 8 cents per KWH—the equivalent of 1 gallon of gasoline in energy (34 KWH) costs $2.72. Assuming that amount of electric energy can move a car at least 110 miles, driving on electricity costs about 2 cents per mile. In comparison, for a conventional hybrid that gets 50 mpg on gasoline costing $3 per gallon, each mile in a hybrid costs 6 cents—more than double the cost of fueling with electricity.

Terry Penney, manager of the National Renewable Energy Laboratory's (NREL) FreedomCAR program, compared the costs associated with electricity rates and gasoline prices for a plug-in hybrid with enough batteries for a mere 10-mile all-electric range. He found that in 45 out of 50 states (all but the few states with the highest electricity rates), driving a plug-in hybrid would put money in the driver's pocket: The fuel savings would more than offset a plug-in hybrid's slightly higher projected sales price.

Cash-Back Cars. With vehicle-to-grid technology, a plug-in hybrid can become a "cash-back hybrid," a term coined by Jon Wellinghoff, Federal Energy Regulatory Commission member. According to Wellinghoff, some electrical utilities and power aggregation companies have already expressed interest in the idea of contracting with plug-in hybrid owners to get occasional access to the electricity stored in their vehicles' batteries. V2G on plug-in hybrids is likely to be used to supply electricity for what's called "spinning reserves," for times when it is difficult for the utilities to meet the instantaneous demand of the grid. They could also be used to shave peak loads by some individual V2G utility customers. That, says Wellinghoff, would make dollars and sense for a plug-in hybrid owner, especially if the owner also had a V2G contract. Wellinghoff says that, in the future, plug-in hybrid owners could conceivably make *profits* of $400 for spinning reserve V2G contracts and $2,700 per year for regulation contracts. The owner's contract would specify how much energy may be drawn from the car's batteries. For example, they could specify that their vehicle must retain at least 50% of its battery charge.

Reduced Pollution. While electric utilities are waking up to the possibilities of plug-in hybrids, some environmentalists are concerned about an increase in power plant pollution if everyone starts plugging in their cars. Most electricity in the United States is still generated by fossil-fueled (read: polluting) power plants and adding cars to the grid's loads would increase electricity demands.

The data on plug-in hybrids, however, has calmed most environmentalists' fears. Even plugged into the U.S. electrical grid, which gets more than half of its energy from coal, plug-in hybrids would produce 42% less carbon dioxide, and reduce emissions of other greenhouse gases and pollutants when compared to conventional fossil-fueled cars, according to NREL.

As more wind and solar generation is added to the grid mix, driving with grid electricity becomes cleaner still. Plug-in cars are synergistic with renewable energy, and V2G expands that synergy. For example, in many locations the wind blows mostly at night, when few people are awake to make use of wind energy. In fact, it's estimated that there's more than enough of an untapped wind resource in the United States to meet all current U.S. electrical needs, but there's no place to store that wind energy during times of off-peak demand. However, nighttime is when people usually plug in to recharge their EV batteries, and the batteries could serve as distributed storage for that additional wind energy. The U.S. Department of Energy estimates that plug-in electric vehicles with V2G technology could increase America's access to wind energy by a factor of three. And owners of off-grid RE-powered homes, which store renewable energy in batteries, could be driving cars that run partially on their surplus homemade renewable electricity and use the vehicle battery as further reserve capacity.

A Japanese Web site created in 2005 prominently showcases another important possibility of plug-in hybrid vehicles—providing a source of emergency backup electricity

Better Batteries?

Although car companies say they're waiting for better battery technology before they mass-market plug-in hybrids, that doesn't sit well with drivers like Marc Geller of San Francisco, a PV systems salesman who co-founded the nonprofit group Plug In America. The nickel-metal hydride (NiMH) batteries in Geller's all-electric 2002 Toyota RAV4-EV give the compact SUV plenty of power, take him all over the Bay Area, and are expected to last the life of the car, based on utility company fleet tests.

Long before unveiling its "new" plug-in hybrid Volt, GM displayed a prototype plug-in hybrid version of its EV1 electric car at auto shows in the 1990s. The EV1 plug-in hybrid could go 25 miles on electricity stored in NiMH batteries before the gasoline engine turned on, which would then extend the range to 320 miles. Professor Andrew Frank at the University of California at Davis collaborated with the NiMH battery company Energy Conversion Devices in 1998 to convert an early Toyota Prius to a plug-in hybrid, with similar results. Toyota will be testing their plug-in Prius in Japan, and will be delivering one each to UC–Berkeley and UC–Irvine. The cars are expected to have only a 7- to 8-mile range on their NiMH batteries, but if the cars move into production, more advanced batteries are likely to be used.

People who have been driving electric cars for years using NiMH batteries suggest that the car companies are stalling by insisting on Li-ion batteries. The major auto manufacturers say that Li-ion batteries are preferable because they store more energy in less space, so fewer batteries are needed and less weight is added to the vehicle. It's unclear, however, whether Li-ion batteries will last as long as expected in conventional warranties. California state regulators are considering modifying warranty requirements for hybrids, which could jump-start production of plug-in cars with Li-ion batteries. Or, as GM's CEO Robert Lutz acknowledged in a recent interview on PodTech.net, if Li-ion doesn't work out, "we might use NiMH for plug-in hybrids after all."

for a home during blackouts. It showed the plug-in Prius as an integral part of the "Toyota Dream House PAPI"—one example of environmentally friendly, energy saving, intelligent home design. The project suggested that if a hurricane or other disaster knocks out the electric grid, the car could supply electricity for some of a home's critical electrical loads for up to 36 hours.

Pulling for Plug-Ins

Unfortunately, while the merits of plug-ins have been pimped by the popular press and garnered the favor of an impressive aggregation of advocates, ranging from G. W. Bush to the activist environmental organization Rainforest Action Network, plug-in hybrids have yet to hit the mainstream market.

Courtesy CalCars.org

Lithium-ion battery pack in CalCars' EnergyCS/EDrive converted Prius.

To convince automakers that there is a market for these cars, the City of Austin, Texas, launched a Plug-in Partners campaign and has gathered more than 8,000 advance "soft" (no financial commitment) orders for plug-in hybrids. Austin's green energy comes from west Texas wind, and the city would like to use more of it. With plug-in hybrids, Austin aims to "replace Middle East oil with west Texas wind," according to the campaign motto.

And another famous Texan is helping drive the plug-in revolution: The day after his State of the Union speech in January 2007, President Bush issued an executive order saying that when plug-in hybrids become available, federal fleets with 20 or more vehicles must buy them. With the stroke of a pen, he signified his administration's support for these cars.

Are automakers listening? Maybe.

Several automakers developed plug-in hybrid prototypes in the 1990s, but cast them aside during their battle to weaken California's Zero Emission Vehicle mandate. Stung by bad publicity from *Who Killed the Electric Car?*, at least one automaker has started to reverse its course. At the 2007 North American International Auto Show in Detroit, General Motors showcased its prototype plug-in hybrid—aptly named the Volt. With electricity stored in a lithium-ion (Li-ion) battery pack, this car purportedly can deliver 40 miles before the flex-fuel (gasoline, E85, petrodiesel, or biodiesel) engine turns on to recharge the batteries and extend the car's range to 640 miles.

In the past year, at least five other major car companies have said they're developing plug-in vehicles. But the automakers are quick to say that plug-in hybrids won't hit the market until more research is done on advanced Li-ion batteries (see Better Batteries sidebar).

Move for the Future

The same day that Google switched on a 1.6-megawatt solar-electric array at its California headquarters—the largest PV installation on a corporate campus in North America—Google.org made another strong move toward energy independence, launching RechargeIT.org. They unveiled five plug-in hybrid conversions and plans to build a fleet of up to 100 plug-in hybrids for employee use. The company also awarded a $150,000 grant for a large-scale V2G planning and implementation research project, and is set to take proposals for $10 million in funding for companies focused on plug-in hybrids, electric vehicles, batteries, and V2G technology, demonstrating that where there's a will (and some substantial financial backing), there's a way.

In the meantime, plug-ins might not be hitting the showroom floor soon, but you can still support the push for these resource-efficient vehicles. Here's how:

- Support plug-in hybrids by joining Austin's Plug-in Partners campaign, and by using collective buying power as leverage. Plug In America lists the phone numbers of the major automakers on its Web site and urges consumers to call them. "Tell the automakers that you won't buy a new car unless it has a plug on it," says EV driver and Plug In America cofounder Marc Geller.
- Push for government incentives or interventions to help plug-in hybrids get to market. Plug In America and other advocates have been lobbying the California Air Resources Board—which this year is revising its weakened Zero Emission Vehicle Mandate—to put some teeth back into clean-car regulations.
- Do it yourself. If you have some experience in high-voltage electronics, you can convert a conventional hybrid to a plug-in hybrid. Costs vary widely depending on components and the type and number of batteries. And there's no standard conversion kit available yet, so be prepared to do lots of research first. (See Plug-In Pioneers sidebar.)

Access

Sherry Boschert (info@sherryboschert.com) is the author of *Plug-in Hybrids: The Cars that Will Recharge America* (New Society Publishers) and is on the steering committee of Plug In America.

California Cars Initiative • www.CalCars.org

Do-it-yourself plug-in hybrid conversions • www.eaa-phev.org

Electric Auto Association • www.eaaev.org

Plug In America • www.PlugInAmerica.com

Plug-in Partners • www.PlugInPartners.org

RechargeIT.org • Google.org's initiative to reduce CO_2 emissions, cut oil use & stabilize the electrical grid by accelerating the adoption of PHEVs

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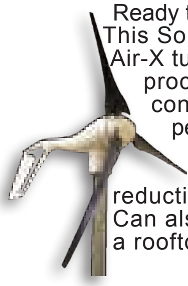

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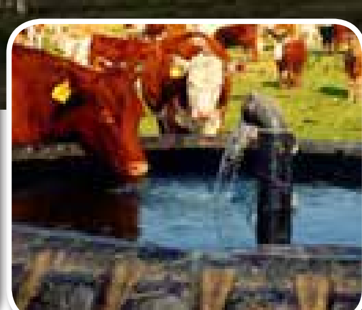

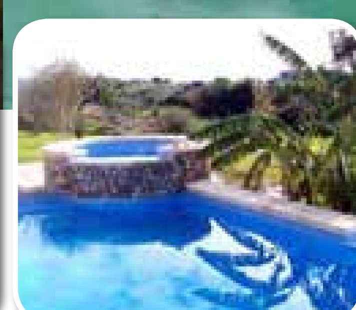

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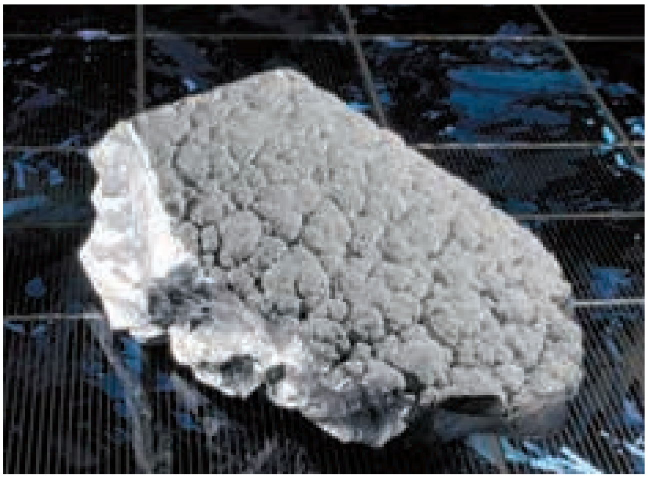
A Peek Inside a PV Cell

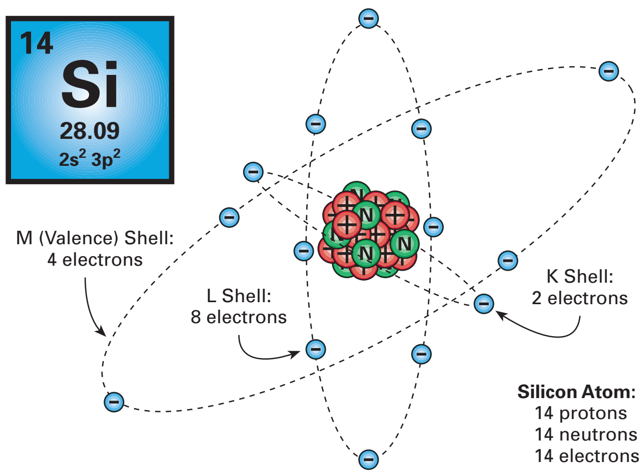
Scott Aldous, Zeke Yewdall & Sam Ley



Courtesy www.recgroup.com

Polycrystalline silicon, ready to be manufactured into photovoltaic cells.

How a slice of silicon often thinner than a human hair can harvest sunlight to make electricity may seem like magic. But what may appear as a bit of sorcery actually boils down to uniting science and engineering wizardry with some of Earth's most abundant resources—sunshine and silicon.



Photovoltaic (PV) cells are made of a special class of materials called semiconductors. Of all the semiconductor materials, silicon is most commonly used because of its availability (it's the second-most abundant element in Earth's crust) and its special chemical properties.

An atom of silicon has fourteen electrons arranged in three different levels, or shells. The first two shells, those closest to the center, are completely full. The outer shell, with four electrons, is only half full. A silicon atom will always look for ways to fill up its last shell (which would like to have eight electrons). To do this, it will share electrons with four of its neighboring silicon atoms. It's like every atom holds hands with its neighbors, except that in this case, each atom has four hands joined to four neighbors. That's what forms the crystalline structure, and that arrangement turns out to be important to the function of a PV cell.

Making a Better Carrier

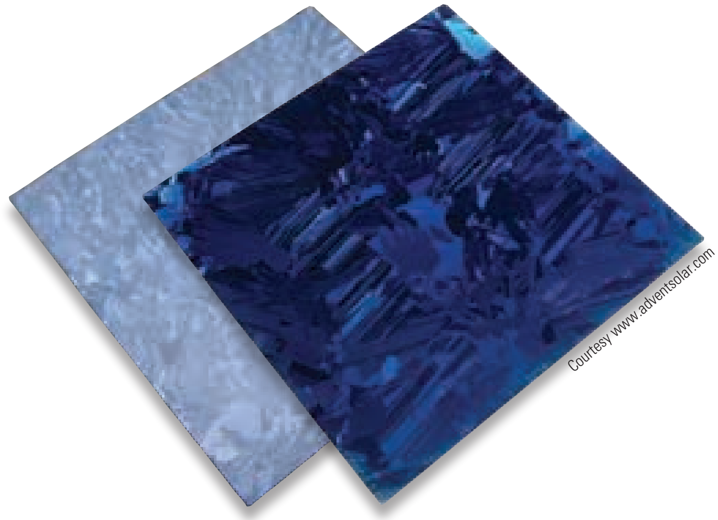
Energy added to pure silicon can cause a few electrons to break free of their bonds and leave their atoms, leaving a "hole" (an unfilled bond) behind. These "free carrier" electrons wander randomly around the crystalline lattice structure, eventually falling into another hole. But there are so few free carriers available in pure silicon that they aren't very useful. Scientists found they could improve silicon's electron carrier ability (conductivity) by adding other atoms in a process know as "doping."

Silicon doped with an atom of phosphorous here and there (maybe one for every million silicon atoms), will still bond with its silicon neighbor atoms. But phosphorous, which has five electrons in its outer shell, has one electron that doesn't have anyone to hold hands with, so it takes a lot less energy to knock it loose. As a result, most of these electrons do break free, resulting in more free carriers. Phosphorous-doped silicon is called N-type ("n" for "negative") because of the prevalence of free electrons.

But only one part of our solar cell can be N-type. The other part is typically doped with boron, which has three electrons in its outer shell. Instead of having free electrons, P-type ("p" for "positive") has free *holes*.

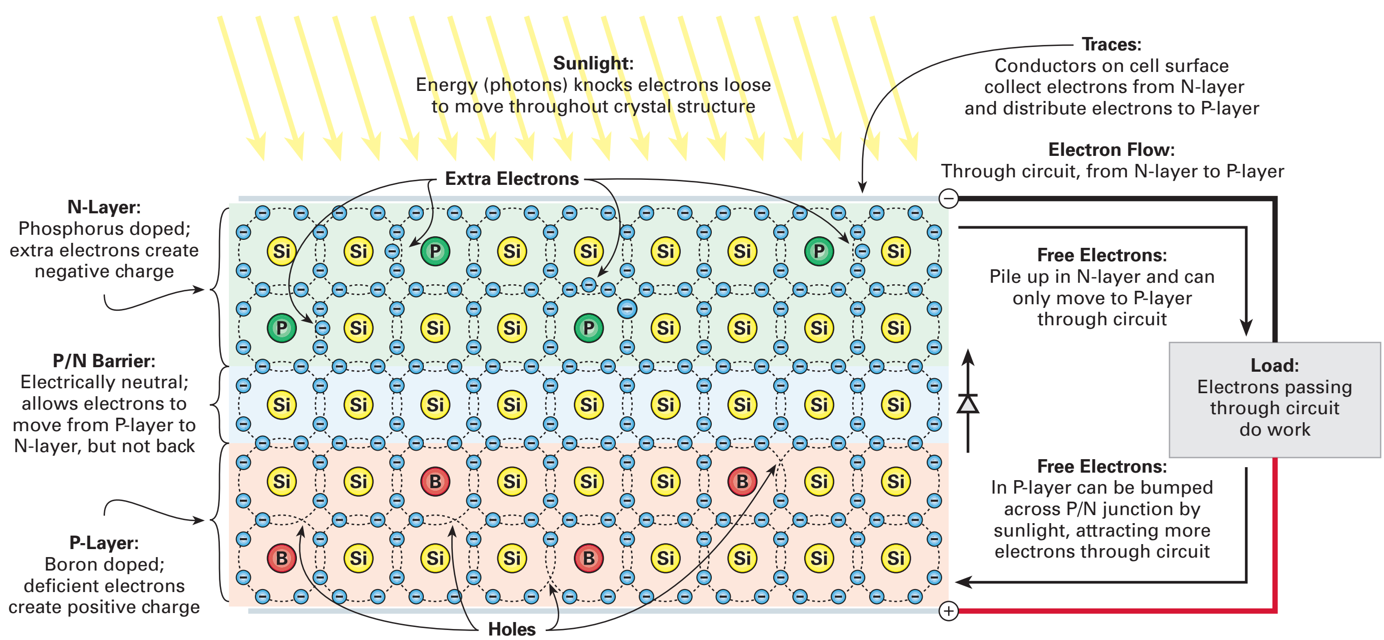
The interesting part starts when you put N-type silicon next to P-type silicon—a silicon sandwich of sorts. When the electrons and holes mix at the junction between N-type and P-type silicon, silicon's neutrality is disrupted and the free electrons mix to form a barrier, making it harder and harder for electrons on the N side to cross to the P side. Eventually, equilibrium is reached, and an electric field separates the two sides. The electric field allows (and even pushes) electrons to flow from the P side to the N side, but not the other way around. A P–N junction is commonly known as a diode—an electrical one-way valve for electricity. The special thing about PV cells is that they are diodes designed to absorb energy from sunlight.

When a photon—the electromagnetic energy of sunlight—with enough energy hits the N-layer, it knocks an electron free. These electrons stay in the N-layer. When a photon of light hits an atom in the P-layer, it knocks an electron free that can easily cross into the N-layer. The result is that extra electrons accumulate in the N-layer. A series of metal



Polycrystalline wafers: uncoated (left) and with the telltale blue antireflective coating (right).

P/N Silicon and the Function of a PV Cell



(Si) **Silicon Atom:** 4 electrons in outer shell. Shares with other silicon atoms to form a stable crystal bond of 8 electrons.

(B) **Boron Atom:** 3 electrons in outer shell. Shares with silicon atoms to form a crystal bond of 7 electrons and 1 hole, readily attracting extra electrons.

(P) **Phosphorus Atom:** 5 electrons in outer shell. Shares with silicon atoms to form a crystal bond of 8, plus one extra electron.

(–) **Electron:** Knocked around by energy of sunlight; moves through circuit from N-layer to P-layer.

Courtesy www.solarworld-ca.com

Measuring single-crystalline silicon ingots at the SolarWorld PV plant in Vancouver, British Columbia.

wires (traces) attached to the N-layer gives the electrons someplace to go, and they enter a DC circuit, flowing from the negative side of the cell and re-entering the cell through the positive side.

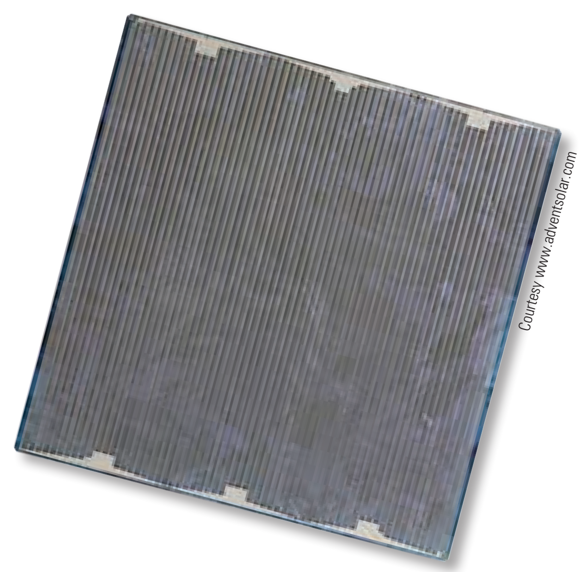
PV modules are made by connecting numerous cells in series, parallel, or series/parallel to achieve useful levels of voltage and current. These cell networks include positive and negative wiring terminals so we can channel the electricity generated to our uses. As long as sunlight is coming in, the electrons will keep flowing and can deliver electrical energy to a load that's connected to the circuit.

Electrons & Efficiency

One way to think about the process of electron movement is to imagine that the P-layer is a pool filled with electrons and your deck is the N-layer. If a sufficiently strong photon hits one of the electrons in the pool (P-layer), it can kick it up onto the deck (N-layer) where you can catch it and put it to useful work. Ideally, every photon coming into the pool would bump an electron up onto the deck that you could collect and put to use. However, silicon's limitations, along with design challenges, prevent PV cells from being 100% efficient. In reality, most commercially available cells are between 4% and 22% efficient at converting the energy in the photons to useful electricity. Here are several reasons why:

Too Little or Too Much Energy. The light that hits a cell contains photons with a wide range of energies, but a PV cell will only respond to certain energies, or wavelengths. The required level of photon energy to activate an electron is referred to as the band gap. Different types of photovoltaic materials have different band gaps—higher and lower decks, so to speak. Some photons don't have enough energy, and although they bump electrons, they don't give them enough energy to get them up on the "deck." This energy is wasted as heat. The lower the deck (lower band gap), the lower the minimum energy required.

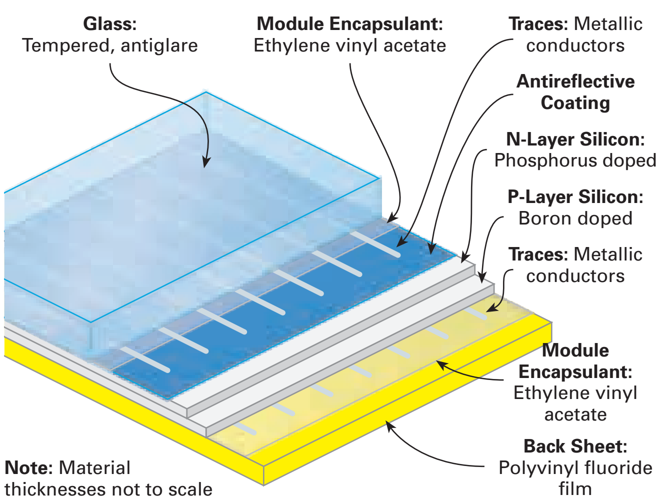
So why can't we choose a material with a really low band gap, so we can use more of the photons? Unfortunately, the band gap also determines the voltage of our solar cell. If it's too low, what we make up in extra current (by absorbing more photons) we lose by having a small voltage (remember that power is voltage times current). If the incoming photon



Courtesy www.adventsolar.com

Densely spaced traces on the back of a PV cell help transfer electrons to the P-layer.

PV Module Anatomy



is too strong, it bumps the electron up higher than the deck, before it falls back down. In a PV cell, this energy expenditure is also wasted in the form of heat.

To capitalize on the higher energies of some photons, some exotic PV materials have two levels of decks. If a photon has enough energy, it can bump the electron all the way up to a higher deck where it can be collected. Some amorphous PV modules have two or three levels of decks, so if an electron isn't excited enough to get on the highest deck, it might at least end up on a lower one and be used there.

These two effects alone—too little energy and too much energy in incoming photons—account for the loss of about 70% of the radiation energy incident on our cell.

Imperfect Junctions. A second source of inefficiency is that a lot of electrons just roll through slots between the deck boards before you can collect them. A perfect crystal doesn't have any holes—every electron that is collected stays on the deck until it can be collected. However, polycrystalline solar cells have joints between crystals, resulting in an imperfection in the P–N junction—holes in the deck, so to speak, that allow electrons to slip back into the pool before they can be collected.

Even in a single-crystal solar cell, you still can't collect all the electrons. The metal traces that collect electrons in a PV cell are spaced apart, and an electron that ends up too far from it may be lost before it can travel to the nearest trace and be collected.

PV Cell Particulars

Model-T maker Henry Ford was fond of telling consumers they could have any color car, "so long as it was black." Options in PV module choices used to be as limited, but that's changing. Today, you can choose from three basic types of PV modules: monocrystalline, polycrystalline, and thin-film.

Most of us are familiar with the iridescent-blue faces of monocrystalline and polycrystalline modules. In both cases, fragile razor-thin wafers of silicon are embedded in a rigid frame and protected behind a layer of tempered glass. The difference between the two crystallines lies in the production of the cell. Monocrystalline ingots are extracted from melted silicon and then sawed into thin plates. Polycrystalline cells are created by pouring liquid silicon into blocks that are sawed into plates.

In the thin-film process, a silicon film (or other materials, such as cadmium telluride or copper indium gallium selenide) is deposited on glass or stainless steel, or within a flexible laminate. Although production costs are lower due to lower material costs, the efficiency of thin-film modules is typically about half that of either mono- or polycrystalline cells.

R&D technicians inspect a monocrystalline wafer at a Suntech Power PV plant in China.

Courtesy www.suntech-power.com

Amorphous silicon has a similar problem called hydrogen diffusion. Instead of being a solid silicon crystal, it has all kinds of loose hydrogen atoms, which function like a deck full of gaps. Also, electrons in a position to be bumped by photons are fewer and farther between because the hydrogen leaves less silicon to hit. The hydrogen atoms are the reason that amorphous silicon decreases in efficiency over the first few months before stabilizing: Hydrogen in the atmosphere slowly diffuses into the module.

Reflection, Obstruction & Temperature. Silicon is very reflective, which makes harvesting sunlight challenging, since a cell can't use photons that are reflected. For that reason, an antireflective coating (typically titanium dioxide or silicon nitride) is applied to the top of the cell to reduce reflection losses to less than 5%. This coating is what gives solar cells their blue appearance, instead of gray, as raw silicon would appear. The antireflective coating can be modified to get different colors, such as red, yellow, green, or gray, but these colors are less efficient than dark blue, so you very rarely see PV modules in these other colors. The glass on a module also has a special textured surface to minimize the reflection of sunlight.

Because silicon is a semiconductor, it's not nearly as good as a metal for transporting electrical energy. Its internal resistance is fairly high, and high resistance means high losses. To minimize these losses, a cell is covered by a metallic contact grid that shortens the distance that electrons have to travel from one side of the cell to the other while covering only a small part of the cell surface. We could cover the bottom with a metal, allowing for good conduction, but if we completely cover the top too, photons can't get through the opaque conductor and we lose all of our energy. If we put our contacts only at the sides of our cell, the electrons have to travel an extremely long distance (for an electron) to reach the contacts.

Various solutions to this obstruction have been considered, from BP Solar's laser-grooved buried-grid modules that put the collection grid in trenches instead of using flat ribbons on the surface, to placing the metal contacts on the back surface of the cell (as on SunPower modules), to transparent conducting layers that are being used for some amorphous and organic PV materials.

Temperature also affects a cell's efficiency. Typically, for each degree centigrade increase in operating temperature over its rated temperature, a PV cell loses about 0.5% of its specified power. For example, a PV module that experiences temperatures 50°C higher than its rated temperature (which is quite common for rooftop modules) may produce 25% less than its rated power. This happens because the thermal energy is distributed unevenly, with some electrons having enough energy to "go the wrong way"—back across the barrier, where they fall into holes we don't want them to.

The Reality of Efficiency

After all this talk about efficiency, you might be surprised to discover that buying the most efficient module on the market shouldn't be your only goal. When you're talking about energy production, it's watts that we're really after. If a less efficient PV module allows us to get those same watts for less cost, it may be a more cost-efficient choice than a more efficient, but more expensive, module.

If you have limited space on your roof or a small solar window, using more efficient modules can often make sense. But if you have acres of warehouse roof, for example, it may not. It all depends on your particular situation. To optimize your investment, prioritize cost per installed kilowatt-hour, longevity, and efficiency, in that order, if space is not a consideration.

Access

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Sam Ley (sam@cosunflower.com) is a physicist who works at Sunflower Solar, and has extensive experience in science education at museums.

Portions of this article were adapted from Scott Aldous's article, "How Solar Cells Work," courtesy ©2007 HowStuffWorks.com.

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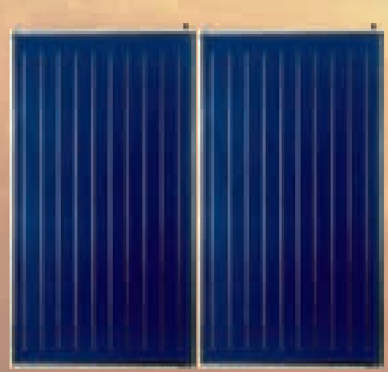

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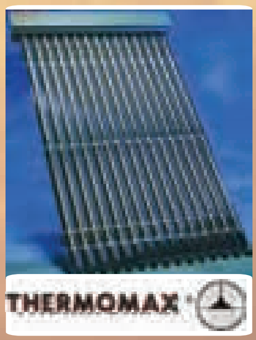

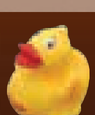

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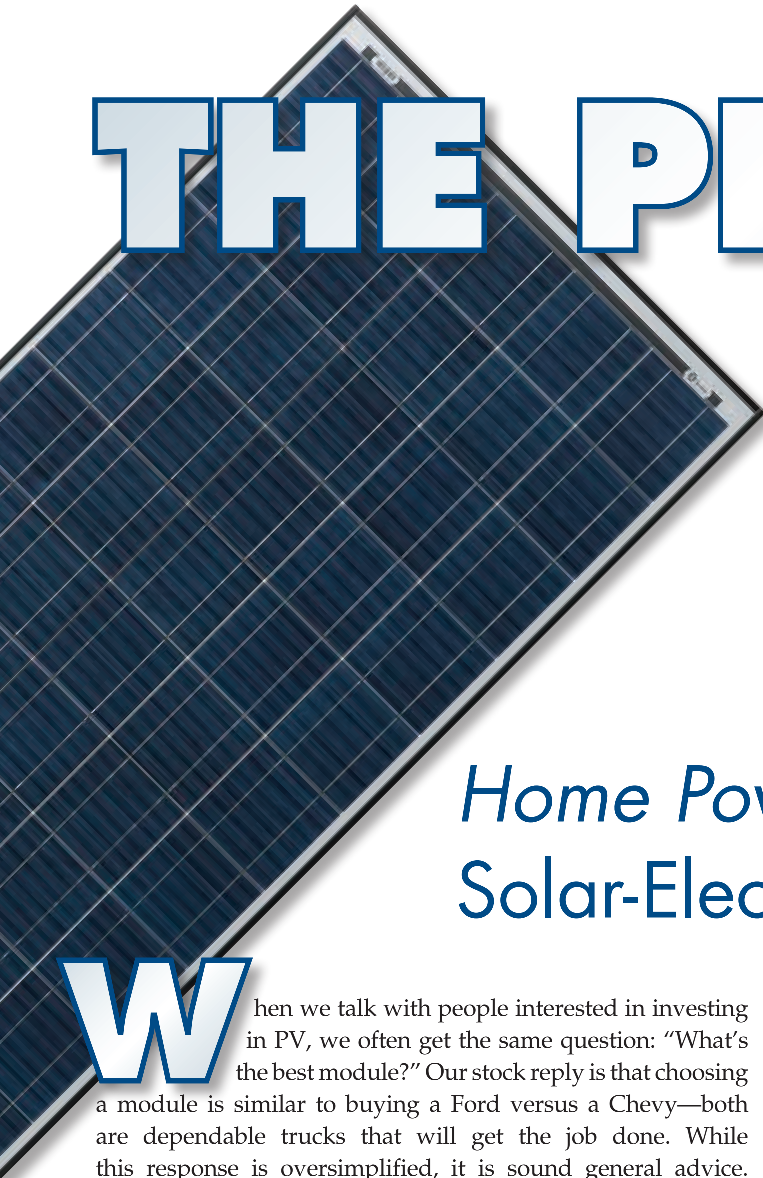


THE PERFECT

Home Power's 2007 Solar-Electric Module Guide

When we talk with people interested in investing in PV, we often get the same question: "What's the best module?" Our stock reply is that choosing a module is similar to buying a Ford versus a Chevy—both are dependable trucks that will get the job done. While this response is oversimplified, it is sound general advice. Compared to most consumer products, the cost, performance, and durability of PV modules are relatively consistent—as long as you purchase UL-listed modules that carry a warranty of 20 years or more.

But when you dig into module specs and compare them side by side, the distinguishing characteristics begin to emerge. Because PV modules have 25-year-plus operational life spans, small distinctions in performance or suitability for a given application will be magnified over time. What may seem to be minor differences in daily array output can result in megawatt-hours of energy lost or gained over the life of the system.

A Changing PV Market

Over the last few years, a shortage of silicon—the main material in nearly all PV modules—resulted in a tight seller's market. This left many installers who had been loyal to a specific brand scrambling to get their hands on any available modules to keep their projects rolling. The silicon shortage limited options for choosing the optimal module for a given application.

More recently, increased investment in production and long-term contracts between module manufacturers and silicon producers has eased the availability crunch significantly. Existing PV manufacturers have ramped up production capacity, and new players are joining the manufacturing base. As a result, consumer choice is back on the table, and that's good for the PV industry, good for installers, and good for businesses and individuals ready to invest in solar electricity.

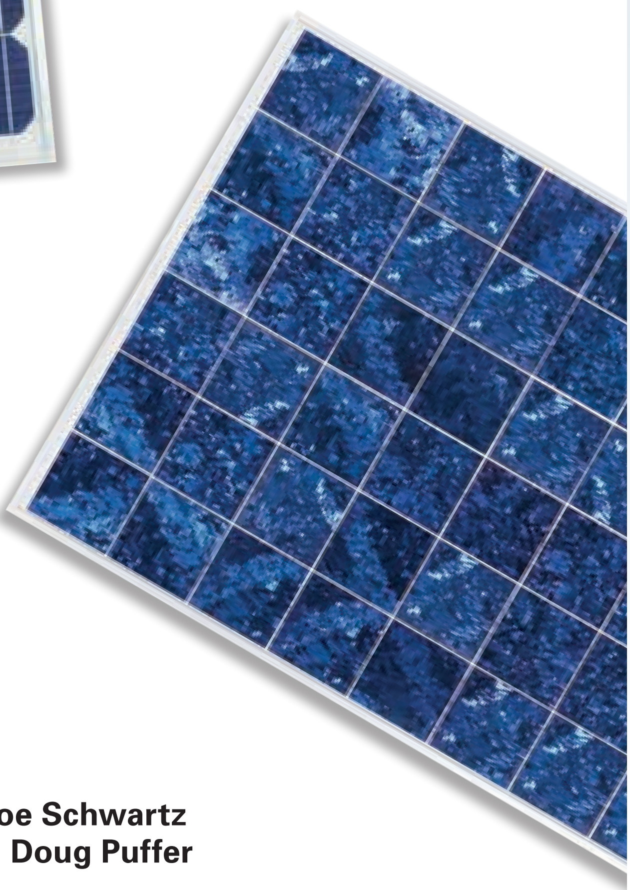
How to Use This Guide

This article provides a comprehensive listing of PV modules that are UL listed and available in the United States (or in a few cases, conservatively projected to be available in the first quarter of 2008). Included modules have a rated output of 100 watts or higher at standard test conditions (STC) and a minimum power output warranty of 20 years.

To navigate the detailed specifications tables on the following pages, get familiar with the definitions and descriptions provided. They'll give you an understanding of each spec's relevance to designing a high performance system. The specifications included in the table will help you determine which modules will allow optimal integration with a given system's inverters or charge controllers, and overcurrent protection. They will also assist you in specifying the highest power array for sites with mounting space limitations. (Note that specifications were collected from spec sheets, provided directly by the manufacturers or calculated, and are subject to change.)

PV systems represent a significant financial investment. How an individual module model performs when coupled with a given inverter or charge controller can make the difference between a design that is simply functional and a design that performs optimally over the system's decades-long operational life.

PV SPECS...



by Joe Schwartz
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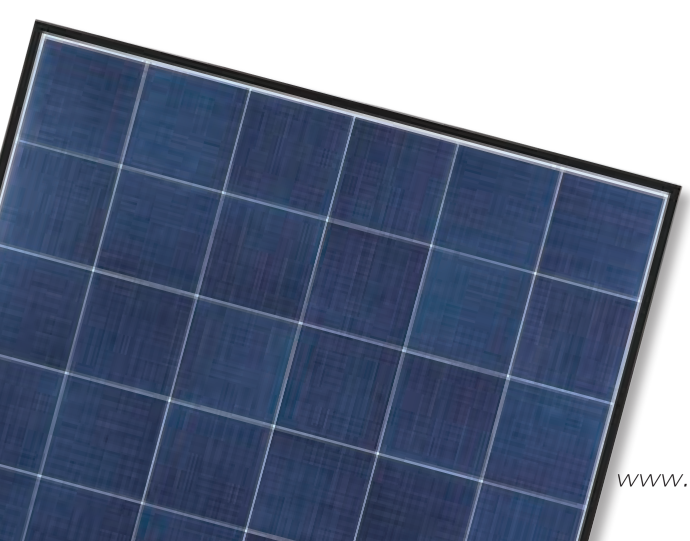

Manufacturer

Definition: A company that designs and builds a line of PV modules.

Importance: PV manufacturers include global energy companies like BP and GE. Manufacturers with long histories of producing consumer or industrial electronics such as Sanyo, Sharp, and Kyocera are devoting significant resources to PV production capacity. And there are "pure play" companies that focus on one thing—manufacturing photovoltaic modules. Examples include Advent Solar, Canadian Solar, Day4Energy, Evergreen, SolarWorld, and Suntech Power.

Model

Definition: The identifier used to distinguish one module from another.

Importance: Other than giving you a reference point to compare modules, model specifications and availability often change and should be verified prior to purchasing.

Rated Power at STC (watts)

Definition: Module wattage rating at standard test conditions (STC)—1,000 watts per square meter solar irradiance, 25°C (77°F) cell temperature.

Importance: The STC rating establishes a consistent basis for comparing the power output of individual PV models—but this specification shouldn't be mistaken for the actual power a module will generate consistently in the field. Rated power tolerance (described below) and array operating temperatures are two factors that result in real-world module output that, in most instances, will be significantly lower than a module's rating at STC. If you purchased a 100-watt module with a measured power tolerance of minus 3%, that module could potentially generate 97 watts in the field. If the module was installed in a hot climate like Southern California and the array spent much of its life operating at 50°C (122°F), the actual output of that 100-watt module during the heat of the day might be about 85 watts. The real-world wattage would be better if the module had a 0% power tolerance rating and was operating in a cooler climate, and worse if it had a lower tolerance rating and was installed in a hotter climate.

Rated Power Tolerance (%)

Definition: The specified range within which a module will either overperform or underperform its rated power at STC.

Importance: Power tolerance is the most contentious module specification. Depending on the module, this specification can vary from as much as plus 10% to minus 9%. With only a positive power tolerance (plus 2.5%), Evergreen's new 195-watt module is guaranteed to generate at least 195 watts at STC. Shuco also manufactures two modules with no negative power tolerance. Due to the recent trend of rating modules in small increments, for example, a 5-watt difference between models, the reality is that modules that meet the power tolerance of the next highest model will be classified as such. The result? Modules are more likely to produce at the lower end of the tolerance range. The bottom line is that the tighter the rated power tolerance, the better, so you can be assured that you're getting the wattage you pay for.

Courtesy www.bpsolar.us

Rated Power per Square Foot (watts)

Definition: Power output at STC per square foot of module (not cell) area; calculated by dividing module rated power by the module's area in square feet.

Importance: If you have limited space available for a PV array, this metric will help you determine which module will maximize power output in a given area (power density). Rated power per square foot is one tangible way to compare the efficiency of one module to another. Currently, specific modules manufactured by Sanyo and SunPower achieve the highest power densities.

Module Efficiency (%)

Definition: The ratio of output power to input power, or how efficiently a PV module uses the photons in sunlight to generate DC electricity.

Importance: Module efficiency is another indicator of which modules will generate the highest power if space is limited. While high efficiency is great, it typically comes at an increased cost. For the modules surveyed, efficiencies range from 10.3% to 19.3%. Manufacturers may also advertise the efficiency of individual cells, which should not be confused with overall module efficiency—a more important figure to consider. Finally, there has been a fair amount of hype on the Internet recently about solar technologies reaching efficiencies greater than 40% in the lab. But these devices are not ready for prime time, and probably won't be for decades. Most importantly, they shouldn't be compared to warranted, commercially available modules that you can put to work today.

Module Physical Dimensions (inches)

Definition: Length, width, and depth of a given module.

Importance: Module dimensions vary, often significantly. Careful consideration of module dimensions during the system design phase will result in an attractive array that is visually integrated with the building and uses available space wisely. Poor layout planning can result in an installation that's less aesthetically pleasing, such as arrays extending past the roof's ridgeline or gable ends.

Weight (lbs.)

Definition: Module weight in pounds.

Importance: The total weight of an installed array (including modules and racking) is not usually a factor that needs to be considered unless ballasted mounts will be used or engineering is required for the project. The weight figures here are for modules only and do not include packaging for shipping.

Series Fuse Rating (amps)

Definition: Amperage value of a series fuse used to protect a module from overcurrent, under fault conditions.

Importance: Series strings of modules wired in parallel at a combiner box typically require overcurrent protection for each string. The module manufacturer specifies the amperage rating of the required fuse or breaker. Many batteryless inverters are designed to accept the individual output wiring of two or more series strings without additional series fusing.

Connector Type

Definition: Module output terminal or cable/connector configuration.

Importance: To decrease installation time, most PV manufacturers have moved away from accessible junction boxes where installers terminated module wiring at screw-type connectors. Preinstalled cabling that includes "plug and play" weather-tight connectors is now the standard. The most common connector types are manufactured by Multi-Contact USA, which offers a line of connectors commonly referred to as MC connectors. Two manufacturers, Day4Energy and GE, use Solarlok connectors manufactured by Tyco Electronics.

Courtesy www.isofoton.com

Materials Warranty (years)

Definition: A limited warranty on module materials and workmanship under normal application, installation, use, and service conditions.

Importance: Of the modules surveyed, materials warranties vary from 1 to 10 years.

Power Warranty (years)

Definition: A limited warranty for module power output based on the minimum peak power rating (STC rating minus power tolerance percentage) of a given module.

Importance: Few consumer products have warranties that come anywhere close to those carried by PV modules: at least 20 years. The fine print typically breaks down module power warranties based on a percentage of minimum peak power output within two different time frames—90% of minimum peak power is typically guaranteed for 10 years, and 80% for 20 to 25 years.

Courtesy www.suntech-power.com

Cell Type

Definition: The material that comprises a specific cell, based on the cell manufacturing process.

Importance: There are three general types of PV cell materials—monocrystalline, polycrystalline, and thin film. As the specs here indicate, neither mono- nor polycrystalline cells show a clear performance advantage. A module's performance is more directly related to the specifications of the particular cells used, and the specific design of a given module. Thin-film modules have roughly half the power density of crystalline module types, and other than a couple of companies that combine two smaller thin-film modules together, no framed thin-film modules rated at more than 100 watts at STC are available in the United States. UniSolar manufactures flexible roof laminates that are adhered to standing-seam metal roofing. Depending on their length, they may generate more than 100 watts per laminate. An interesting note is that Sanyo manufactures modules that combine monocrystalline cells with layers of thin-film material, which enables the modules to use a wider range of the sun's light spectrum.

Cell Size (inches)

Definition: Indication of relative cell size.

Importance: The voltage of PV cells is relatively consistent no matter what their size, while cell current directly correlates to cell area. Roofs with limited space may benefit from modules with smaller cells to increase series string voltage to match a specific inverter. Modules with larger cells are well suited for high-power commercial installations.

Cells in Series

Definition: Number of individual PV cells wired in series to generate the module design voltage.

Importance: Module voltage increases as additional cells are wired in series. Historically, module design voltage was based on recharging a battery bank of a specific voltage (typically multiples of 12 volts nominal). Today, most PV systems operate at high voltages (up to 600 VDC), are grid connected, and use inverters and charge controllers that optimize array output over a wide voltage range. As a result, some modules have a maximum power voltage (based on the number of cells in series) that will not be compatible with systems using non-maximum power point tracking (MPPT) charge controllers.

Cells in Series per Bypass Diode

Definition: Bypass diodes provide an alternate path for electricity to flow if a portion of a module is shaded. A certain number of cells in series are configured with bypass diodes wired in parallel between series strings.

Importance: Poorly designed arrays may operate near the bottom of the voltage-tracking window of a batteryless inverter. In this instance, module shading can cause the array voltage to drop below the minimum inverter voltage threshold, and power output will cease until the array is again sufficiently illuminated. Bypass diodes allow nonshaded cell series strings within a module to continue to generate electricity if another series string within the same module is shaded, keeping the array voltage as high as possible to keep the system functioning.

Maximum Power Voltage (Vmp)

Definition: The voltage generated by a PV module or array when exposed to sunlight and connected to a load—typically a batteryless inverter or a charge controller and battery.

Importance: Batteryless inverters have a range in which they track and optimize the output of a PV array as its voltage and current vary throughout the day. The maximum power voltage of an array should be designed to stay within the tracking window of your inverter or MPPT charge controller.

Manufacturer	Model	Rated Power at STC (W)	Rated Power Tolerance (%)	Rated Power Per Sq. Ft. (W)	Module Efficiency (%)	Length (In.)	Width (In.)	Depth (In.)	Weight (Lbs.)	Series Fuse Rating (Amps)	Connector Type
Advent Solar	Advent 200	200	+/-3.0	11.2	12.0	66.14	38.98	1.97	50	15	MC
	Advent 205	205	+/-3.0	11.5	12.3	66.14	38.98	1.97	50	15	MC
	Advent 210	210	+/-3.0	11.7	12.6	66.14	38.98	1.97	50	15	MC
	Advent 215	215	+/-3.0	12.0	12.9	66.14	38.98	1.97	50	15	MC
	Advent 220	220	+/-3.0	12.3	13.2	66.14	38.98	1.97	50	15	MC
	Advent 225	225	+/-3.0	12.6	13.5	66.14	38.98	1.97	50	15	MC
	Advent 230	230	+/-3.0	12.8	13.8	66.14	38.98	1.97	50	15	MC
	Advent 235	235	+/-3.0	13.1	14.1	66.14	38.98	1.97	50	15	MC
	Advent 240	240	+/-3.0	13.4	14.4	66.14	38.98	1.97	50	15	MC
BP Solar	BP 3115J	115	+/-3.0	10.5	11.3	59.45	26.54	1.97	26.64	15	J-Box
	BP 3125J	125	+/-3.0	11.4	12.3	59.45	26.54	1.97	26.64	15	J-Box
	SX 3140J	140	+/-9.0	12.8	12.8	59.45	26.54	1.97	26.64	15	J-Box
	SX 165B	165	+/-9.0	12.2	13.1	62.72	31.10	1.97	33.88	15	MC
	SX 170 I	170	+/-9.0	12.4	13.3	62.48	31.61	1.97	33.88	15	MC
	BP 170 I	170	+/-5.0	12.4	13.3	62.48	32.61	1.97	33.88	15	MC
	BP 170 B	170	+/-5.0	12.6	13.5	62.72	31.10	1.97	33.88	15	MC
	SX 175B	175	+/-9.0	12.9	13.9	62.72	31.10	1.97	33.88	15	MC
	BP 175 B	175	+/-5.0	12.9	13.9	62.72	31.10	1.97	33.88	15	MC
	BP 175 I	175	+/-5.0	12.8	13.7	62.48	32.61	1.97	33.88	15	MC
	BP 4175 B	175	+/-5.0	12.9	13.9	62.72	31.10	1.97	33.88	15	MC
	BP 4175 I	175	+/-5.0	12.8	13.7	62.48	32.61	1.97	33.88	15	MC
	BP 4180 B	180	+/-5.0	13.3	14.3	62.72	31.10	1.97	33.88	15	MC
	BP 4180 I	180	+/-5.0	13.1	14.1	62.48	32.61	1.97	33.88	15	MC
	SX 3190 N, B	190	+/-9.0	12.6	13.5	66.14	32.95	1.97	37.84	15	MC
	SX 3195 N, B	195	+/-9.0	12.9	13.9	66.14	32.95	1.97	37.84	15	MC
	SX 3200 B, W	200	+/-9.0	13.2	13.2	66.14	32.95	1.97	37.84	15	MC
	BP 3200 B, W	200	+/-5.0	13.2	13.2	66.14	32.95	1.97	37.84	15	MC
Canadian Solar	CS5A-170	170	+/-3.0	12.4	13.3	62.80	31.54	1.57	34.17	10	MC
	CS6A-175	175	+/-3.0	12.5	13.5	52.13	38.66	1.57	35.27	15	MC
	CS6A-180	180	+/-3.0	12.9	13.8	52.13	38.66	1.57	35.27	15	MC
	CS5A-180	180	+/-3.0	13.1	14.1	62.80	31.54	1.57	34.17	10	MC
	CS6A-185	185	+/-3.0	13.2	14.2	52.13	38.66	1.57	35.27	15	MC
	CS5P-210	210	+/-3.0	11.5	12.4	63.07	41.77	1.57	44.09	10	MC
	CS6P-210	210	+/-3.0	12.1	13.1	64.49	38.66	1.57	40.79	15	MC
	CS5P-220	220	+/-3.0	12.0	12.9	63.07	41.77	1.57	44.09	10	MC
	CS6P-220	220	+/-3.0	12.7	13.7	64.49	38.66	1.57	40.79	15	MC
	CS5P-230	230	+/-3.0	12.6	13.5	63.07	41.77	1.57	44.09	10	MC
Day4 Energy	Day4 36MC 115	115	+/-3.5	10.8	11.6	57.70	26.59	1.38	28.44	15	Solarlok
	Day4 36MC 120	120	+/-3.5	11.3	12.1	57.70	26.59	1.38	28.44	15	Solarlok
	Day4 36MC 125	125	+/-3.5	11.7	12.6	57.70	26.59	1.38	28.44	15	Solarlok
	Day4 36MC 130	130	+/-3.5	12.2	13.1	57.70	26.59	1.38	28.44	15	Solarlok
	Day4 36MC 135	135	+/-3.5	12.7	13.6	57.70	26.59	1.38	28.44	15	Solarlok
	Day4 36MC 140	140	+/-3.5	13.1	14.1	57.70	26.59	1.38	28.44	15	Solarlok
	Day4 36MC 145	145	+/-3.5	13.6	14.6	57.70	26.59	1.38	28.44	15	Solarlok
	Day4 48MC 160	160	+/-3.5	11.5	12.4	51.46	39.01	1.38	38.28	15	Solarlok
	Day4 48MC 165	165	+/-3.5	11.8	12.7	51.46	39.01	1.38	38.28	15	Solarlok
	Day4 48MC 170	170	+/-3.5	12.2	13.1	51.46	39.01	1.38	38.28	15	Solarlok
	Day4 48MC 175	175	+/-3.5	12.6	13.5	51.46	39.01	1.38	38.28	15	Solarlok
	Day4 48MC 180	180	+/-3.5	12.9	13.9	51.46	39.01	1.38	38.28	15	Solarlok
	Day4 48MC 185	185	+/-3.5	13.3	14.3	51.46	39.01	1.38	38.28	15	Solarlok
	Day4 48MC 190	190	+/-3.5	13.6	14.7	51.46	39.01	1.38	38.28	15	Solarlok
Evergreen	ES-170	170	+4.0/-5.0	10.6	11.4	61.80	37.50	1.60	40.10	15	MC
	ES-180	180	+4.0/-2.0	11.2	12.0	61.80	37.50	1.60	40.10	15	MC
	ES-190	190	+4.0/-2.0	11.8	12.7	61.80	37.50	1.60	40.10	15	MC
	ES-195	195	+2.5/-0.0	12.1	13.1	61.80	37.50	1.60	40.10	15	MC
GE	GEPVc-170-MS	170	+/-5.0	12.5	13.5	62.50	31.30	1.40	32.30	15	Solarlok
	GEPVp-200-MS	200	+/-5.0	12.8	13.7	58.50	38.60	1.40	39.00	15	Solarlok
Kyocera	KC130TM	130	+10.0/-5.0	13.0	14.0	56.00	25.70	2.20	26.90	15	J-Box
	KC130GT	130	+10.0/-5.0	13.0	14.0	56.00	25.70	1.40	26.90	15	MC
	KC175 GT	175	+10.0/-5.0	12.7	13.7	50.80	39.00	1.40	35.30	15	MC
	KC200GT	200	+10.0/-5.0	13.1	14.2	56.20	39.00	1.40	40.80	15	MC

Notes: a-Si = Amorphous silicon • Poly = Polycrystalline • Mono = Monocrystalline • MC = Multi-Contact • J-Box = Junction box • NA = Not available

Materials Warranty (Yrs.)	Power Warranty (Yrs.) 90%/80%	Cell Type	Cell Size (In.)	Cells in Series	Cells in Series per Bypass Diode	Max. Power Voltage (Vmp)	Max. Power Current (Imp)	Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coefficient (%/Deg. C)	Open-Circuit Voltage Temp. Coefficient (mV/Deg. C)	Short-Circuit Current Temp. Coefficient (mA/Deg. C)
NA	10 / 25	Poly	5	60	20	28.1	7.1	34.9	8.0	-0.52	-126	4.07
NA	10 / 25	Poly	5	60	20	28.4	7.2	35.1	8.1	-0.52	-126	4.12
NA	10 / 25	Poly	5	60	20	28.4	7.4	35.1	8.2	-0.52	-126	4.20
NA	10 / 25	Poly	5	60	20	28.7	7.5	35.4	8.3	-0.52	-127	4.22
NA	10 / 25	Poly	5	60	20	29.1	7.6	35.7	8.4	-0.52	-129	4.28
NA	10 / 25	Poly	5	60	20	29.3	7.8	36.0	8.5	-0.52	-130	4.35
NA	10 / 25	Poly	5	60	20	29.7	7.8	36.3	8.6	-0.52	-131	4.37
NA	10 / 25	Poly	5	60	20	29.7	7.9	36.3	8.6	-0.52	-131	4.41
NA	10 / 25	Poly	5	60	20	30.0	8.0	36.6	8.7	-0.52	-132	4.43
5	10, 12 / 25	Poly	6	36	18	17.1	6.7	21.8	7.5	-0.50	-80	4.88
5	10, 12 / 25	Poly	6	36	18	17.4	7.2	22.0	8.1	-0.50	-80	5.27
5	10, 12 / 25	Poly	6	36	18	17.5	8.0	22.0	8.2	-0.50	-80	5.33
5	10, 12 / 25	Poly	5	72	24	35.2	4.7	44.2	5.1	-0.50	-160	3.32
5	10, 12 / 25	Poly	5	72	24	35.4	4.8	44.2	5.3	-0.50	-160	3.43
5	10, 12 / 25	Poly	5	72	24	35.4	4.8	43.6	5.3	-0.50	-160	3.43
5	10, 12 / 25	Poly	5	72	24	35.4	4.8	43.6	5.3	-0.50	-160	3.43
5	10, 12 / 25	Poly	5	72	24	36.1	4.9	44.2	5.3	-0.50	-160	3.45
5	10, 12 / 25	Poly	5	72	24	36.1	4.9	43.6	5.3	-0.50	-160	3.45
5	10, 12 / 25	Poly	5	72	24	36.1	4.9	43.6	5.3	-0.50	-160	3.45
5	10, 12 / 25	Mono	5	72	24	35.4	4.9	43.6	5.5	-0.50	-160	3.54
5	10, 12 / 25	Mono	5	72	24	35.4	4.9	43.6	5.5	-0.50	-160	3.54
5	10, 12 / 25	Mono	5	72	24	35.5	5.1	43.6	5.6	-0.50	-160	3.64
5	10, 12 / 25	Mono	5	72	24	35.5	5.1	43.6	5.6	-0.50	-160	3.64
5	10, 12 / 25	Poly	6	50	10, 20	24.3	7.8	30.6	8.5	-0.50	-111	5.53
5	10, 12 / 25	Poly	6	50	10, 20	24.4	8.0	30.7	8.6	-0.50	-111	5.59
5	10, 12 / 25	Poly	6	50	10, 20	24.5	8.2	30.8	8.7	-0.50	-111	5.66
5	10, 12 / 25	Poly	6	50	10, 20	24.5	8.2	30.8	8.7	-0.50	-111	5.66
2	10 / 25	Mono	5	72	24	34.4	5.0	43.2	5.4	-0.30	-158	3.49
2	10 / 25	Poly	6	48	16	23.2	7.5	28.8	8.2	-0.30	-105	5.33
2	10 / 25	Poly	6	48	16	23.2	7.8	28.8	8.4	-0.30	-105	5.47
2	10 / 25	Mono	5	72	24	34.4	5.2	43.2	5.7	-0.30	-158	3.70
2	10 / 25	Poly	6	48	16	23.2	8.0	28.8	8.7	-0.30	-105	5.62
2	10 / 25	Mono	5	96	24	46.0	4.6	57.6	5.0	-0.30	-208	3.23
2	10 / 25	Poly	6	60	20	28.9	7.3	36.1	7.9	-0.30	-131	5.15
2	10 / 25	Mono	5	96	24	46.4	4.7	57.9	5.2	-0.30	-208	3.36
2	10 / 25	Poly	6	60	20	29.1	7.6	36.2	8.3	-0.30	-131	5.38
2	10 / 25	Mono	5	96	24	46.8	4.9	58.1	5.4	-0.30	-208	3.51
5	10 / 25	Poly	6	36	18	16.8	6.9	21.0	7.6	-0.48	-110	7.80
5	10 / 25	Poly	6	36	18	17.0	7.1	21.2	7.7	-0.48	-110	7.80
5	10 / 25	Poly	6	36	18	17.2	7.3	21.5	7.9	-0.48	-110	7.80
5	10 / 25	Poly	6	36	18	17.6	7.5	21.9	8.1	-0.48	-110	7.80
5	10 / 25	Poly	6	36	18	17.8	7.6	22.1	8.1	-0.48	-110	7.80
5	10 / 25	Poly	6	36	18	18.0	7.8	22.3	8.2	-0.48	-110	7.80
5	10 / 25	Poly	6	36	18	18.2	8.0	22.6	8.3	-0.48	-110	7.80
5	10 / 25	Poly	6	48	24	22.6	7.1	28.3	7.7	-0.48	-110	7.80
5	10 / 25	Poly	6	48	24	23.0	7.2	28.6	7.8	-0.48	-110	7.80
5	10 / 25	Poly	6	48	24	23.0	7.4	28.8	7.9	-0.48	-110	7.80
5	10 / 25	Poly	6	48	24	23.4	7.5	29.2	8.1	-0.48	-110	7.80
5	10 / 25	Poly	6	48	24	23.7	7.6	29.4	8.1	-0.48	-110	7.80
5	10 / 25	Poly	6	48	24	23.8	7.8	29.5	8.2	-0.48	-110	7.80
5	10 / 25	Poly	6	48	24	24.0	7.9	29.7	8.3	-0.48	-110	7.80
5	10 / 25	Poly Ribbon	6 x 3	108	18	25.3	6.7	32.4	7.6	-0.49	-112	4.50
5	10 / 25	Poly Ribbon	6 x 3	108	18	25.9	7.0	32.6	7.8	-0.49	-112	4.60
5	10 / 25	Poly Ribbon	6 x 3	108	18	26.7	7.1	32.8	8.1	-0.49	-113	4.80
5	10 / 25	Poly Ribbon	6 x 3	108	18	27.1	7.2	32.9	8.2	-0.49	-114	4.80
5	10 / 25	Mono	5	72	18	36.5	4.7	43.9	5.1	-0.37	-150	4.60
5	10 / 25	Poly	6	54	18	26.3	7.6	32.9	8.1	-0.50	-120	5.60
1	10 / 20	Poly	6	36	18	17.6	7.4	21.9	8.0	-0.49	-82	3.18
1	10 / 20	Poly	6	36	18	17.6	7.4	21.9	8.0	-0.49	-82	3.18
1	10 / 20	Poly	6	48	16	23.6	7.4	29.2	8.1	-0.49	-109	3.18
1	10 / 20	Poly	6	54	18	26.3	7.6	32.9	8.2	-0.49	-123	3.18

Manufacturer	Model	Rated Power at STC (W)	Rated Power Tolerance (%)	Rated Power Per Sq. Ft. (W)	Module Efficiency (%)	Length (In.)	Width (In.)	Depth (In.)	Weight (Lbs.)	Series Fuse Rating (Amps)	Connector Type
Mitsubishi	PV-UE115MF5N	115	+10.0/-5.0	10.6	11.4	58.90	26.50	1.81	29.80	15	MC
	PV-UE120MF5N	120	+10.0/-5.0	11.1	11.9	58.90	26.50	1.81	29.80	15	MC
	PV-UE125MF5N	125	+10.0/-5.0	11.5	12.4	58.90	26.50	1.81	29.80	15	MC
	PV-UE130MF5N	130	+10.0/-5.0	12.0	12.9	58.90	26.50	1.81	29.80	15	MC
	PV-UD175MF5	175	+/-3.0	11.8	12.7	65.30	32.80	1.81	37.00	15	MC
	PV-UD180MF5	180	+/-3.0	12.1	13.0	65.30	32.80	1.81	37.00	15	MC
	PV-UD185MF5	185	+/-3.0	12.4	13.4	65.30	32.80	1.81	37.00	15	MC
	PV-UD190MF5	190	+/-3.0	12.8	13.7	65.30	32.80	1.81	37.00	15	MC
Sanyo*	HIP-180BA3	180	+10.0/-5.0	14.2	15.3	51.90	35.20	1.40	30.86	15	MC
	HIP-186BA3	186	+10.0/-5.0	14.7	15.8	51.90	35.20	1.40	30.86	15	MC
	HIP-190BA3	190	+10.0/-5.0	15.0	16.1	51.90	35.20	1.40	30.86	15	MC
	HIP-195BA3	195	+10.0/-5.0	15.4	16.5	51.90	35.20	1.40	30.86	15	MC
	HIP-200BA3	200	+10.0/-5.0	15.8	17.0	51.90	35.20	1.40	30.86	15	MC
	HIP-205BA3	205	+10.0/-5.0	16.2	17.4	51.90	35.20	1.40	30.86	15	MC
Schott	ASE-250-DGF/50	250	+/-4.0	9.6	10.3	74.50	50.50	2.00	107.00	12	MC
	ASE-270-DGF/50	270	+/-4.0	10.3	11.1	74.50	50.50	2.00	107.00	12	MC
	ASE-300-DFG/50	300	+/-4.0	11.5	12.2	74.50	50.50	2.00	107.00	12	MC
Schuco	S 130-SP	130	+5.0/-0.0	12.1	13.0	49.13	31.61	1.81	27.56	15	MC
	S 165-SP	165	+5.0/-0.0	12.1	13.1	62.20	31.50	1.81	34.17	15	MC
	S 165-SPU	165	+/-5.0	12.1	13.1	62.20	31.50	1.81	34.17	15	MC
	S 170-SPU	170	+/-5.0	12.5	13.1	62.20	31.50	1.81	34.17	15	MC
Sharp	ND-L3EJEA	123	+10.0/-5.0	11.5	12.4	59.02	26.06	1.81	30.86	15	J-Box
	ND-L5E1U	125	+10.0/-5.0	11.7	12.6	59.02	26.06	1.81	30.86	15	MC
	ND-N2ECU	142	+10.0/-5.0	11.4	12.3	45.87	38.98	1.81	31.96	15	MC
	ND-162U1F	162	+10.0/-5.0	11.5	12.4	51.90	39.10	1.81	36.40	15	MC
	ND-167U1F	167	+10.0/-5.0	11.9	12.7	51.90	39.10	1.81	36.40	15	MC
	NE-170U1	170	+10.0/-5.0	12.1	13.1	62.01	32.52	1.81	37.49	10	MC
	NT-180U1	180	+10.0/-5.0	12.9	13.8	62.00	32.50	1.81	37.50	10	MC
	ND-181U1F	181	+10.0/-5.0	11.4	12.3	58.30	39.10	2.26	39.60	15	MC
	ND-187U1F	187	+10.0/-5.0	11.7	12.7	58.70	39.10	2.26	39.60	15	MC
	ND-200U1F	200	+10.0/-5.0	11.4	12.3	64.60	39.10	1.81	46.30	15	MC
	ND-208U1F	208	+10.0/-5.0	11.9	12.8	64.60	39.10	1.81	46.30	15	MC
SolarWorld	SW 155 - Mono	155	+/-3.0	11.0	11.9	63.39	31.89	1.34	33.00	15	MC
	SW 165 - Mono	165	+/-3.0	11.8	12.7	63.39	31.89	1.34	33.00	15	MC
	SW 175 - Mono	175	+/-3.0	12.5	13.4	63.39	31.89	1.34	33.00	15	MC
SunPower	SPR-205-BLK	205	+/-5.0	15.3	16.5	61.39	31.42	1.81	33.00	15	MC
	SPR-210-WHT	210	+/-5.0	15.7	16.9	61.39	31.42	1.81	33.00	15	MC
	SPR-315-WHT	315	+/-5.0	17.9	19.3	61.39	41.18	1.81	53.00	15	MC
Suntech Power	STP 160S-24/Ab-1	160	+/-3.0	11.6	12.5	62.20	31.81	1.38	34.17	15	MC
	STP 160-24/Ab-1	160	+/-3.0	11.6	12.5	62.20	31.81	1.38	34.17	15	MC
	STP 165S-24/Ab-1	165	+/-3.0	12.0	12.9	62.20	31.81	1.38	34.17	15	MC
	STP 165-24/Ab-1	165	+/-3.0	12.0	12.9	62.20	31.81	1.38	34.17	15	MC
	STP170S-24/Ab-1	170	+/-3.0	12.4	13.3	62.20	31.81	1.38	34.17	15	MC
	STP170-24/Ab-1	170	+/-3.0	12.4	13.3	62.20	31.81	1.38	34.17	15	MC
	STP 175S-24/Ab-1	175	+/-3.0	12.7	13.7	62.20	31.81	1.38	34.17	15	MC
	STP175-24/Ab-1	175	+/-3.0	12.7	13.7	62.20	31.81	1.38	34.17	15	MC
	STP180S-24/Ab-1	180	+/-3.0	13.1	14.1	62.20	31.81	1.38	34.17	15	MC
	STP180-24/Ab-1	180	+/-3.0	13.1	14.1	62.20	31.81	1.38	34.17	15	MC
Sunwize	SW100C	100	+/-5.0	9.9	15.0	56.93	25.43	1.34	26.00	10	J-Box
	SW115	115	+/-5.0	11.4	15.0	56.93	25.43	1.34	26.00	12	J-Box
	SW120	120	+/-5.0	11.9	15.0	56.93	25.43	1.34	26.00	13	J-Box
	SW150	150	+/-5.0	10.7	15.0	66.61	30.27	1.65	44.00	15	MC
	SW155	155	+/-5.0	11.1	15.0	66.61	30.27	1.65	44.00	15	MC
	SW160	160	+/-5.0	11.4	15.0	66.61	30.27	1.65	44.00	15	MC
Yingli	YL 120 (17)	120	+/-5.0	12.4	12.0	51.90	26.80	1.45	26.40	N/A	J-Box

Notes: a-Si = Amorphous silicon • Poly = Polycrystalline • Mono = Monocrystalline • MC = Multi-Contact • J-Box = Junction box • NA = Not available

*Also available: Sanyo's DA3 series (double-sided) modules, which generate up to 130% of rated wattage at STC in certain conditions

Materials Warranty (Yrs.)	Power Warranty (Yrs.) 90%/80%	Cell Type	Cell Size (In.)	Cells in Series	Cells in Series per Bypass Diode	Max. Power Voltage (Vmp)	Max. Power Current (Imp)	Open-Circuit Voltage (Voc)	Short-Circuit Current (Isc)	Max. Power Temp. Coefficient (%/Deg. C)	Open-Circuit Voltage Temp. Coefficient (mV/Deg. C)	Short-Circuit Current Temp. Coefficient (mA/Deg. C)
1.25	10 / 25	Poly	6	36	18	17.1	6.8	21.5	7.6	-0.45	-74	4.08
1.25	10 / 25	Poly	6	36	18	17.2	7.0	21.6	7.8	-0.45	-74	4.16
1.25	10 / 25	Poly	6	36	18	17.3	7.2	21.8	7.9	-0.45	-75	4.24
1.25	10 / 25	Poly	6	36	18	17.4	7.5	21.9	8.1	-0.45	-75	4.32
1.25	10 / 25	Poly	6	50	20	23.9	7.3	30.2	7.9	-0.45	-104	4.26
1.25	10 / 25	Poly	6	50	20	24.2	7.5	30.4	8.0	-0.45	-105	4.31
1.25	10 / 25	Poly	6	50	20	24.4	7.6	30.6	8.1	-0.45	-105	4.37
1.25	10 / 25	Poly	6	50	20	24.7	7.7	30.8	8.2	-0.45	-106	4.42
2	10 / 20	Mono, a-Si	4	96	24	54.0	3.3	66.4	3.7	-0.33	-173	1.10
2	10 / 20	Mono, a-Si	4	96	24	54.4	3.4	67.0	3.7	-0.30	-168	0.85
2	10 / 20	Mono, a-Si	4	96	24	54.8	3.5	67.5	3.8	-0.30	-169	0.86
2	10 / 20	Mono, a-Si	4	96	24	55.3	3.5	68.1	3.8	-0.30	-170	0.87
2	10 / 20	Mono, a-Si	4	96	24	55.8	3.6	68.7	3.8	-0.29	-172	0.88
2	10 / 20	Mono, a-Si	4	96	24	56.7	3.6	68.8	3.8	-0.29	-172	0.88
1	10 / 20	Poly	4	108	18	48.3	5.2	60.3	5.8	-0.47	-229	5.80
1	10 / 20	Poly	4	108	18	49.1	5.5	61.3	6.1	-0.47	-233	6.10
1	10 / 20	Poly	4	108	18	50.6	5.9	63.2	6.5	-0.47	-240	6.50
5	12 / 25	Poly	6	40	20	19.2	6.8	24.2	7.4	-0.49	-88	4.80
5	12 / 25	Poly	6	50	25	24.2	6.8	30.4	7.4	-0.48	-111	4.19
5	12 / 25	Poly	6	50	25	24.2	6.8	30.4	7.4	-0.48	-111	4.19
5	12 / 25	Poly	6	50	25	24.2	6.8	30.4	7.4	-0.48	-111	4.19
1	10 / 25	Poly	6	36	18	17.2	7.2	21.3	8.0	-0.49	-72	3.20
1	10 / 25	Poly	6	36	18	17.2	7.3	21.7	8.1	-0.49	-72	3.24
1	10 / 25	Poly	6	42	21	20.0	7.1	24.9	7.9	-0.49	-84	3.16
1	10 / 25	Poly	6	48	16	22.8	7.1	28.8	8.0	-0.49	-96	3.20
1	10 / 25	Poly	6	48	16	23.0	7.3	29.0	8.0	-0.49	-96	3.20
1	10 / 25	Poly	5	72	24	34.8	4.9	43.2	5.5	-0.49	-144	2.20
1	10 / 25	Mono	5	72	24	35.9	5.0	44.8	5.6	-0.49	-144	1.68
1	10 / 25	Poly	6	54	18	25.8	7.0	32.4	7.9	-0.49	-108	3.16
1	10 / 25	Poly	6	54	18	25.8	7.3	32.7	8.0	-0.49	-108	3.20
1	10 / 25	Poly	6	60	20	28.4	7.0	36.0	7.9	-0.49	-120	3.16
1	10 / 25	Poly	6	60	20	28.7	7.3	36.3	8.0	-0.49	-120	3.20
2	10 / 25	Mono	5	72	24	34.8	4.5	43.6	4.9	-0.35	-145	1.40
2	10 / 25	Mono	5	72	24	35.3	4.7	44.0	5.1	-0.35	-145	1.40
2	10 / 25	Mono	5	72	24	35.8	4.9	44.4	5.3	-0.35	-145	1.40
10	12 / 25	Mono	5	72	24	40.0	5.1	47.8	5.5	-0.38	-137	3.50
10	12 / 25	Mono	5	72	24	40.0	5.3	47.7	5.8	-0.38	-137	3.50
5	12 / 25	Mono	5	96	24/48	54.7	5.8	64.6	6.1	-0.38	-177	3.50
5	12 / 25	Mono	5	72	24	34.4	4.7	43.2	5.0	-0.48	-150	0.87
5	12 / 25	Poly	5	72	24	34.4	4.7	43.2	5.0	-0.47	-150	2.30
5	12 / 25	Mono	5	72	24	34.8	4.7	43.6	5.0	-0.48	-150	0.87
5	12 / 25	Poly	5	72	24	34.8	4.7	43.6	5.0	-0.47	-150	2.30
5	12 / 25	Mono	5	72	24	35.2	4.8	43.8	5.1	-0.48	-150	0.87
5	12 / 25	Poly	5	72	24	35.2	4.8	43.8	5.1	-0.47	-150	2.30
5	12 / 25	Mono	5	72	24	35.2	5.0	44.2	5.2	-0.48	-150	0.87
5	12 / 25	Poly	5	72	24	35.2	5.0	44.2	5.2	-0.47	-150	2.30
5	12 / 25	Mono	5	72	24	35.6	5.1	44.4	5.4	-0.48	-150	0.87
5	12 / 25	Poly	5	72	24	35.6	5.1	44.4	5.4	-0.47	-150	2.30
1	NA / 25	Mono	8 x 3.5	48	24	23.0	4.4	28.5	5.0	-0.50	-143	3.39
1	NA / 25	Mono	6	36	18	16.7	6.9	21.0	7.7	-0.50	-105	6.01
1	NA / 25	Mono	6	36	18	16.7	7.2	21.0	8.0	-0.50	-105	6.24
1	NA / 25	Mono	8 x 3.5	72	36	33.4	4.5	42.0	5.1	-0.50	-210	3.99
1	NA / 25	Mono	8 x 3.5	72	36	33.4	4.7	42.0	5.3	-0.50	-210	4.12
1	NA / 25	Mono	8 x 3.5	72	36	33.4	4.8	42.0	5.4	-0.50	-210	4.24
2	10 / 25	Poly	NA	36	NA	17.5	6.9	22.0	7.6	-0.45	-81	7.60

Courtesy www.solarworld-usa.com

Maximum Power Current (Imp)

Definition: Maximum amperage produced by a module or array when exposed to sunlight and connected to a load.

Importance: Maximum power current is one specification used when sizing an array for a given inverter or charge controller.

Open-Circuit Voltage (Voc)

Definition: The maximum voltage generated by a PV module or array when exposed to sunlight with no load (inverter or battery) connected.

Importance: Open-circuit voltage will increase as PV module temperature decreases. To eliminate the possibility of overvoltage conditions that will damage most inverters and charge controllers, a maximum Voc calculation based on the coldest historical temperature for a given site is required during system design.

Short Circuit Current (Isc)

Definition: The amperage generated by a PV module or array when exposed to sunlight with output terminals shorted.

Importance: Modules will not operate at short circuit in the field unless they are incorrectly wired. Using a digital multimeter to check the current of an individual module will briefly short the terminals while the measurement is being taken, allowing you to compare the actual output to the manufacturer's specification during troubleshooting. Additionally, Isc specifications are used for calculating the appropriate amperage rating of overcurrent protection devices.

Maximum Power Temperature Coefficient (% per degree C)

Definition: The change in module output power in percent-per-degree Celsius at temperatures other than 25°C (STC temperature rating).

Importance: Module voltage decreases as cell temperature increases. A maximum power temperature coefficient is one metric that enables you to predict the real-world power output of an array that's operating at elevated cell temperatures. In hot climates, cell temperatures can reach an excess of 70°C (158°F). For example, consider a module maximum power rating of 200 watts at STC, with a temperature coefficient of minus 0.5% per degree C. At 70°C, the actual output of this module would be approximately 155 watts.

Open-Circuit Voltage Temperature Coefficient (mV per degree C)

Definition: The change in module open-circuit voltage in millivolts per degree Celsius at temperatures other than 25°C (STC temperature rating).

Importance: Open-circuit voltage will increase as cell temperature decreases, based on the 25°C STC reference temperature. In turn, Voc will decrease as cell temperature increases. Applying the open-circuit voltage temperature coefficient is one way to determine absolute maximum Voc at a site's coldest historical temperature, and allows you to calculate the reduction in module or array voltage at elevated temperatures.

Short-Circuit Current Temperature Coefficient (mA per degree C)

Definition: The change in module short-circuit current in milliamps per degree C at temperatures other than 25°C (STC temperature rating).

Importance: Short-circuit current will increase in varying degrees as cell temperature increases and Voc decreases. This relationship is interesting in terms of module function, but is not particularly relevant in most system designs.

Access

Joe Schwartz (joe.schwartz@homepower.com), Home Power CEO and executive editor, holds a Renewable Energy Technician license in Oregon. His home and home office are powered exclusively by renewable energy.

Special thanks to *Home Power* Technical Assistant Doug Puffer for module specification research and compilation.

Images on pages 70 & 71 (clockwise from upper left): Courtesy of BP Solar (SX 3195 module); Canadian Solar Inc. (CS5A-180 module); Advent Solar (240 module); Day4Energy (48MC 190 module).

Module Manufacturers:
Advent Solar • www.adventsolar.com
BP Solar • www.bpsolar.com
Canadian Solar Inc. • www.csisolar.com
Day4Energy • www.day4energy.com
Evergreen • www.evergreensolar.com
GE • www.gepower.com/solar
Kyocera • www.kyocerasolar.com
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150VDC
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6 breakers or 4 fuses
Deadfront cover hides wiring
Copper bus can be split for two PV systems
Why pay for a ten or 12 position PV combiner
when most systems have a maximum of six
strings?

Pick the Right Pump

CHOOSING A CIRCULATOR FOR SOLAR HOT WATER SYSTEMS

by Chuck Marken

Some things—the coldest beer or the biggest slice of pizza— are easy to pick, but selecting the right pump for a solar hot water (SHW) system isn't that simple. Pump choices are numerous—DC or AC powered; bronze, stainless steel, iron, or plastic; high, medium, or low head. But picking the right pump doesn't have to be a painful experience. Here's some sound advice on how to best match a pump to your SHW system for years of trouble-free service and high performance.

Low-Head Pumps

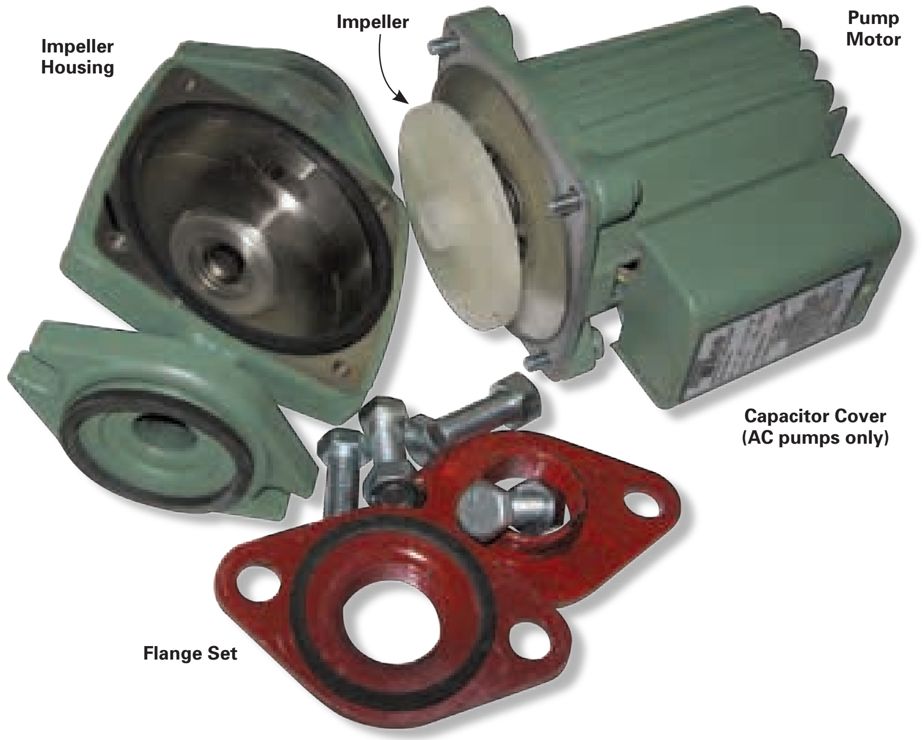
Grundfos 15-18 SU pump. The "S" stands for stainless steel and the "U" is for union (union set shown, extra cost).

El-Sid 10 PV, DC pump. Although it may run on a 10-watt PV module, this pump is usually coupled with a 20-watt module to make sure it starts in all applications.

Pumps used in solar heating systems are called hot water circulators. They move fluid through the solar collectors and/or heat exchanger to where the heated fluid can be stored or used. A circulation pump is made up of a motor, impeller, and impeller housing. The motor spins the impeller in the housing and, through centrifugal force, moves liquid through a plumbing circuit.

Circulation pumps must be primed or wet when they start, as they are not designed to suck liquid into the impeller. Unlike positive-displacement pumps, which can lift a fluid from below the pump, circulation pumps must have the impeller housing filled with the circulating fluid at all times. They are used in closed plumbing loops that are always entirely filled, or in systems with the pump situated lower than a tank's water level.

Common circulation pumps have maximum service temperatures of about 140°F, but almost all hot water circulators are rated above 200°F. Hot water circulators are a must for virtually all active-type solar water heating systems.



Typical flange pump pieces.

Selecting a pump is not difficult—your solar hot water system design will dictate which pumps are suitable, with alternatives falling into three application criteria:

- Pump material
- Pump head and flow rate
- Power source

Taco 006-B4, domestic hot water pump. Note the 3/4-inch copper solder connections.

The Right Materials

Oxygen is good for us, but bad for iron pumps. Oxygen creates a corrosion problem in cast iron pumps, just as steel or iron rusts (oxidizes) when exposed to water and air. The less expensive circulation pumps are made with an iron impeller housing. They are usable in closed-loop systems where little or no oxygenated water exists.

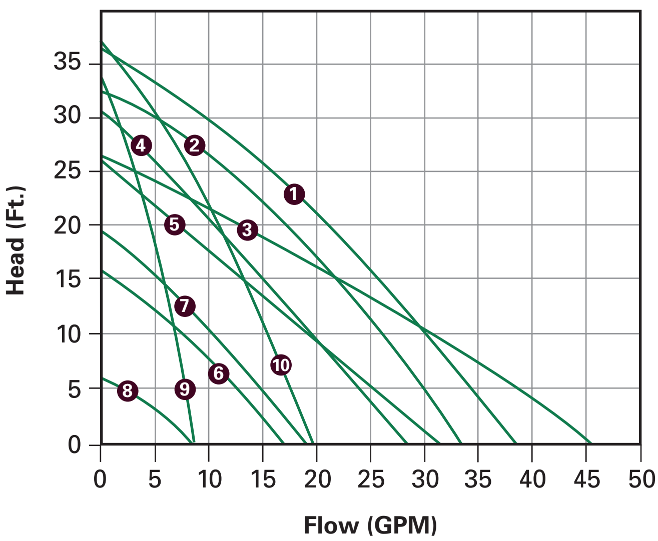
But in open and potable water loops, an iron pump will corrode, impeding the flow or stopping it completely, often within a few months. Domestic hot water loops need pumps with a bronze, stainless steel, or plastic impeller housing and impeller. These corrosion-resistant materials are also recommended for any drainback system that does not use distilled water as the collector loop fluid.

The most common domestic hot water (DHW) pumps are bronze or stainless steel but plastic housing DHW pumps also can last for decades. The cost of bronze pumps has increased quite a bit in the last few years with the increase in copper prices. This has made stainless steel pumps more attractive.

Head & Flow

Depending on their application, pumps must overcome two different types of head—atmospheric and friction. Atmospheric head is the difference in height between the natural level of the liquid when the pump is off, and the height to which the pump needs to push the liquid when the system is operating. The pump must develop enough pressure to push the circulating fluid to the top of the loop or, in the case of a drainback solar water heater, to the top of the collectors. If the pump falls short,

Grundfos AC Pump Performance Curves



1 UP 26-116 F; **2** UP 26-99 F; **3** UP 43-75 F/UP 50-75 F; **4** UP 26-96 F; **5** UP 26-64 F; **6** UP 15-42 F BRUTE II; **7** UPS 15-58F/FC (Spd 3); **8** UP 15-10 F/FR; **9** UP 15-100 F; **10** UP 26-120 U

the system will not function. Pumps in a plumbing circuit that always remains full of liquid do not need to overcome any atmospheric head. These kinds of loops include closed-loop antifreeze and direct-pump open systems.

Friction-head loss is the resistance to flow due to the circulating fluid's contact with the pipe walls. Frictional head increases with smaller pipe diameter, increased length, changes in direction (like elbows, etc.), and increased flow. Given the details of those factors, frictional head loss can be accurately calculated. But normally, those factors are not significant enough to bother calculating in small solar heating systems—except in rare circumstances such as very long piping runs (100 feet or more) with small tubing.

The flow rate through solar collectors should meet the manufacturers' specifications, but there is a good deal of fudge

Installation Notes

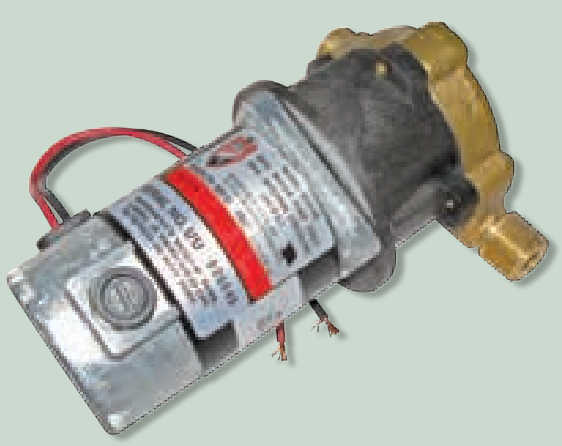
✔ You can put two pumps in series to double the total head pumped. But beware: Using series or stacked pumps to achieve the head required in some drainback systems can cause big problems. If one pump quits during colder months (and they all quit eventually), and the other keeps pumping, it could lift the water just high enough to where it can sit and freeze. The frozen pipe can burst, and then the system could pump all the water in its drainback tank into the attic. This is one reason for the less-than-stellar reputation of drainback systems in some parts of the United States. The solutions to this head problem are to raise the drainback tank to a level that will accommodate the head of the chosen pump (see how James Dontje solved this in his article in *HP120*) or to select a higher-head pump if available.

✔ Many new pump installations will need a flange set or union set to connect the pump to the piping system. Make sure you have the additional parts you need before you start work on the system.

✔ Installing two pumps in a parallel piping arrangement will increase the flow of the circulating fluid, but will not increase the total head.

✔ All the SHW pumps mentioned in this article are classified as "fractional horsepower" and don't require a separate electrical circuit. However, fractional hp pumps do require a disconnect—an appropriately rated switch or breaker or a UL-approved cord and plug connection.

Medium-Head Pumps



The March 809-HS magnetic drive, bronze DC pump needs a 50-watt module to pump to its rated 15-foot head. The magnetic drive tends to be noisier than other types of pumps.

A Grundfos 15-42 iron pump suitable for most small- and medium-sized antifreeze-type solar water heaters (shown with pump flange set).

Solar Pump Specifications

AC Pumps	Volts	Watts	Head Category	Cutoff Head (Ft.)	Gpm at Head	Pump Material	Suitable Applications	Price
Taco 009F	120	168	High	34.00	5 at 20 ft.	Iron	Drainback or large antifreeze systems	$255
Taco 009B	120	168	High	34.00	5 at 20 ft.	Bronze	Drainback systems	420
Grundfos 26-96 F	120	205	High	30.00	15 at 14 ft.	Iron	Drainback or large antifreeze systems	297
Grundfos 26-96 BF	120	205	High	30.00	15 at 14 ft.	Bronze	Drainback or large antifreeze systems	325
Taco 011F	120	211	High	30.00	15 at 18 ft.	Iron	Drainback or large antifreeze systems	273
Grundfos 15-42 F	120	85	Medium	16.00	10 at 9 ft.	Iron	Drainback or large antifreeze systems	108
Taco 008F	120	95	Medium	16.00	10 at 8 ft.	Iron	Drainback or large antifreeze systems	158
Taco 008B	120	95	Medium	16.00	10 at 8 ft.	Bronze	Drainback systems	319
Taco 006B	120	62	Low	8.00	5 at 5 ft.	Bronze	DHW[b] systems	179
Grundfos 15-18 SU	120	85	Low	7.00	5 at 5 ft.	Stainless	DHW[b] systems	179
DC Pumps								
March 809-BR-HS, 12 VDC	12	50	Medium	15.50	4 at 8 ft.	Bronze	Drainbacks or large antifreeze systems	$228
March 809-BR, 12 VDC	12	20	Low	7.00	3 at 3 ft.	Bronze	DHW[b] systems	200
El-Sid 20 PV-direct	12	20[a]	Low	4.17	3 at 42 in.	Bronze	DHW[b] or small antifreeze systems	334
El-Sid 10B12	12	10	Low	3.33	2 at 35 in.	Bronze	DHW[b] or hydronic heating systems	242
El-Sid 10 PV-direct	12	10[a]	Low	3.33	2 at 35 in.	Bronze	DHW or small antifreeze systems	245

Note: The El-Sid warranty only covers pumps to temperatures up to 175°F, which could be a problem in collector loops that experience higher temperatures. [a]Double the PV wattage when not using water as a heat-transfer fluid; in some cases, even circulating water will require a larger PV module to start the pump reliably. [b]Potable water

factor here. Solar collector loops will operate efficiently over a wide range of flow rates, but choosing too large a pump can cost more up-front and will use more energy. And an undersized pump without sufficient head in a drainback system is a disaster—the system just won't work. Collector manufacturers' recommended flow rates are usually published in their literature. If not, you can find this information in the OG-100 ratings directory (see Access).

High-Head Pumps

A Taco 009F high-head iron pump, suitable for most drainback and larger antifreeze systems.

A pump's performance under various conditions is shown by its "pump curve." This performance curve is typically presented as a graph or a table, with selected flow rates given at different pump pressures. The pressure a pump exerts is usually expressed in feet (sometimes decimeters) of head. Feet of head is a more useful way of expressing the pressure in real-world circumstances and is used in most pump curves. It can also be expressed in pounds per square inch (psi), where 1 psi equals 2.31 feet of head. In graph form, the head is the vertical axis and the flow is the horizontal axis. As you can see in the example graph (opposite page), as the head decreases, the flow increases.

AC or DC?

One of your final considerations for choosing a pump depends on whether you're planning to use AC or DC to power it. Both kinds of pumps are available, but the range of available DC pumps is much narrower than for AC. AC pumps have an unlimited energy supply if they are powered by a reliable utility grid. DC pumps can be run directly by a PV module and make a solar water heating system independent of the grid.

One way to approach the DC and AC pump choice is to examine relative system efficiencies. The efficiency of some heating systems is rated by the relationship of the amount of energy output to the energy input. If you have a system that produces a certain amount of heat with half the equivalent electrical input, the "coefficient of performance" (COP) is 2. Produce four times as much hot water as the amount of energy input from electricity and the COP is 4. We can use this same methodology in evaluating the efficiency of SHW pumps.

Using a utility-powered AC pump for your solar water heating system will give you a COP between 12 and 25, and this is an excellent value compared to electric water heaters, which have a COP of 1. But the COP will never be as good as a DC PV-powered SHW system. DC hot water circulation pumps can have a higher COP than AC pumps because there is no traditional energy input if a PV module powers the system. If you use a solar-electric module to power the pump, your COP is infinite—you're not adding *any* input energy. The sun provides it all, and you get something for nothing after the initial investment. PV-powered systems are also immune to utility outages. This is a big plus with antifreeze systems, since the collectors can overheat on sunny days if the pump stops operating due to a power failure. An overheated collector can actuate the pressure-relief valve, which will make it necessary to recharge the system with antifreeze solution. In some cases, the overheating can be so severe that the antifreeze solution will be compromised to the point of needing replacement.

Although it seems like a no-brainer to go with a DC PV-direct power source for your solar water heater pump—not so fast. A few other factors can influence your decision about the power source:

- Some DC pumps are noisier than AC pumps, which can make an installer think twice about the placement of a DC pump.
- High-head drainback DC pumps are few and far between. Finding a reliable high-head DC hot water circulator is impossible at this time, limiting the head of a DC drainback system to about 15 feet.
- Any given PV module and SHW collector are rarely a perfect match. The PV module often will "outproduce" the collector and the pump may run early in the morning or late in the afternoon when the collector isn't producing useful heat. The result? Unwanted pump operation can actually cool the water in the solar storage tank. Until recently, no DC-powered differential controllers were available to limit this unwanted pump operation. Art Tec (see Access) recently began manufacturing a DC differential controller that optimizes pump run-time in PV-direct SHW systems.

AC hot water circulators are firmly entrenched in normal distribution in the United States and are therefore less expensive and easier to procure. A DC pump will cost more than an AC pump of the same head and category, and the PV module will add to the cost—but if it fits into your design and budget, the extra cost is well worth the expense. PV-powered DC pumps are normally the optimal choice for a solar heating system except in high-head drainback and very large antifreeze systems.

The Fine Print

Knowing how to decipher the fine print on the pump can give you valuable insight into whether or not it'll be a good match for your SHW system. For example, the "15-18 SU" model number of a Grundfos pump tells you that the impeller housing inlet is 15 millimeters and the maximum head is 18 decimeters; "S" is for stainless steel, and "U" is for union attachment.

Other manufacturers have model numbers that may also denote the power consumed or the pump construction. An "F" in a model name usually denotes a flange iron pump, which can make the pump housing easily removed and replaced. "B" stands for bronze, so a "BF" would be a bronze flange pump. Look at the Solar Pump table (previous page) to see some of the relationships between model numbers and specifications.

Common Pumps

Several pumps and manufacturers are listed in the table and Access. The models listed were included because they are readily available and most folks in the solar industry are familiar with them, but there are also others on the market. One very important point: Make sure any circulation pump you consider for a SHW system is intended for hot water—at least 200°F for most systems.

Besides that, knowing a few simple rules and the manufacturer's pump specifications is all you need to make an intelligent choice, whatever your needs. After almost thirty years installing and servicing solar hot water circulation pumps, almost all the models I've used seem very durable and long lasting. So pick your pump(s) and get into some really hot water.

Access

Contributing editor **Chuck Marken** (chuck.marken@homepower.com) is a New Mexico licensed plumber, electrician, and heating and air conditioning contractor. He has been installing and servicing solar thermal systems since 1979. Chuck is a part-time instructor for Solar Energy International and the University of New Mexico.

Art Tec • 866-427-8832 • www.arttec.net • DC differential temperature controller

Solar Rating and Certification Corp. • www.solar-rating.org • OG-100 ratings directory

Pump Manufacturers:
Bell & Gossett • 847-966-3700 • www.bellgossett.com

Grundfos Pumps Corp. • 913-227-3400 • www.grundfos.com

Ivan Labs • 561-747-5354 • El-Sid pumps

March Manufacturing Inc. • 847-729-5300 • www.marchpump.com

S. A. Armstrong Ltd. • 416-755-2291 • www.armstrongpumps.com

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Solmetric SunEye

Solar Site Evaluation Tool

by Joe Schwartz

In August 2006, I heard from a friend at Hewlett-Packard that a former co-worker of hers had designed a new solar shading analysis tool that I should check out. Two weeks later at the SolFest renewable energy fair, Willard MacDonald, president of Solmetric, walked up to the *Home Power* booth with the tool my friend had mentioned. After a 15-minute guided tour of Solmetric's SunEye, it felt like solar site analysis had just been launched into the twenty-first century.

Solar Site Analysis

Home Power regularly stresses the importance of accurate solar site assessment. PV generation will be crippled if the array is installed in a location with excessive shading. Shading also affects the productivity of solar hot water collectors, although to a lesser degree than for PV modules. And shading analysis is important when designing passive solar buildings—it helps determine optimal building orientation, window locations, or trees that might need to be removed (or planted) to improve or limit solar access for particular sides of a structure.

SunEye Overview

The Solmetric SunEye is a handheld solar access and shade analysis tool. It integrates a Hewlett-Packard iPAQ PDA, used as the processor and user interface, with a digital camera, compass, and bubble level. Solmetric has refitted the iPAQ with custom software. The touch-screen interface provides easy navigation and operation with the touch of a finger. With a suggested retail price of $1,355, the SunEye is designed and built for PV, solar thermal, and passive solar building professionals (and is compliant with California's incentive programs).

Setup

The initial SunEye setup takes just a few minutes—complete the guided touch-screen calibration, set the date and time, and the unit is good to go. The SunEye Desktop Companion software, provided on CD-ROM, enables you to export collected site data to a Windows-based computer for further analysis, report generation, and archiving. Free connectivity software can be downloaded to allow the SunEye to interface with your PC, and SunEye software updates are made available on Solmetric's Web site. Mac operating systems are not supported.

Solmetric SunEye Details

MSRP: $1,355

Warranty: One year

Computer System Minimum Requirements: Windows Vista, Windows XP, or Windows 2000; 700 MHz processor, 256 MB RAM, 20 MB hard drive space; and Internet Explorer

Surveying a Site

Once you're ready to perform a solar site survey, power up the SunEye, create a new session, and select the city and state nearest to the site location. Alternatively, latitude, longitude, and magnetic declination can be entered manually. The array orientation (azimuth) and tilt angle default to true south and latitude respectively. But both of these variables can be changed in the Skyline Properties menu. This feature also allows you to determine solar access for arrays oriented east or west of true south, as well as at different tilt angles.

To capture a skyline graphic of the site, fully open the SunEye cover and select "Skyline" from the Display menu. Orient the compass toward magnetic south (declination is automatically calculated based on the selected location), and use the bubble level to level the tool. Then, simply touch the "Snap" icon to capture the image. Holding the curved edge of the SunEye firmly against your body will help you keep the tool steady.

The SunEye can store skylines and data for more than 50 site readings before uploading to your computer for archiving. The captured skyline is automatically saved, and an annual solar access percentage is instantly generated, along with separate percentages for May to October, and November to April. Changing to the "Monthly Solar Access" view generates a month-by-month bar graph of solar access percentages.

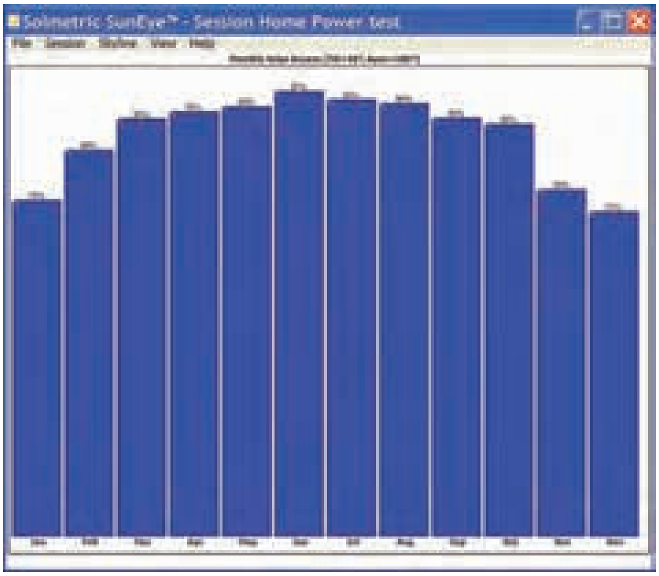
One great feature of the SunEye is its option to average multiple skylines from a single survey session. This is useful when surveying the entire area being considered for a large PV array. For example, a skyline from each corner of the potential array site can be captured to calculate the average solar access. This approach also helps determine daily shading patterns on various segments of the proposed array to plan the optimal configuration and layout of individual PV series strings.

Image Editing & Reports

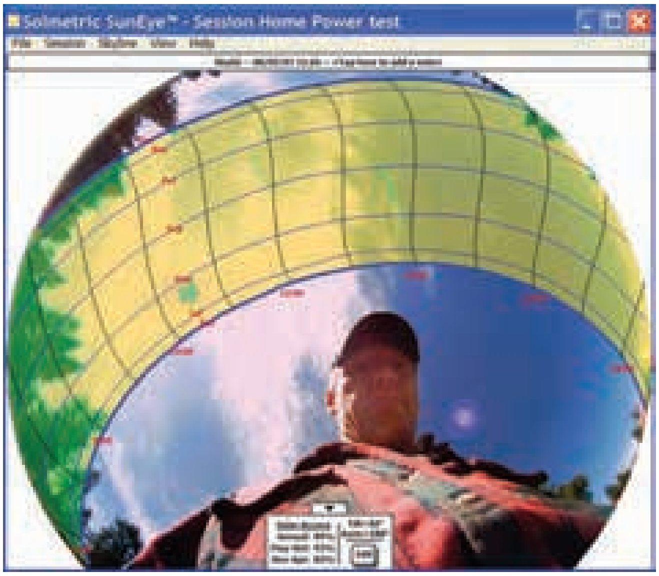
Both the SunEye and the Desktop Companion include skyline image editing software to fine-tune any shading patterns that may not have been interpolated accurately by the SunEye software. The image-editing tool also lets you "remove" objects, such as trees that are creating unwanted shade in a skyline/sun path image. At the touch of a finger, you can remove a tree that's causing excessive shading, and automatically recalculate the solar access that would be available if the real obstruction were removed.

The SunEye Companion software generates a comprehensive report that includes sun-path images, monthly solar access bar graphs, and links to spreadsheet-compatible tables for a survey session. The tables include data for daily

SunEye's "Monthly Solar Access" display.



SunEye's sun-path display.



solar access, insolation, shading, and obstruction elevations for further analysis.

SunEye Battery Basics

The SunEye can be charged using the provided AC charger, from a computer via the USB cable, or using an optional DC car charger. The lithium-ion (Li-ion) battery in the iPAQ has an expected life of 400 to 500 full charge cycles. At a typical discharge of 50%, the manufacturer estimates a battery life of 800 to 1,000 cycles. The battery is not removable, so in the case of failure, the unit must be shipped to Solmetric for replacement. Solmetric policy keeps the typical battery replacement turnaround time to one day, plus shipping time. Loaner units are available if a battery replacement would result in unacceptable downtime for the user.

In good condition, a fully recharged SunEye battery will power the unit for about three hours of continuous use. The Li-ion battery has a fairly high self-discharge rate and will completely lose charge after about nine days if left unused without charging. Data will be held in memory in this case, but the touch-screen and date and time will need to be reset. If you're used to keeping cell phones, MP3 players, PDAs, and the like recharged and ready for use, adding the SunEye to your charging routine will be easy.

Solmetric recommends keeping the unit continuously connected and charging so it's ready to go when you are. I was curious about how much energy the SunEye would draw under a constant float charge. After 24 hours, the Kill A Watt power meter I used for testing didn't register a single kilowatt-hour (KWH). In float service, the SunEye draws between 0 and 1.2 watts. Over 24 hours, I estimate the unit would consume less than 20 watt-hours.

More to Come

Solmetric is developing a new version of their SunEye software package called SunEye Pro. This major software upgrade is expected to cost less than $200 and will be compatible with existing SunEye units. The upgrade will incorporate state-specific incentive program shading criteria. The SunEye Pro software will report the optimal array tilt and azimuth for a given site, and data output will be converted to KWH in addition to the percentage figures provided by the current SunEye software. One great advantage of the SunEye's software-based design is the ability to upgrade the unit as new features become available—this tool will just get better and better.

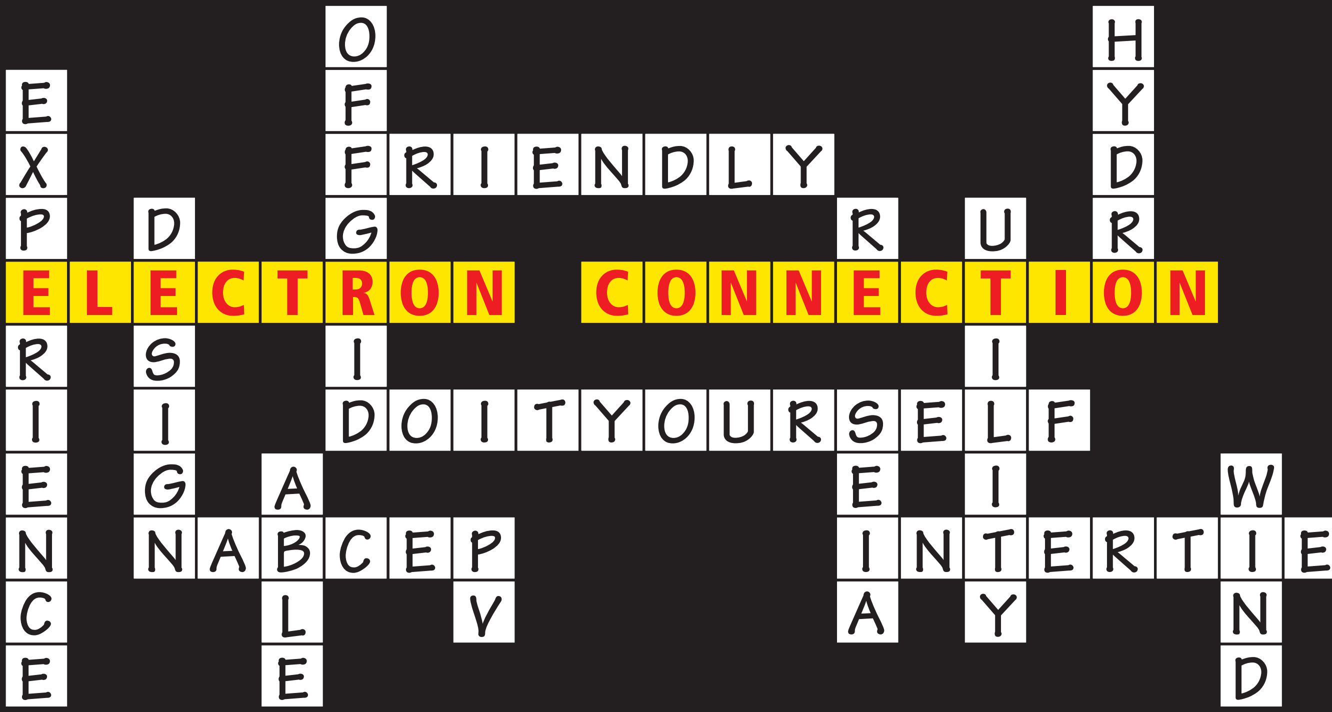
Access

Joe Schwartz (joe.schwartz@homepower.com), Home Power CEO and executive editor, holds a Renewable Energy Technician license in Oregon. His home and home office are powered exclusively by renewable energy.

Solmetric Corp. • www.solmetric.com • Manufacturer

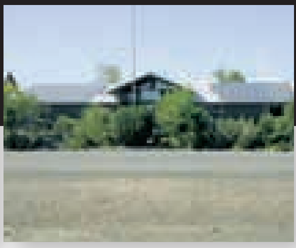
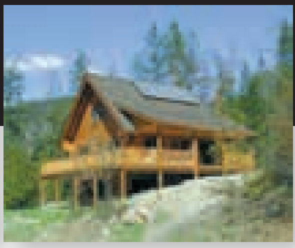
DC Power Systems • www.dcpower-systems.com • SunEye distributor

Puzzled? We've Got the Solution.



A well designed renewable energy system is much more than a pile of hardware.

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Profiting from PV

Peter, Tanya, and Noelle Ptak in front of their PV-powered residence.

by Regina Anne Kelly

If you were to stop people on the street and ask them to name states known for strong growth in solar-electric system installations, chances are that few would mention New Jersey. But the state has some of the most favorable residential and commercial solar incentives in the nation. Here's how a New Jersey couple put solar electricity to work for them—at home and on their rental properties.

In 2006, the total number of residential and small business grid-tied solar-electric systems in New Jersey topped 1,500. This was an exponential increase from just five years earlier, when there were only *six* installed in the state. The impetus for this amazing change? New Jersey's incentive-based clean energy program, which was launched in 2001.

Strong financial incentives enticed Peter and Tanya Ptak to invest in three solar-electric systems. In 2005, they installed a system on their Red Bank home and, because New Jersey's solar support was so sweet, decided to have two more systems installed on their rental properties in 2006.

PV's Appeal

The Ptaks wanted to put an end to their electric bills and support clean energy in a state that generates almost half its electricity by burning coal. Then they discovered that New Jersey's Clean Energy Program (NJCEP) could allow even a family with an average income to afford an investment in solar electricity.

Especially enticing was the short economic payback period for PV systems under NJCEP's program. "Many people here pay [their utility] $200 per month for electricity," says Peter. "When do they finish paying that off? *Never!*" In contrast, investing in a solar-electric system can be likened to paying electricity bills several years in advance, and at a fixed rate. With New Jersey's attractive renewable energy incentives, the Ptaks calculated that a properly sized PV system that would meet all their electricity needs could pay for itself within seven to ten years. After that, all the electricity it produces is not only free, but surplus electricity generated means that the system will be *earning* them money.

When the Ptaks installed their first system, they received a one-time rebate of 70% of the system's total cost. New Jersey also issues Solar Renewable Energy Certificates (SRECs)—financial credits granted by the state's public utility commission. Owners of systems that produce energy from renewable sources receive credits for the clean energy their systems generate—credits they can then sell to electricity suppliers to help them meet the state's renewable portfolio standard.

Another important financial incentive is net metering, by which utilities credit owners of grid-tied PV systems at the retail rate for any electricity their systems produce, until their cumulative electricity use is offset. In New Jersey, annualized net metering zeroes a customer's account at the end of a 12-month cycle, based on the system's initial commissioning date. This allows surplus energy generated during sunnier months to be banked, and the credits applied against utility electricity used during seasons when the PV system produces less energy. At the anniversary date, any surplus energy credit generated beyond what the home or business has consumed is purchased by the utility at their "avoided cost" rate (usually about 25% to 30% of the retail rate per kilowatt-hour), and a check is issued to the customer.

The up-front incentives, coupled with solar energy certificates, a solid net-metering program, and the prospect of generating pollution-free power, appealed to the Ptaks. They were consuming approximately 6,800 KWH of electricity per year, and spending up to $90 per month on electricity for lighting, localized space heating, and appliances. Investing in PV systems to power both their home and rental buildings would be good for the environment—and their pocketbooks.

Solar Savings

Sea Bright Solar, a PV system design and installation company, provided the Ptaks with an estimate for a batteryless 5.44 kilowatt (KW) solar-electric system that would offset all their home's annual electricity usage. The Ptaks took advantage of Sea Bright's payment program of floating the rebate, a common practice among New Jersey installers that allows customers to divide the after-rebate cost into installments. To ease any impact on their budget, they divvied the total cost into three payments: a deposit, a payment upon equipment delivery, and a final payment after the system passed local electrical and building inspections.

Since the system's installation in 2005, besides eliminating their electricity bill and saving them $780 in their first year, it has earned the Ptaks $1,000 through SREC sales. In 2006, on the system's first anniversary, they also received a $65 check from Jersey Central Power & Light for the surplus energy their system generated.

The Ptaks predict additional "future" savings beyond their utility bills and SRECs if they ever decide to sell their home. According to a report funded by the U.S. Environmental Protection Agency and the Department of Housing and Urban Development, every dollar saved in utility bills the first year that a PV system is installed represents a $20 increase in property value. Based on this estimate, the Ptaks' PV system's first-year savings would translate into a property value increase of $15,600—well above their initial investment of about $13,000. Not factoring in the increase in property value, their financial break-even point to recoup the system's initial cost will only be about eight years.

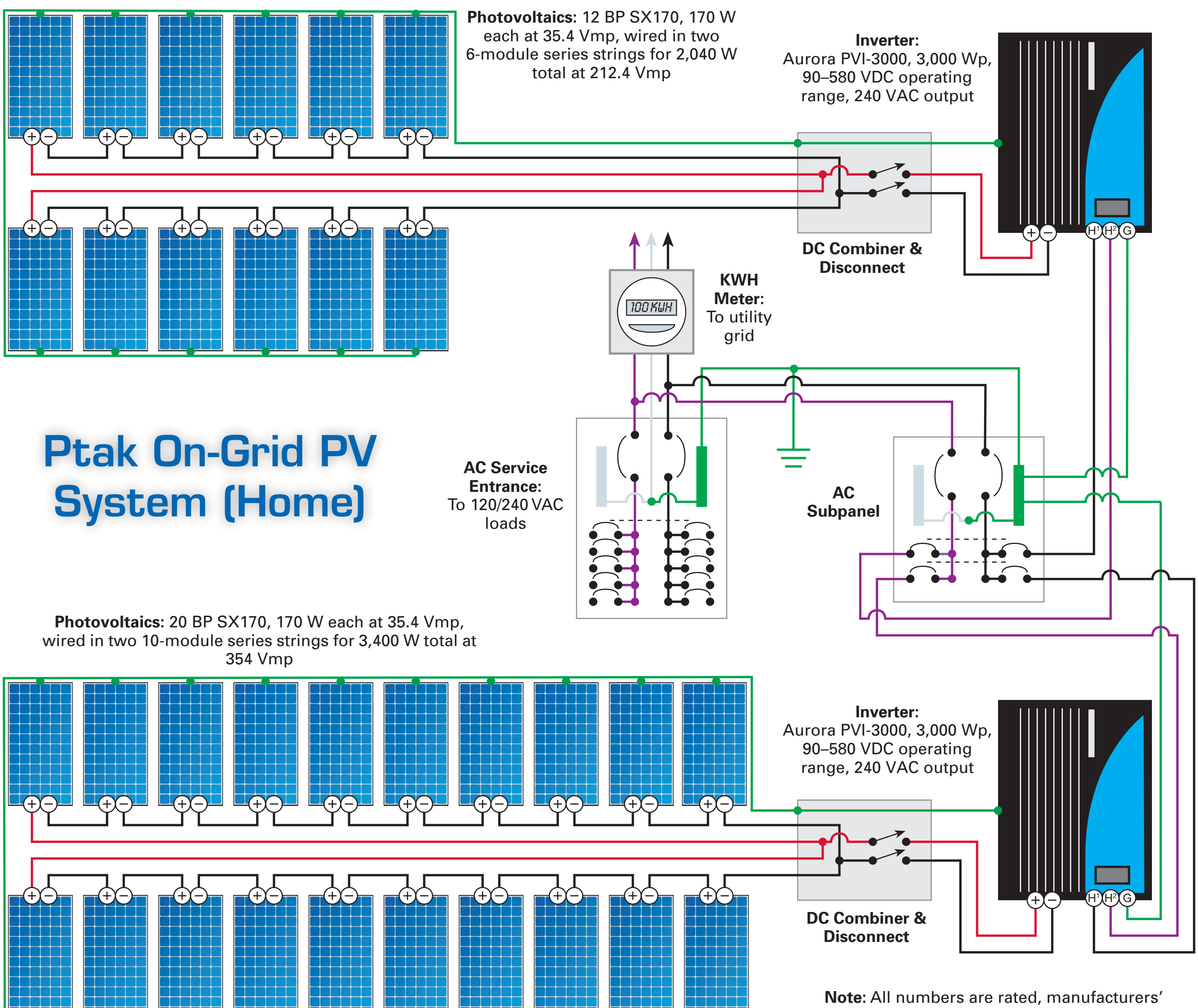
After installing PV on their residence, the Ptaks also installed solar-electric systems on their rental properties.

Renewable Rentals

Their home PV system's many benefits inspired Peter and Tanya to consider solar electricity for their two rental homes, across the street from their house. After some serious number-crunching, they realized installing PV systems on the two rentals would make them eligible for a combined rebate of more than $50,000. Plus, they'd own the SREC production of their rental properties' systems, estimated to generate about $2,500 in annual income. Installing the systems as a business venture also meant the Ptaks could take a 30% federal investment tax credit.

It was too good to pass up. In the fall of 2006, the Ptaks had a 5.27 KW system installed on one three-bedroom, single-family rental property and a 4.59 KW system installed on their other Cape Cod-style rental home, as part of a Solar Energy International PV design and installation class. Three primary criteria determined the size of each system: the area of the available south-facing roof, the Ptaks' desire to eliminate as

Two Power-One Aurora inverters synchronize the solar-electric system's output with the utility grid.



To maximize the solar energy rebate, the system design fully utilized the available roof space on the Ptaks' rental properties.

much of the buildings' grid electricity use as possible, and a unique rebate policy that considers two adjacent properties with the same owner to be eligible for one combined rebate. Under the current NJCEP solar rebate schedule, the greatest rebate is available on systems that are no greater than 10 KW. To maximize the rebate, Sea Bright Solar's system design fully utilized the available roof space on both houses, for a combined system size of 9.86 KW—just under the maximum.

"Before installing the PV systems, I found that our renters had a tendency to use—if not *waste*—more energy than we, as homeowners, did," says Peter. Housemates typically would split the electric bill evenly, resulting in lower individual costs—with little incentive to conserve energy. Peter and Tanya were interested in encouraging more energy conservation, while passing the solar savings on to their tenants. They charge their tenants about 90% of the utility value for the solar-generated electricity, while the tenants are responsible for paying any utility balance beyond what the PV system generates. "Charging a slightly reduced rate for electricity makes it more enticing for them to rent," says Peter. "This keeps the properties rented longer, which keeps our profit margin higher over the years."

Practical PV Payoff

The Ptaks are passionate about the practical benefits of tapping into the sun for electricity. They now have a minimal to nonexistent electric bill and annually receive a check for any surplus electricity their systems generate. They are also proud to have effectively reduced their "carbon footprint," environmental pollution, and other associated impacts of burning fossil fuels. Their home's PV system alone saves about 9,100 pounds of carbon dioxide, 32 pounds of nitrogen oxide,

Tech Specs (Ptak Residence)

Overview

System type: Batteryless, grid-tie solar-electric

Location: Red Bank, New Jersey

Solar resource: 4.7 average daily peak sun-hours

Production: 540 AC KWH per month, average

Utility electricity offset annually: 100%

Photovoltaics

Modules: Thirty-two BP SX170, 170 W STC, 35.4 Vmp

Array: Two 6-module series strings parallel, 2,040 W STC, 212.4 Vmp; two 10-module series strings parallel, 3,400 W STC, 354 Vmp; 5.44 KW STC total

Array disconnect: Two Square D, 30 A, 600 VDC

Array installation: UniRac mounts; south-facing; 12 modules mounted parallel to roof at 35 degree tilt; 20 modules mounted on elevated racks at 10 degree tilt

Balance of System

Inverters: Two Power-One (Magnetek) Aurora PVI-3000, 600 VDC maximum input voltage, 90–580 VDC operating range, 240 VAC output

System performance metering: Internal inverter meters & utility KWH meter

PV in New Jersey—Incentive Ups & Downs

With favorable financial incentives for PV systems, it's no surprise that solar energy has had a strong start in New Jersey. During the first six years of the New Jersey Clean Energy Program (NJCEP), the state granted more than $120 million in rebates for PV projects, with the highest number of rebates and installations occurring in 2006. The total amount of rebates given in 2006 was *1,670 times greater* than that in 2001.

But with so many new systems going online with the help of state funds, New Jersey's Board of Public Utilities began reducing the rebate in 2005. When the solar rebate program launched, the NJCEP offered $5.50 per watt, or 70% of the cost of the installed system (whichever was lower), up to a maximum of 10 KW of installed capacity. As of August 2007, the rebate is $3.80 per watt—smaller, but still substantial. The NJCEP has announced a new rebate reduction to $3.50 per watt effective September 1, 2007. However, due to high demand and rapid growth of the program, some customers and installers have been waiting more than a year to find out whether their rebate applications have been accepted.

In an effort to smooth what has at times been a roller-coaster ride for New Jersey PV system installers and potential customers, NJCEP is investigating a performance-based rebate structure for commercial systems and a performance-based/smaller up-front rebate structure for systems less than 10 KW. Under the performance-based model, consumers receive their incentives on an ongoing basis as their systems produce clean energy, and solar facility owners are awarded a cost-per-KWH incentive for the electricity they generate with PV systems. This past spring, the NJCEP implemented a pilot program in which the state does not offer an up-front rebate, but instead compensates system owners by awarding them SRECs (Solar Renewable Energy Certificates), financial credits granted by the state's public utility commission.

Significant financial incentives that support solar electricity are not limited to New Jersey. About 20 states have their own clean energy rebate programs that make solar energy an attractive investment for residential and commercial energy consumers alike, and individual utilities in these and other states may offer their own incentive programs as well. (For specifics, see the Database for State Incentives for Renewables & Efficiency at www.dsireusa.org.)

A one-time federal tax credit of up to $2,000 is also available for residential solar energy systems, and business owners investing in renewable energy technologies are eligible for a federal tax credit equal to 30% of their system's costs.

and 52 pounds of sulfur dioxide from being emitted each year, according to National Renewable Energy Laboratory estimates.

The Ptaks' multiple PV systems also have had a positive influence on their community. "Everyone was basically blown away," says Peter. "I tell them all about the program, and they become very interested and want to learn more. [Some of them may be] a bit put off by the initial cost, but those who really understand the concept realize that it is ultimately an investment that pays off in the long run." One of Peter's co-workers decided to have an 8.5 KW ground-mounted system installed in 2006. Peter says that several other homeowners he knows "have been very interested in learning more about the systems that they could feasibly install. People are intrigued by the 'no electric bill' factor."

Ptak System Economics

	Residence (5.44 KW)		Rentals (9.86 KW)	
Item	**Amount**	**$ Per KW**	**Amount**	**$ Per KW**
Installed cost	$42,704	$7,850	$75,922	$7,700
State rebate	-29,892	-5,495	-50,286	-5,100
SREC payments	-1,200	-221	-2,400	-243
Electrical savings	-850	-156	-1,600	-162
Federal tax credit & depreciation	0	0	-7,691	-780
Net Cost	$10,762	$1,978	$13,945	$1,414

Access

Regina Anne Kelly is a professional writer and the author of *Energy Supply and Renewable Resources* (Facts On File, 2007). Her articles have appeared in several scientific and trade journals. She holds an M.A. in English literature from Fordham University and a B.A. in journalism and English from Rutgers College.

Peter & Tanya Ptak • ptakpeter@hotmail.com

Sea Bright Solar • 866-SOLAR-1-S • www.seabrightsolar.com • System installer

New Jersey Clean Energy Program • www.njcleanenergy.com

Solar Energy International • www.solarenergy.org • Workshop presenter

PV System Components:

BP Solar • www.bpsolar.com • PV modules

Power-One • www.power-one.com • Aurora inverter

UniRac • www.unirac.com • Array mounts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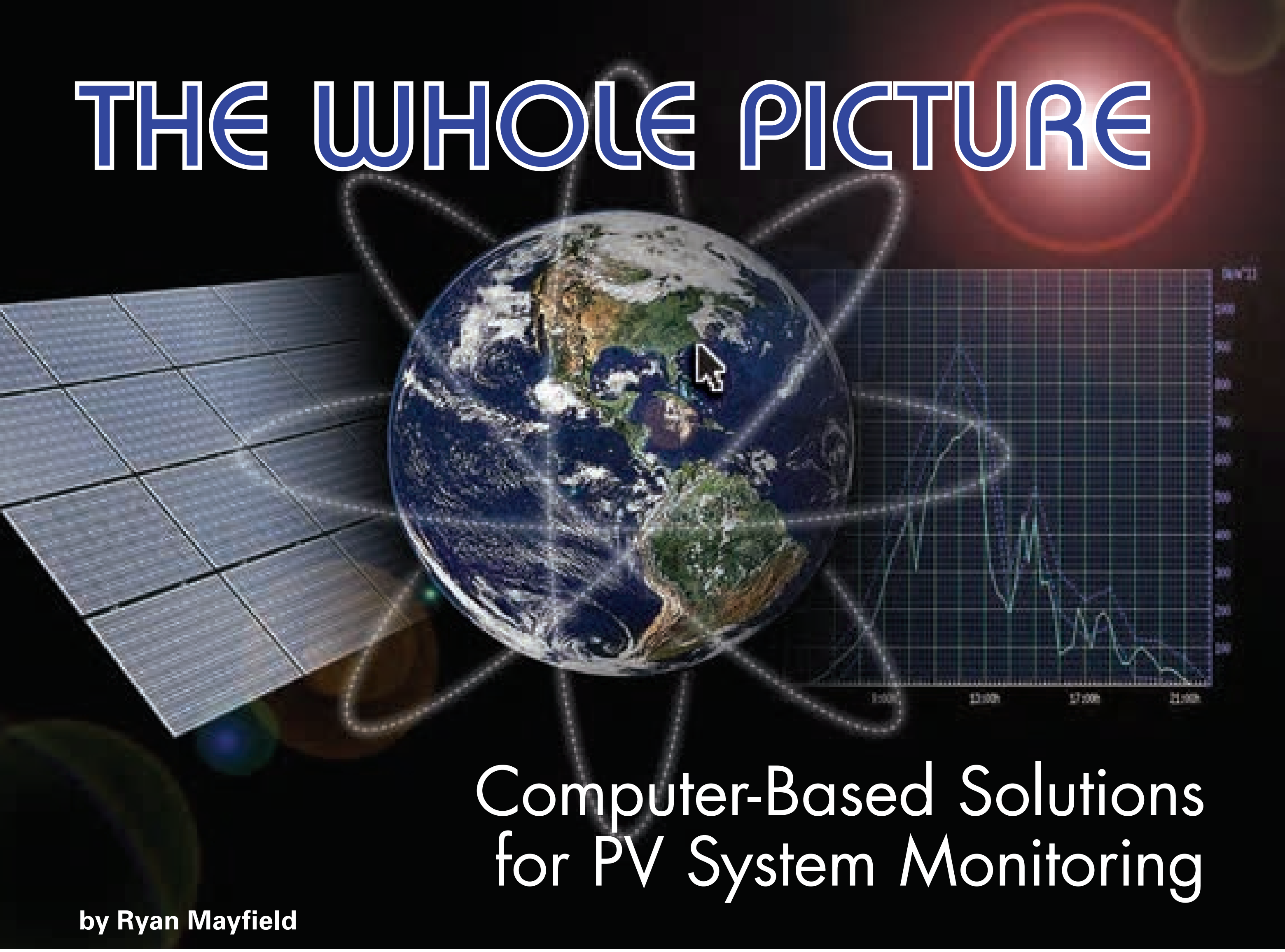


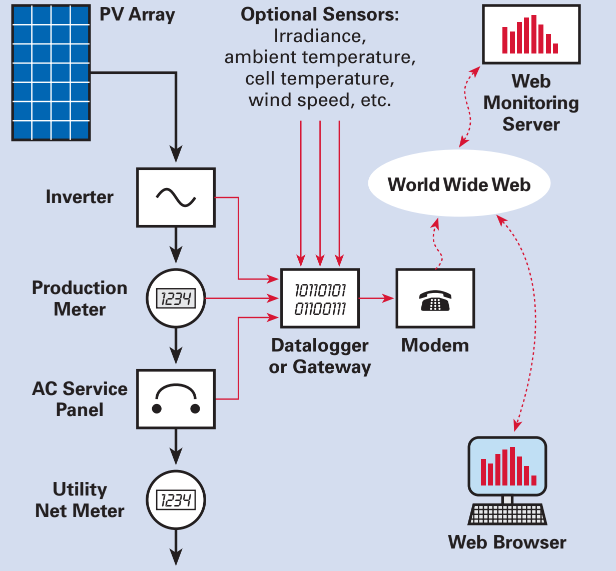
THE WHOLE PICTURE

Computer-Based Solutions for PV System Monitoring

by Ryan Mayfield

The beauty of batteryless grid-tie PV systems lies in their simplicity: Few, if any, components with moving parts translate into virtually maintenance-free electricity generation. But the hands-off nature of grid-tie PV can make it easy for an owner to lose track of their system's daily operation and assume it is functioning optimally—even if it isn't. Unless you tend to keep a close eye on your electric utility bill, in some cases months might go by before a problem is detected.

Example Web-Based Monitoring System



Several inverter manufacturers now provide wireless meters to allow system monitoring from any room in your house.

Monitoring Battery-Based Systems

Battery-based systems, both off- and on-grid, can be monitored with more sophisticated equipment than a standard battery amp-hour meter. Regular monitoring of battery state of charge can make the difference between a battery bank lasting ten years—or less than a year, if the batteries are overdischarged or not fully recharged on a regular basis.

Most battery-based inverter manufacturers offer local monitoring solutions, using software either designed by the manufacturer or by a third-party developer. Several third-party solutions allow battery-based systems to be monitored over the Web, including Chuck Wright Consulting, Draker Solar, Fat Spaniel Technologies, RightHand Engineering, and Watt Plot. Software that interfaces with inverter-direct communication, as well as stand-alone, inverter-independent datalogging equipment, is available.

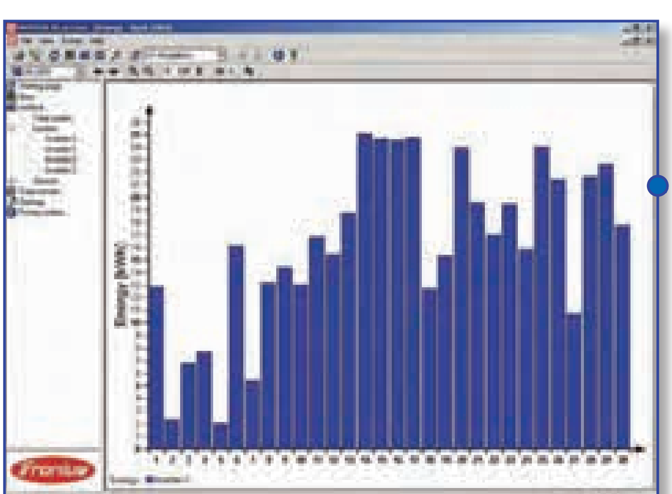
While infrequent, PV system equipment failures or faulty installation work can have a significant financial impact when they go unnoticed. This is especially true of large installations, or systems that receive performance-based incentive payments tied to the kilowatt-hours a system generates. These potential issues are being met by a wave of inverter-based and third-party system monitoring solutions that, with a few components and a computer or handheld mobile device with Internet access, allow PV owners, installers, and integrators to verify system performance on-site—or from the other side of the globe.

There are two basic approaches for monitoring the performance of your PV system with a computer—local and Web-based. Local monitoring can be as simple as checking the data your inverter collects and displays daily, or using a local storage device, such as a datalogger or computer, to store information collected by the inverter. Web-based monitoring relies on either independent or inverter-based communications, and a "gateway." Besides aggregating the data and serving as a node on your local network, this can provide the connection to an outside network (like your Internet service provider) to send the data to the Web for display.

Local Monitoring Options

Meters & Wireless Displays. The simplest method for local PV monitoring relies on the built-in meter that accompanies most batteryless grid-tie inverters. Here, you can view basic performance data that typically includes AC power, voltage, and current, as well as DC array voltage, daily energy production, and cumulative energy production since the inverter was commissioned. Some inverters have transmitters that broadcast data to a small wireless receiver that you can place in a convenient location in your home for easy viewing.

The Fronius datalogger can record information from up to ten inverters. Fronius also offers free Web-based data hosting via their new SolarWeb site.



SMA's WebBox provides a link the between the PV plant and the Internet.

Depending on the inverter design, performance data may be available for only a fixed amount of time, and some of the information may disappear with the sun when the system stops producing energy for the day. In this case, reviewing the details of your system's performance after sunset becomes an impossible task. Your utility KWH meter will always be tracking the amount of energy your PV system generates, but for users who enjoy or require access to both ongoing and cumulative system data, basic inverter-based collection may not be sufficient.

Computers & Dataloggers. If you want to collect and store data over longer periods of time, or want the ability to export system data to a spreadsheet program for further analysis, the next step in local monitoring is to incorporate an interface between the inverter and a data storage medium. A common method is to connect the inverter directly to a computer via a standard RS232 or RS485 serial connection. The computer monitors and logs the system data, which is generally the same information that's tracked by the inverter's integrated meter. Software, either developed by the inverter manufacturer or a third-party developer, runs on the computer, stores the data, and presents it in a simple graphical format. One potential drawback to this method is that the computer must be running the monitoring software for data to be collected. Another minor inconvenience is that many newer computers do not have the older-style serial ports. To make the connection to a USB port, you'll need to pick up an adapter.

Some inverter manufacturers offer add-on datalogging devices that interface between the inverter and a computer. These dataloggers usually have the ability to monitor multiple inverters, allowing you to track individual inverter operation, as well as the functioning of the entire PV system. The datalogger collects and stores data independently, and enables you to connect a computer at a convenient time to download the data. The amount of data that can be stored is a function of the datalogger's memory capacity, the number of different types of data being collected, and the rate of collection.

Many dataloggers have the flexibility to accept information from additional environmental sensors, such as temperature probes, irradiance sensors, and anemometers. You can essentially build your own weather station and synchronize the collected environmental data with your PV system data. When viewed together, environmental and PV performance data can shed a lot of light on how things like temperature and cloud cover affect the voltage, current, and KWH output of your PV system. Some dataloggers can also be used to monitor electrical loads or even individual series strings within a PV array.

Data can be accessed for free through the SunnyPortal site.

Web-Based Monitoring

Web-based monitoring is a great way for both individuals and businesses to promote the benefits of their PV systems to a larger audience. In addition, it allows system installers easy, remote access to performance data if troubleshooting is required. An increasing number of installers are including Web-based monitoring during system installation for just this reason.

The two most common approaches for "pushing" PV system data to the Web use equipment and services provided by the inverter manufacturer or use a third-party data service provider. Some system integrators offer Web-based monitoring options as well.

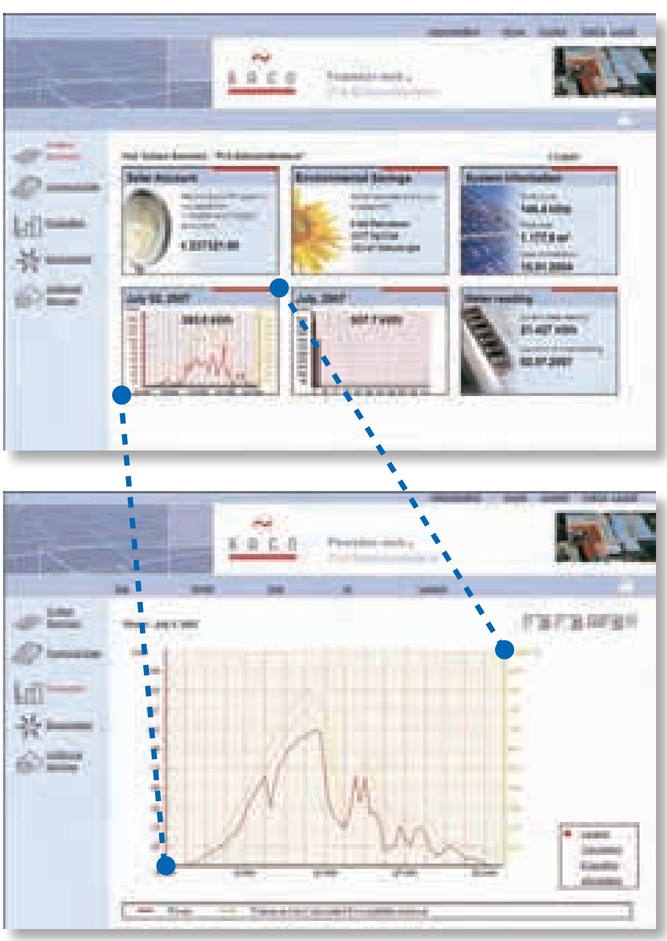
Inverter-to-Web. Most batteryless grid-tie inverter manufacturers have developed equipment for displaying PV system data on the Internet. With a moderate investment in additional communications hardware, you can access system data from any Internet-connected computer or handheld mobile device. Some manufacturers also offer free data hosting services.

Inverter direct-to-Web connectivity requires an inverter with communications capability and, ideally, a high-speed Internet connection—although most manufacturers can facilitate communications with a dial-up service. The inverter is connected to the Internet through a gateway, and the data is sent to a server either hosted by the manufacturer or a third party, where it is compiled and placed in graphical format for display. Some manufacturers offer additional services such as monitoring environmental conditions or sending notifications when abnormal or fault conditions occur.

Manufacturers that currently offer inverter-to-Web solutions include Fronius, GridPoint, Kaco, Power-One, PV Powered, SatCon, Solectria, SMA, and Xantrex. The level of sophistication varies from manufacturer to manufacturer, so make sure to ask your installer what options are available, or do your own research on the manufacturers' Web sites.

If your PV incentive program does not require independent, third-party energy production tracking, perhaps the simplest and least expensive approach for pushing system data to the Web is to choose an inverter manufacturer that also offers free data hosting. Several manufacturers, including Fronius, Kaco, PV Powered, and SMA, currently offer this service, and in the next few years it will likely become a standard feature industry wide.

Kaco Solar has developed a Web-based monitoring solution that offers PV system fault notifications via e-mail, as well as data hosting services.



California's Production-Based Incentive Programs

The majority of PV incentive programs in the United States are capacity based, with an up-front financial incentive provided based on the size (in rated KW) of the installed PV array. Although this approach can be attractive to home and business owners because it lowers the initial expense of investing in PV, it does not necessarily encourage optimal system installation, maintenance, or performance.

In 2007, California implemented a new production-based incentive (PBI) program that ties financial incentives to the number of kilowatt-hours a system generates, rather than a one-time up-front rebate. Not surprisingly, the PBI program requires an independent third-party monitoring system (see list below for approved monitoring systems). PV systems that are larger than 10 KW and receive incentives from California's Emerging Renewables Program also require the installation of an approved production-monitoring solution. For updates on California Solar Initiative-approved monitoring and reporting services, visit: www.consumerenergycenter.org/erprebate/monitors+rsp.html.

CSS Technologies • www.css-technologies.com

Draker Solar Design • www.drakersolar.com

Energy Recommerce • www.energyrecommerce.com

Fat Spaniel Technologies • www.fatspaniel.com

Glu Networks • www.glunetworks.com

Meteocontrol • www.meteocontrol.com

PowerNab • www.powernab.com

Pyramid Solar • www.pyramidsolar.com

Thompson Technology Industries • www.thompsontec.com

Kaco Solar has partnered with Meteocontrol and Integrated Metering Systems to develop the PBI Log, which has been designed to meet the performance-based metering requirements of the California Solar Initiative.

GridPoint manufactures an integrated, battery-based line of products that provide backup energy during grid failures. Advanced Web-based monitoring is included.

Third-Party Solutions. Third-party datalogging services with Web hosting are another popular approach to Web-based monitoring. These services typically involve a monthly or annual service fee that is included in the base price. Once the initial service time has expired, a periodic service fee will be applied.

There are two main data collection methods: use a computer to log system information and upload it to the Internet, or use a gateway to continuously transfer data to a remote server via the Internet. Most third-party systems also give you the capability to monitor multiple pieces of system performance data, independent of the inverter, that is compiled into a single stream of information to be used by the host's servers. If the connection between your site and the host's servers is lost, the on-site hardware will store information and send it to the remote servers once the connection is re-established.

Some third-party monitoring systems obtain data directly from the inverter's internal protocol, which reduces the need (and expense) of additional hardware. For systems that do not communicate directly with the inverter, additional hardware to capture the data is required. One common method is to use an

Third-Party Web-Based Monitoring Systems

Vendor	Web Site	Data Collection Equipment	Method*
Chuck Wright Consulting	www.cwc-das.com	Dedicated datalogger connects to external transducer, meter, or inverter	Inverter-direct or independent
CSS Technologies	www.css-technologies.com	Gateway & datalogger	Inverter-direct or independent
Draker Solar Design	www.drakersolar.com	Campbell Scientific datalogger & sensor clusters	Inverter-direct or independent
Energy Recommerce	www.energyrecommerce.com	Gateway & datalogger	Inverter-direct
		Revenue-grade energy meter	Independent
Fat Spaniel Technologies	www.fatspaniel.com	Gateway & datalogger	Inverter-direct
		Gateway, datalogger, revenue-grade energy meter	Independent
Glu Networks	www.glunetworks.com	Gateway, datalogger, revenue-grade energy meter	Independent
Heliotronics	www.heliotronics.com	Datalogger & dedicated computer	Independent
Intellact	www.wattplot.com	Dedicated computer	Inverter-direct (OutBack Mate)
Meteocontrol	www.meteocontrol.com	Datalogger	Independent
PowerNab	www.powernab.com	Application control engine	Inverter-direct or independent
Pyramid Solar	www.pyramidsolar.com	Revenue-grade energy meter	Inverter-direct (SMA) or independent
RightHand Engineering	www.righthandeng.com	SWCA for Xantrex SW inverter; Mate for OutBack equipment	Inverter-direct
rMeter	www.rmeter.com	Datalogger	Independent
SG Technologies	www.solar-guppy.com/forum	Dedicated computer	Inverter-direct (Xantrex Suntie & GT)
Soltrex	www.soltrex.com	Integrated datalogger & gateway	Independent
Thompson Technology Industries	www.thompsontec.com	Utility-grade meter & datalogger	Inverter-direct (Satcon) or independent

*Inverter-direct: Collects data as measured by inverter. Independent: Collects data using stand-alone hardware.

independent, Internet-ready utility-grade meter connected to the inverter's output to measure power and energy production. If your incentive program includes production-based incentives or renewable energy credits, inverter-independent monitoring is usually required to provide accurate tracking of every kilowatt-hour your system produces.

The number of components and sensors required by third-party, Web-based monitoring systems varies depending on the amount of information you wish to record. When shopping for a monitoring system, ask what components are standard and if your particular application will require add-on components or sensors that will increase the total cost. Most programs can also incorporate weather data and keep track of the building's energy consumption. Other features may include sending alerts when abnormal conditions arise and issuing regular production summaries.

Surfing for Solar Data

Web-based or local computer monitoring is not usually considered a "must have" for residential, grid-tied PV systems unless your incentive program is production-based and

Local Data Storage	Off-Site Server	Residential	Commercial
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔		✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
✔	✔	✔	✔
	✔		✔
✔	✔	✔	
✔	✔	✔	✔
✔	✔		✔

Monitoring Advantages for Commercial Systems

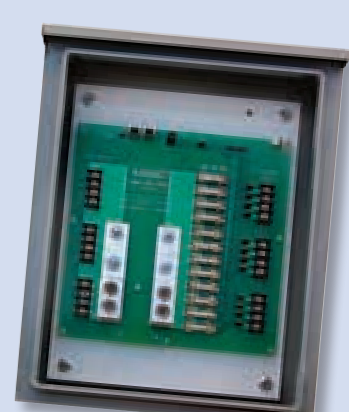
Including advanced performance-monitoring hardware with a PV system installation is becoming the standard for commercial applications. Large commercial installations are often technically complex, require significant capital investment, and also offer a great public relations opportunity for the system owner or owners.

Like residential systems, monitoring commercial PV systems can be done either locally or over the Internet. The latter is more common, since it is easier to aggregate the information and generate a useful format for system owners, installers, and the public to view. As with residential systems, commercial Web-based monitoring services can be hosted by an independent, third-party service provider or directly by the inverter manufacturer. Collected data can be routed to the Internet through the site's existing computer infrastructure or via a dedicated IT network.

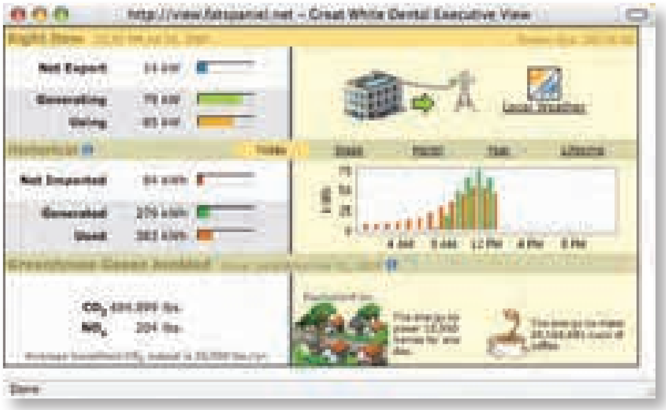
The most commonly monitored parameters include AC power and AC energy production (daily, weekly, monthly, and annual calculations). These are inexpensive to monitor and are included in standard packages. Options can be added to monitor additional parameters such as local environmental conditions (including ambient air temperature, PV cell temperature, wind speed and direction, and irradiance) and the building's energy consumption. For large arrays, the voltage and current of individual PV strings are often monitored to aid with troubleshooting. Each subarray is brought into a combiner box through a current transducer, which is connected to the datalogger, allowing the system installer to remotely diagnose component-level problems.

Many commercial installations include an informational display in a prominent location to make the PV system more visible to employees and customers. Displays can range from a single monitor showing only a few pieces of PV system production information to interactive kiosks that allow individuals to select from different menus to access detailed reports about the PV system's production and components.

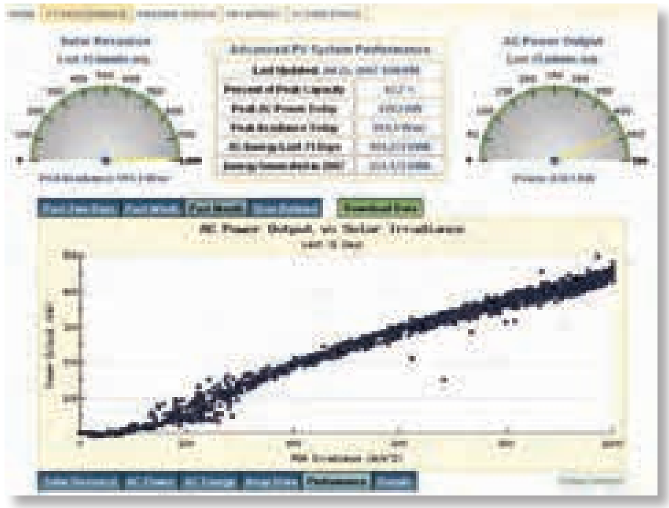
Automated notifications of PV system performance anomalies sent via e-mail, fax, or text message are commonly found in commercial monitoring systems. The alerts can notify users about reduced power output, problems with a particular section of the array, or even a specific fault code from the inverter. These alerts allow remote management and maintenance of the PV system, minimizing system downtime.



Energy Recommerce manufactures UL-listed, data-ready combiner boxes that allow the performance of individual array series strings to be monitored remotely.



Fat Spaniel Technologies' Web-based monitoring solutions provide user-friendly graphical representations.



Draker Solar Design specializes in Internet-based monitoring for commercial-scale PV systems.

requires it. But if you are interested in a precise look at how your system functions and performs, and want convenient access to the data, Web-based monitoring is a great option. In addition, it will give your system installer the information they need to remotely troubleshoot problems if they occur.

For commercial systems, Web-based monitoring is rapidly becoming the standard. Compared to residential systems, commercial systems are more complex and have a significantly higher capital investment. As equipment and software development continue to progress, it is likely that in the next few years the majority of grid-tied systems will include remote monitoring via the Web—commercial and residential alike.

Access

Ryan Mayfield (ryan_mayfield@earthlink.net) earned a degree in environmental engineering from Humboldt State University and now lives in Corvallis, Oregon. He has been working in the RE field since 1999 and founded Mayfield Solar Design, focusing on PV system design, implementation, and industry-related training. He holds a Limited Renewable Energy Technician license in Oregon.

Code Q & A

John Wiles
Sponsored by the U.S. Department of Energy

Q **I'm working on a large grid-tied PV installation and could use some advice on connecting the system to the utility. It's too large to connect via a backfed breaker on the existing 200-amp load center, so what other options exist? I have read the Code Corner in HP112 about supply-side taps, but I could use some additional guidance. I am a master electrician, and have installed few PV systems.**

A Existing load centers may not have enough room to make the necessary connections. The *National Electrical Code (NEC)* limits the number of conductors and splicing devices that can be in any space (Articles 312 and 408). The photo below shows an overcrowded disconnect enclosure that does not meet *NEC* requirements. Even when the conductors between a separate meter and the main disconnect enclosure are accessible, they should not be tapped there unless an enclosure is added to hold the tap device.

In places where net-metering laws are in effect, the utility-side (supply-side) interconnection will be made between the meter and the main service disconnect. In that case, the utility will need to remove the meter from the socket (meter base) to de-energize the service entrance conductors.

If the point of connection is to be the load-side terminals of the meter socket (only when double conductors on these terminals are allowed by the socket listing), extreme caution must be exercised when connecting the new conductors to these terminals. The utility-energized ("hot") input terminals and meter socket jaws are in the same socket and are only a few inches away from each other. Those energized terminals should be covered with a heavy, insulated, protective shield so that they cannot be touched accidentally. Because high torque is needed to loosen and tighten large terminals, slipping screwdrivers and wrenches are possible. Tools should be insulated, and insulated gloves (lineworker's gloves) and a protective face shield should be worn while working in the meter socket. Touching those "hot" input meter jaws could electrocute you.

The maximum output current from the PV system should be no greater than the rating of the service entrance. Careful consideration should be given to conductor sizes if the PV AC output current approaches the rating of the service entrance. Table 310.15(B)(6) for reduced conductor sizes may no longer apply to a very large PV system. For larger systems, the basic ampacities found in Table 310.16 may have to be used. Since these service-entrance tap conductors have no overcurrent protection, they should be as short as possible and be installed in a metal conduit (RMC, EMT, or IMC). The local jurisdiction may have requirements for protecting the service-entrance conductors that need to be followed for these tap conductors. I do not believe the "tap rules" in Article 240 apply to service-entrance taps since these taps are fully addressed in Article 230.

As for other locations, some existing service-entrance disconnects and meter cabinets have an additional set of terminals that are in parallel with the input connections to the main breaker. These are located to allow the main disconnect enclosure to be easily fed from either the top or bottom of the enclosure.

Some combination meter socket/main disconnect enclosures have the meter socket on one side and the disconnects on the other side of the enclosure. Busbars or cables connect the meter socket to the main breaker. After getting the approval of the enclosure manufacturer and the local inspector, it may be possible to tap these circuits with either bolt-on terminals for the busbars or splicing blocks for the cables. However, normally, busbars may not be drilled and tapped to add terminals for a tap.

Safety for ourselves as installers, for the utility, and for the system owner/operator should be primary considerations. Any work on electrical service-entrance conductors *must* be done only when those electrical conductors are de-energized. That usually involves notifying the utility and having them turn off all power to the building or structure. Although some electricians will work with "hot" (energized) conductors, this procedure is *strongly* discouraged. As the old saying goes, *"There are old electricians. There are bold electricians. But there are no old, bold electricians."*

Q **What is the best way to ground the frame of a photovoltaic module?**

A This is an apparently simple question, with a complex answer. When exposed to sunlight, PV arrays can generate dangerous levels of voltage (up to 600 volts) and current. The frames of these modules must be effectively and continually grounded to earth to prevent electrical shocks and to reduce fire hazards from stray ground-fault currents.

When ground faults occur in a PV system, these currents may circulate indefinitely under certain conditions. Unlike a ground fault in an AC power system, which is interrupted immediately, a DC ground fault may exist whenever the module is illuminated. In larger commercial (nonresidential) systems, the ground-fault detection system does not interrupt these currents. The connections that are used for grounding PV modules may have to be as robust as those used for the circuit conductors.

Grounding PV modules is complicated by several factors. A typical aluminum-framed PV module has a clear or colored anodizing on its surface that must be removed or breached for good electrical contact. When these coatings are removed, the bare aluminum will oxidize very quickly (in seconds) and build up an insulating film that also prevents good electrical contacts. Plus, the copper equipment-grounding conductor must not come directly into contact with the aluminum surface, since galvanic corrosion between these two dissimilar metals will occur, eventually resulting in a failed connection.

Unfortunately, although inspectors have been providing examples of failed grounding methods and devices, the grounding hardware and instructions provided by PV module manufacturers have not yet been tested and evaluated by Underwriters Laboratories (UL). Under pressure from the PV industry and the electrical inspection community, UL now has undertaken a major investigation of PV module grounding. However, the results of the UL investigation are not yet known.

Based on discussions with grounding-lug manufacturer FCI–Burndy and using utility company procedures to connect copper wires to aluminum busbars in an outdoor environment, I'm employing the following procedure to make equipment-grounding connections to module frames. These procedures are used only when they do not directly contradict manufacturer's instructions provided with the listed module.

At one of the marked grounding points on the module frame, an abrasive material like emery cloth is used to remove the clear coat, anodizing, and aluminum oxide from the surface where the ground lug will contact the aluminum surface. Immediately, a thick layer of antioxidant compound is applied to the exposed aluminum surface. Any excess compound will be squeezed out when the lug is bolted in place. A tin-plated, solid-copper, direct-burial-rated lay-in lug is used to connect a copper conductor to the exposed aluminum frame.

A bolt, nut, two flat washers, two split-lock washers and a Belleville (cupped spring) washer are used to bolt the lug to the frame. The flat washers are used to prevent the hard

steel split-lock washers and Belleville washers from digging into the relatively soft copper and aluminum. The split-lock washers and the Belleville washer are used to maintain the assembly under the correct tension. Use a calibrated torque screwdriver set to 12 to 15 inch–pounds (depending on the type of bolt) to ensure a reliable connection. A copper conductor (generally from #12 to #4) is attached to this lug. The size of the conductor depends on the electrical grounding requirements, the need for physical protection, and the requirements of the local inspecting agency.

Other Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write me at the location below. See the SWTDI Web site (below) for more detailed articles on these subjects. The U.S. Department of Energy sponsors my activities in this area as a support function to the PV industry under Contract DE-FC 36-05-G015149.

Access

John Wiles (jwiles@nmsu.edu) works at the Southwest Technology Development Institute, which provides engineering support to the PV industry and provides industry, electrical contractors, electricians, and electrical inspectors with information on code issues related to PV systems. An old solar pioneer, he lives in his utility-interactive PV-powered home in the suburbs.

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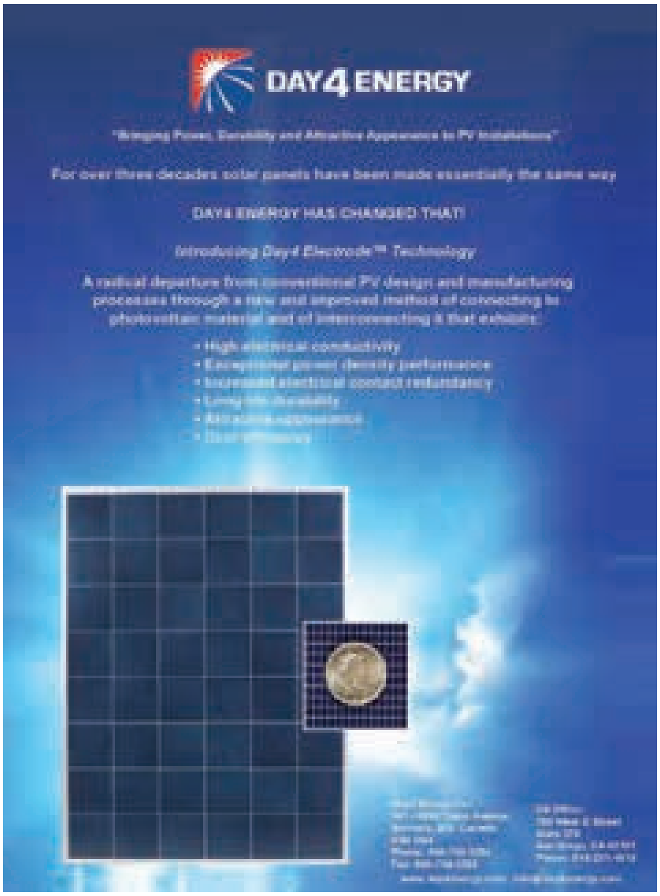

DAY4 ENERGY
DAY4 ENERGY HAS CHANGED THAT!

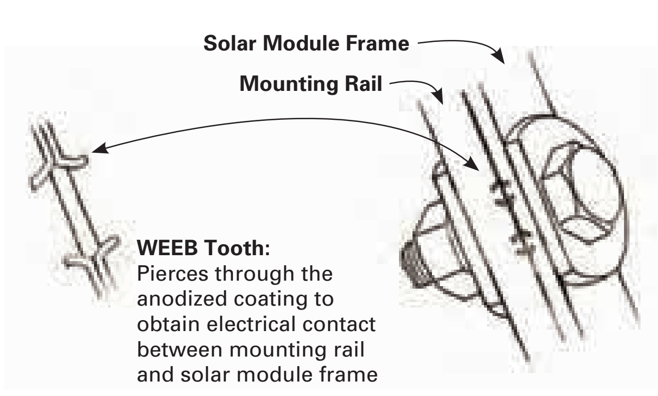
New Grounding Options

by Don Loweburg

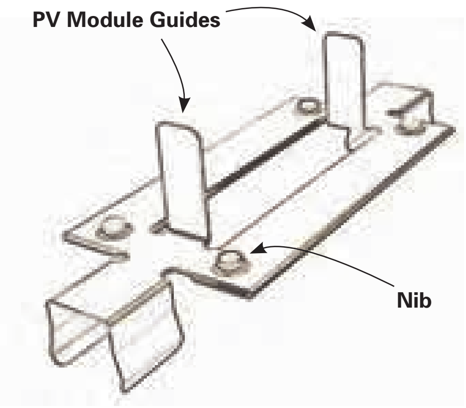
Grounding metal enclosures, raceways, module frames, and mounting structures in electrical systems provides essential protection from electrical shock and fire. The *National Electrical Code (NEC)* dictates the basic methods for accomplishing this safety requirement. For PV arrays, an often-used method of meeting this requirement is to run a ground wire from each PV module frame, and connect it to the racking system and to the electrical system's equipment-grounding conductor (see this issue's *Code Corner* for a discussion of this method). For system installers, this method adds time and expense to the installation.

But in 2006, two manufacturers introduced new Underwriters Laboratories-listed grounding products that eliminate the need to run a wire to each module frame. Both Wiley Electronics' WEEB (washer, electrical equipment bond) product and UniRac's grounding clips are listed to UL Standard 467, which covers bonding washers and grounding devices. In addition, Sharp Solar recently introduced their SRS racking system with integral module grounding, though UL approval is still pending.

WEEB's grounding method uses a special stainless-steel bonding washer. The washer has piercing teeth on both sides, situated so that when the washer is placed between the module frame and the racking system, a water- and airtight, sealed electrical connection between the module frame and racking is created. Tightening the module hold-down nuts to the required torque is critical to making a good ground connection when using these devices. The racking structure is then connected, using appropriate lugs and wire, to the equipment ground of the system.



Detail of Wiley Electronics' WEEB grounding product.



UniRac's grounding clip is designed for use with their SolarMount array racking system.

UniRac's ground clips work similarly to the WEEBs, with the clip being sandwiched between the rack frame and the module frame. When the module frame's hold-down is tightened, the piercing teeth complete the ground connection between the module frame and the rack frame.

Neater, Cheaper PV Installations

These new systems offer the potential for better-looking installations—and labor and material savings, since installation is usually quicker and the need for copper wire is reduced. Reports from the field estimate that these products can reduce time spent grounding arrays by approximately 50 percent.

August Goers, an installer with Luminalt in San Francisco, reports that "the clips drastically reduce installation time and cost because we can complete the entire racking ground system before placing the modules. It also reduces the amount of tin-coated copper lugs used."

But others say that time and cost reductions really depend on the installation specifics. "Our first 'try-it-out' WEEB installation was a big off-grid job, involving twenty-seven BP160 modules on three trackers," says Allan Sindelar of Positive Energy in Santa Fe, New Mexico. "[Using the WEEB method] turned out to be not much of a cost or labor savings because of the multiple tracker layout. But a later installation of 40 roof-mount modules as four rows of ten modules made for a significant wire and labor savings."

Introducing Inspectors to Innovations

Inspectors are trained to look for an equipment ground wire connected to each module frame during field inspections, so it is prudent to clearly document your intention to use any new grounding approach. Installers planning to use grounding washer products should include explicit reference to the grounding method in their plans. This can be done with a note on the electrical one-line diagram that is required for most projects. Also include installation instructions for the grounding washer, UL listing information, and a copy of the module installation directions.

Few module manufacturers explicitly allow bonding washers in their instructions. By providing advance notice to the inspector and full documentation before the inspection, my experience is that there will be no grounding corrections from the inspection. I've been successful gaining approval from the inspectors in all four of the local jurisdictions (Central California) in which I work.

Installer August Goers says he's had similar experiences. "We work mainly in San Francisco, which has very strict grounding policies. When obtaining the permit for our first job with the UniRac clips we brought in a sample UniRac rail, ground clip, and module clamp for the head inspector to see. He approved our use of the product and we haven't had any problems with inspectors."

Code Contentions

Not all installers and PV professionals are comfortable with the use of grounding washers. William Miller of Miller Power and Communications in Atascadero, California, expresses his concern around the fact that modern grid-connected PV systems operate at up to 600 volts DC, posing an extreme hazard if the system isn't adequately grounded.

Thomas W. Bowes, assistant director of the Detroit JATC (an IBEW union training center) and PV installation instructor, shares Miller's concern. In his recently published paper, Bowes cites several sections of the *NEC* that could be interpreted to cast doubt on the use of grounding washers (see Access).

"Even though this method (grounding washers) is available, it is rarely used in the field because of the difficulties in establishing and maintaining a solid, low-impedance grounding connection between electrical devices and their associated mounting racks," says Bowes in his report. "In fact, general practice in the industry is to require a properly sized copper equipment-grounding conductor instead of any other means recognized by the *NEC*." Bowes says he favors the use of a ground wire because this is the general practice, industry-wide, and that this method has been reliable. He questions the ability of other methods to establish and maintain a solid, low-impedance grounding connection. He does not, however, cite any *NEC* sections that specifically prohibit the use of grounding washers.

Brian Wiley, developer of WEEB, responded to Bowes's assertions (see Access). In his response, Wiley engages in a bit of the "code dance" with Bowes by stating his interpretations of the *NEC* articles that allow ground washers. The most convincing part of Wiley's response is his report of the actual tests performed as part of the UL 467 listing process. According to Wiley, "WEEB products are certified to carry a current of 1,530 amps for 6 seconds…results [that] have been tested by Intertek ETL, a nationally recognized testing laboratory." He also points to WEEB's "long-term reliability," citing accelerated lifetime tests conducted in-house in which the WEEB product was subjected to thermal cycle tests and salt water environment tests that "indicate exceptional reliability," especially when compared to the lay-in lug method.

Phil Crosby, product development manager at UniRac, says that UniRac's grounding clips have undergone similar rigorous testing by the company. According to Crosby, the washers tested as good as or better than other approved grounding methods.

But Bowes says that "it is one thing to do a bench evaluation of a product under ideal conditions in a controlled environment, but something quite different to consider the field application of the product and try to examine it in light of how it will actually be used."

Proposed code changes to *NEC* Section 690.43, Equipment Grounding (Revised), due in 2008, seek to clarify this contention. The salient change that would specifically speak to using ground washers would read, "Devices listed and identified for grounding the metallic frames of PV modules are permitted to ground the exposed metallic frames of PV modules to grounded mounting structures."

Grounding Details

Most parties do agree on one particular safety issue that may arise with either the traditional lay-in lug or the new clip-grounding approaches. Ground faults can occur if a module frame becomes energized due to faulty equipment or installation work. When removing a ground-faulted module from an energized PV array, an extreme shock hazard will exist if the module equipment ground is removed before the power wiring is opened.

This is a major safety concern, but it has nothing to do with grounding methods. Rather, this safety issue is directly a result of the fact that PV modules cannot be easily turned off. This reality must be understood and respected by all installers. The solution requires safe work practices and knowledgeable, experienced installers. All module manufacturers, in their instructions, require modules to be covered during service. As an extra precaution, a separate, temporary ground jumper can be attached to the module frame and rack before the module is lifted from the rack and disconnected from the power circuit wiring. Because safety is paramount, servicing PV systems and arrays should only be done by qualified persons.

Moving Forward

The future of the PV industry depends on the safety and reliability of installed systems. Manufacturers, installers, and inspectors must continually strive for high standards. And although intelligent, well-meaning people may not always agree, engaging an issue from a conversational context often produces great results and better, safer, and more durable products. After all, today's innovation may likely be tomorrow's tradition.

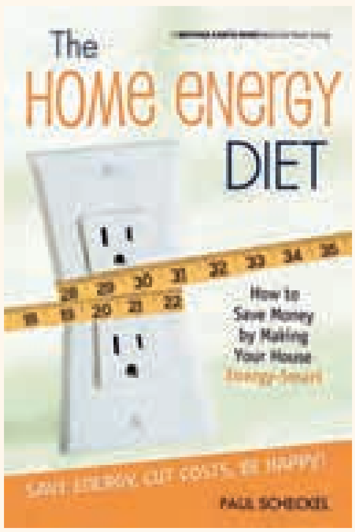
Access

Don Loweburg (don.loweburg@homepower.com) is a solar pioneer in Central California. He owns and operates Offline Independent Energy Systems, and sits on the boards of the California Solar Energy Industries Association and the North American Board of Certified Energy Practitioners.

Bowes, Thomas. "A Critical Look at PV Module Grounding" • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html

Wiley, Brian. "A Progressive Look at PV Module Grounding" • www.we-llc.com/WEEB.html

Proposed *NEC* code changes for 2008 • www.nmsu.edu/~tdi/pdf-resources/2008NECproposals2.pdf



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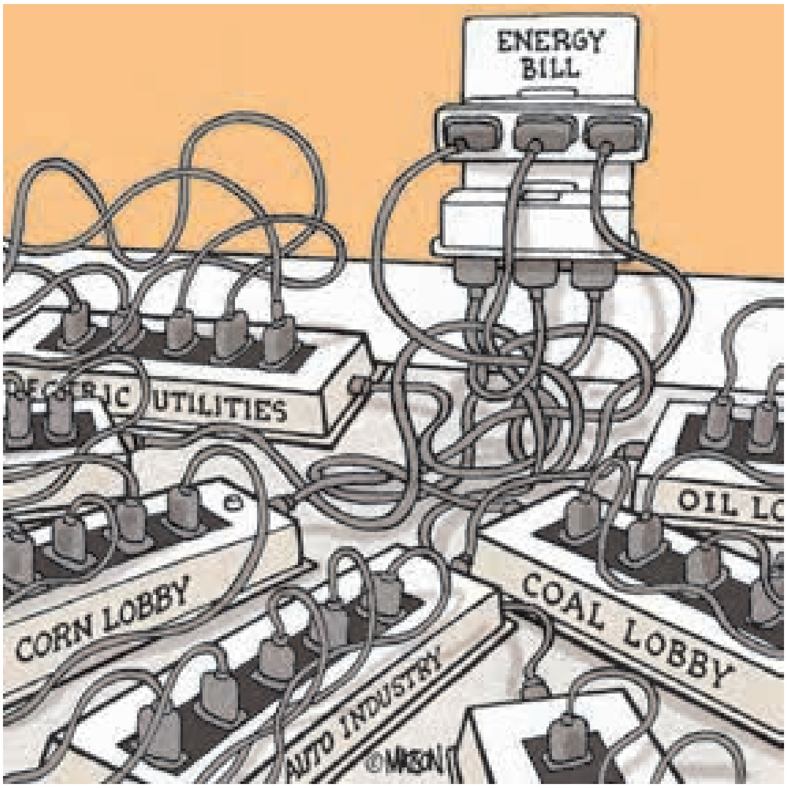
Show RE the Money

by Michael Welch



Giant energy-related companies continue to feast on the abundance of fat government subsidies, while renewable energy industries scramble for meager scraps, trying to find the means to make RE the commonplace energy source that it should be. What are government subsidies for, and how do they impact business in the United States, including our slowly growing renewable energy industries?

The original goal of most subsidies is to lower the consumer cost of the targeted product. Subsidies are designed to work within basic market economics of supply and demand, supporting businesses so they will develop, manufacture, and sell more of a product to increase supply (such as R&D incentives) or stimulating consumer demand (such as PV rebates).

Occasionally, subsidies are used to *discourage* production of a product to give a competing product an advantage or to stabilize prices for the target product. An example of this is when some dairy farmers are paid to *not* bring milk to market, which manages supply to keep prices up so other farmers can make a living.

Most subsidies have a dollar amount associated with them and are "direct," since the payments usually go straight to the recipient. Indirect subsidies include just about everything else, like tax breaks and international trade barriers. But in all cases, it is important to remember that somebody (taxpayers) or something (like the environment) is paying the price of subsidies.

Intangibility

There are other less tangible means of subsidizing products and industries. For example, federal issuance of inexpensive or free leases for drilling for natural gas or crude oil on public lands and waters makes it cheaper for oil companies to produce more of their end product. Allowing the flooding of vast watersheds makes it possible for utilities to use dams to provide hydro electricity. While the government incurs little or no monetary expense for allowing the use of public spaces, there are larger costs to the general citizenry—such as loss of land that is held on behalf of the public good and loss of habitat that is important to non-human species.

An example of a very intangible subsidy is the Price–Anderson Act, which limits the liability of nuclear power plant utilities in the event of an accident. The only way we will find out the cost of this subsidy is if a major U.S. nuclear accident occurs, in which case the largest share of the burden (potentially hundreds of billions of dollars) will be shifted to taxpayers. Yet this very subsidy is crucial to keeping the industry alive, since nuclear utilities would not accept (and could not afford) the risk on their own.

The most important result of subsidies should be to give favor to a product or industry that needs a boost to break into a market, or to make a product more readily available. This assumes that availability is needed or desirable by society. Green energy technologies that are promising or developing too slowly are appropriate targets for subsidies. Given the right breaks, solar, wind, and alternative transportation industries can be boosted to help replace nonrenewable technologies, furthering the environmental and sociopolitical goals that are important to the public good, like reversing human-caused climate change and decreasing acid rain, and eliminating wars over diminishing oil resources.

In theory, "mature" technologies, which have approached or achieved their pinnacle of development, don't need the subsidies that newer technologies can benefit from. In fact, subsidizing those mature technologies can impede the advancement of desirable, immature technologies when the technologies are competing for the same market share. In the energy industry, subsidizing fossil fuel and nuclear technologies just makes it more difficult for renewable technologies to get the momentum they need.

Corporate Welfare

But "need" is a very subjective concept and is often misused. After a few decades of government handouts, many businesses that have become accustomed to receiving public funds make it their goal to continue getting subsidies. Corporations are the worst of the bunch, because by design they are just money-making vehicles—nothing more, nothing less. To them, subsidies are just another source of money that they can tap into.

Ironically, the bigger and more powerful the industry, the more likely it is to get government handouts—the exact opposite of the way it should be working. For example, the 2005 federal energy bill included $8.1 billion in tax breaks, with mature fossil fuel and nuclear industries receiving 93% of the subsidies and renewable energy industries receiving only about 7%. The bill included about $80 billion in authorized direct spending largely being paid out to nonrenewable-based industry. Indirect subsidies were also included in the bill, like exempting "hydraulic fracturing," a particular natural gas well-drilling method, from the Clean Water Act. These inappropriate allocations make it very difficult for renewable energy to get a solid foothold in the energy market.

Determining appropriate need is where government subsidy programs often get on the wrong track, helped, of course, by fat campaign contributions, bevies of aggressive lobbyists, and the "revolving door" syndrome that often puts industry heads in charge of the very agencies designed to regulate them (which is also a kind of indirect subsidy). The constant pressure by business interests for our government to take care of *the business's* particular needs results in passing massive government handouts to mature industries—many of which are at odds with national environmental and social priorities.

Good, Bad, or Just Ugly

Government subsidies are, depending upon any individual's priorities, one of the best government ideas ever to be implemented, an evil to be tolerated, or very bad policy.

People adept at playing the stock market have learned to keep an eye out for many different indicators, and try to predict which corporations are going to be the beneficiaries or losers of government funds, both contracts and subsidies. Successfully making such predictions gives the opportunity to buy or sell stocks before prices change as a result of subsidies. Other investors who buy stock for longer-term investments benefit when their companies are subsidized—it makes it more likely that their dividends and stock values will go up, while often bringing future payoffs for new and successful products.

Free-market advocates are certain that subsidies, and nearly every other kind of government meddling in business affairs, are the worst thing that can happen in our economy. They believe that the most appropriate products, industries, and technologies will automatically win out on a truly competitive and even playing field. But this would require a nearly pure economic system devoid of government interference, along with highly informed consumers—both highly improbable situations under any known form of government.

Under the current political system, the reality is that corporations are too powerful to be stripped of their unwarranted subsidies, so if and until control of politics and government changes, advocates for a clean and safe future must swallow a bitter pill and continue to ask that a share of government money be allocated to fund their priorities.

Take It Back

In many cases, our government's system of subsidies is failing to support its citizenry's efforts toward a more sustainable future, and this is going to be difficult to change. A recent example of this is the 2007 Farm Bill, which was passed in the House, and now has the blessing of Senate leadership. Massive efforts by progressive activists and leaders were put into trying to remove the billions of dollars in subsidies for corporate agribusiness, which is already profitable, instead of supporting the independent family farms that continue to struggle. But corporate America prevailed in their efforts to include those unneeded payments.

Two major areas need to be addressed to bring the system of subsidies back on track. First, political power needs to be removed from the hands of big business, and put back into the hands of the citizenry. Second, until that happens, the renewable energy industry must continue fighting for consumer incentives, research and development funds, and other forms of assistance to be on a fair playing field with the fossil fuel, nuclear, and transportation industries. Until then, it will be difficult, if not impossible, to adequately address solutions to climate change and other environmental problems that are so important to the public welfare.

Michael Welch (michael.welch@homepower.com) has been working for a clean, safe, and just energy future since 1978 as a volunteer for Redwood Alliance and with *Home Power* magazine since 1990.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On & Off...Grid

The Utility Network

by Ian Woofenden


kajetan

Derivation: From gridiron*, from Middle English* gridire *or* griddle*, and indicating something consisting of or covered with a network.*

In 1880, Thomas Edison electrified a string of streetlamps on Broadway in New York City—one of the first steps toward our modern utility grid. Gradually, companies selling electricity to homes and businesses in the United States strung wires to connect their generating plants to their customers. This evolved into our present-day electricity grid, which connects about 140 million customers with about 17,000 generating plants in the Continental states, using millions of miles of cable. This network is an incredibly useful tool that makes good use of energy resources to feed the varying load demand.

Gradually over the last 40 years, renewable energy technology for homes and businesses has hit the mainstream. This has led to two general types of renewable energy systems, with variations in each.

ON-GRID systems come in a few different flavors. One major distinction is between battery-based systems and batteryless systems.

Battery-based on-grid systems include energy storage to power critical loads during grid outages. They require a battery bank sized to handle the loads needing backup and for the number of hours or days of outage protection desired.

These systems can be configured to sell surplus energy back to the grid, crediting the user's account. Or they can be similar to off-grid systems, not selling back any energy, but using the grid to charge batteries or run loads directly when there isn't enough renewable energy. We don't have standardized terminology to distinguish these two types of on-grid systems from each other. Calling them "utility-interactive" and "utility-supported" might be appropriate.

In the case of utility-interactive systems, the inverter (an electronic device that converts DC electricity to AC electricity) is programmed to synchronize with the grid and send to it any electricity the home or business isn't using at the moment, "spinning the meter backward." This excess energy is used to offset utility energy consumed when the customer is using more than their home system produces. The inverter also maintains the batteries at a set voltage, shunting excess energy generated to the grid. Utility-supported systems aren't configured to send excess electricity to the grid, but to use the grid for backup and battery charging when necessary.

Batteryless grid-tied systems have no batteries for storage, offering no utility outage protection. When the grid fails, these systems are designed to automatically shut down. When the grid is operational, any renewable energy that isn't being used at a given time is sent back to the utility to offset energy used from the grid. Batteryless systems are simpler, less expensive, and more efficient, but they provide no backup. No single inverter on the market today will let you choose between batteryless and battery-based grid-tie at the flip of a switch—you must make this decision up front.

OFF-GRID renewable energy systems run independently of the utility grid, using batteries to store and deliver energy. Many people live and work beyond the reach of utility lines, and the cost of line extension can be very high (in my area, more than $20 a foot). Others have a desire to cut the cord and be off grid even though the utility lines are near. This is an impractical choice in my opinion, but may be more attractive if the utility does not allow you to sell your surplus electricity, or if they have unreasonable charges or requirements for connection. But off-grid systems cannot use the grid as a "battery," so once the batteries are filled, any surplus energy they generate is wasted. These systems also must supply 100 percent of the electricity needed, which usually means having a backup, fossil-fueled generator (a dirty and expensive source of electricity), unless you have sufficient renewable resources at your site.

Off-grid homes are a good microcosmic example of the responsibilities and challenges of gradually making the grid more and more sustainable. We either live within the capacities of our renewably powered systems and deal with the vagaries of the wind, sun, and water; or we wrestle with ways to wean ourselves from depending on fossil fuels (with its costs and impacts) for backup energy. Off-gridders also must take on all the responsibilities that the rest of the population pays a utility to handle—financing, R&D, design, installation, maintenance, troubleshooting, operation, and replacement. As years go by, we try to invest in more renewable capacity, and learn to use it wisely. This long-term investment gives us cleaner, more reliable energy.

With the perspective and experience of more than 25 years living off grid, I encourage you to view the grid as a useful tool, and use it to your advantage when it comes to installing an RE system. But whether you cook your waffles off-grid or on, I hope you too will move toward using more and more *renewable* energy.

Ian Woofenden (ian.woofenden@homepower.com) lives off grid in Washington's San Juan Islands, using sun, wind, and a bit of propane to make electricity and hot water for his family. In addition to his work with *Home Power*, he organizes workshops for SEI, consults, and teaches.


As seen in HP 90, pg 50
and HP 103, pg 72
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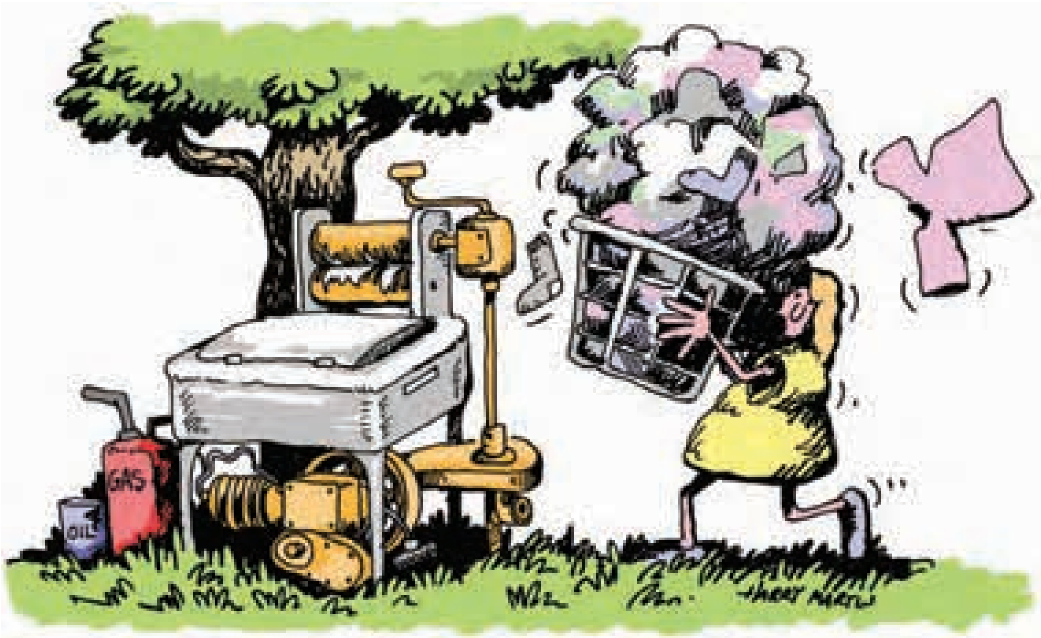
What Goes 'Round, Comes 'Round

by Kathleen Jarschke-Schultze



Both of my parents were born off grid. Oh, there was electricity back then, just not where they were. The doctor who delivered my mother drove out from Stockton, California, in a horse and buggy. My father was born in a log cabin in the wilds of Manitoba, Canada.

When my father was seven years old, my grandfather sold the homestead, loaded his five kids and trunks into the horse-drawn wagon and drove to town. Later that day, my father saw his first automobile, his first electric light, and his first train.

Face the Changes

It amazes me to think of all the world and technological changes my father has seen in his lifetime. He has enthusiastically embraced it all. When we were kids, he used to wake us up so we could see the Mercury and Gemini space shots live on TV. "You're watching history," he'd say. We recently celebrated at Dad's annual birthday bonfire. He's ninety now. Technology is at a dead run, from zero to global warming during my dad's lifetime.

My dad gave me a good grounding in the common-sense basics of living with renewable energy, although he didn't know it. He taught us to turn off lights when we left a room and to turn off electrical devices if we weren't using them. Long before recycling was popular, he taught us to separate our trash. He got more satisfaction out of rebuilding or reusing old parts than buying new.

Stepping Off

With my dad's conservation ethic, it's no surprise I had little trouble adapting to an off-grid, self-sufficient lifestyle. The first renewable energy I lived with was microhydro power. In the mountainous area along the Salmon River in California, where little streams and creeks abounded, a lot of people used small AC or DC hydro plants. Old mining ditches and ponds were utilized. Hydro, twenty-four hours a day, rain or shine, was preferable to running a gas or diesel generator.

My husband Bob-O bought his hydro turbine years before I met him, and we used it at our high-head, low-flow site. It was a great unit, but the regulator failed almost immediately. In *HP2*, publisher Richard Perez wrote about a circuit for an alternator controller for a gas engine. Bob-O adapted it for our hydro turbine, made the controller, and it worked pretty well. Bob-O wrote Richard a fan letter, which led to our meeting Richard and his wife Karen.

In our home, most of the electrical devices, including lights, were 12 volt. We had a very small inverter for when we needed 120 VAC. If we needed more energy, we used a gas driven generator/arc welder. At that time, because Bob-O's work kept him away from the cabin for lengths of time, I had a crash course in microhydro maintenance and repair. I learned how to clean the intake of forest debris, how to reset the alternator, and how to check the batteries. Most importantly, I learned how to check the nozzle for plugging at the wheel *before* climbing the mountain to check the intake.

One day, while walking along our water ditch with a rakehoe and cleaning the length up and then down, I spotted a large madrone tree with fresh bear-claw marks on it at about my eye level (I'm 5'10"). At first, this made me very nervous to go up there alone. Old Dick Haley, a decorated Iwo Jima veteran from downriver, told me to take a knife and carve some of my own marks above the bear's. While my dad was visiting, we did just that in an effort to make the bear think we were the bigger bear.

Appliance Adventures

Although mountain living offered almost daily adventures with wildlife, my housekeeping chores also provided me with some interesting episodes. My ringer washing machine, for instance, had its *own engine*. A pull-start Briggs and Stratton. Bob-O always called it the "Briggs and Scrap Iron," but it was pretty reliable. I learned to check the oil and gas before I did the laundry.

It sat outside, under some oak trees, and was a pleasant place to be in the summer. The winter, however, was a different matter. I told Bob-O that the water was just too damn cold to put my hands into in the winter. He sympathized. A couple of weeks later, he surprised me with elbow-length, flannel-lined, rubber gloves.

We had two refrigerators. Both small, aged Servel propane models, named Harold and Sylvia. Harold had a right-hand hinge and Sylvia's was left-handed. They sat side by side on our enclosed screen porch. In the summer they were barely adequate and in the winter they were freezers.

As part of a neighborhood purchase, we did buy two solar-electric panels one time. The PV modules sat in their boxes for over a year. With our year-round hydro system providing for all our electrical needs, we just never seemed to need the modules. Then we moved across the county, where our hydro resource is seasonal, and solar became our mainstay.

In the cabin, I was short on mainstream household appliances. Over time, I have remedied that. For more than 15 years now I've used a Sun Frost RF16 refrigerator. My Sun Frost F10 freezer is about 10 years old. My front-loading clothes washer is a Frigidaire, as is my gas dryer. My automatic dishwasher is a Swedish Asko. I use a Dyson vacuum cleaner. All my appliances are very efficient. They need to be.

Finally, mainstream American manufacturers and consumers are getting the point of energy conservation. Household appliances have gotten more efficient and energy-conscientious consumers have a wider array of choices.

Renewable Explosion

Recently Bob-O and I saw a commercial for a national real estate company. In it, the clean-cut young couple queried, "What if we want a home that uses solar power? Or wind power?" The advertising company assured that it was no problem for their agents.

Boy, have things changed. Not that long ago, the image most folks had of the renewables lifestyle was two hippies living in a teepee and listening to a PV-powered 12-volt car stereo. In fact, when we started our renewable energy design and installation business, all our jobs were for off-grid systems. It is still true that land beyond the grasp of the power lines is cheaper, which is where our "stand-alone" clients are.

While we still design and install off-grid systems and provide service for off-gridders like us, what we're seeing more and more are people on the utility grid who want to use renewables—even if the system doesn't completely cover their energy usage. And in states like ours that financially encourage grid-tie solar-electric systems, the response is steadily growing.

My dad understood the value of conservation and passed this ethic on to me, where I've made it my business to share it with others. Being married to Bob-O, one of the silverbacks of solar, has given me an early view of what RE can do. I see my RE past becoming actively sought-after in the present, and, like my dad, I'm eagerly looking forward to new technological developments in renewable energy. After all, necessity is the mother—or father—of invention.

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is the ant, not the grasshopper, at her off-grid home in northernmost California.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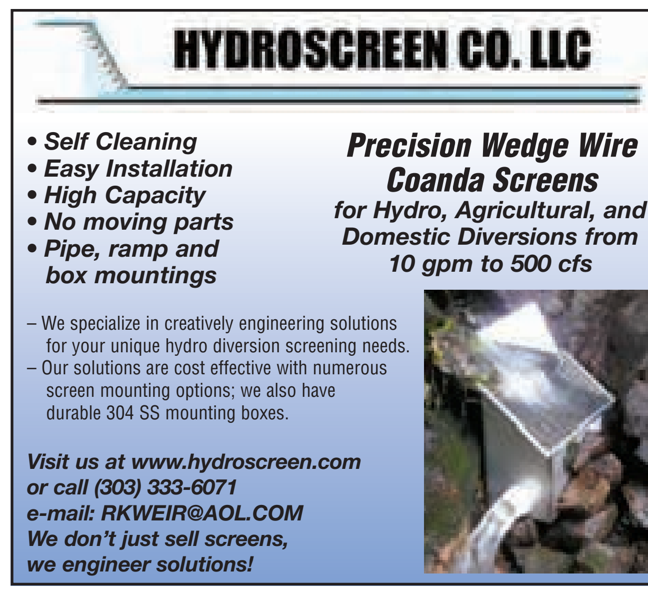
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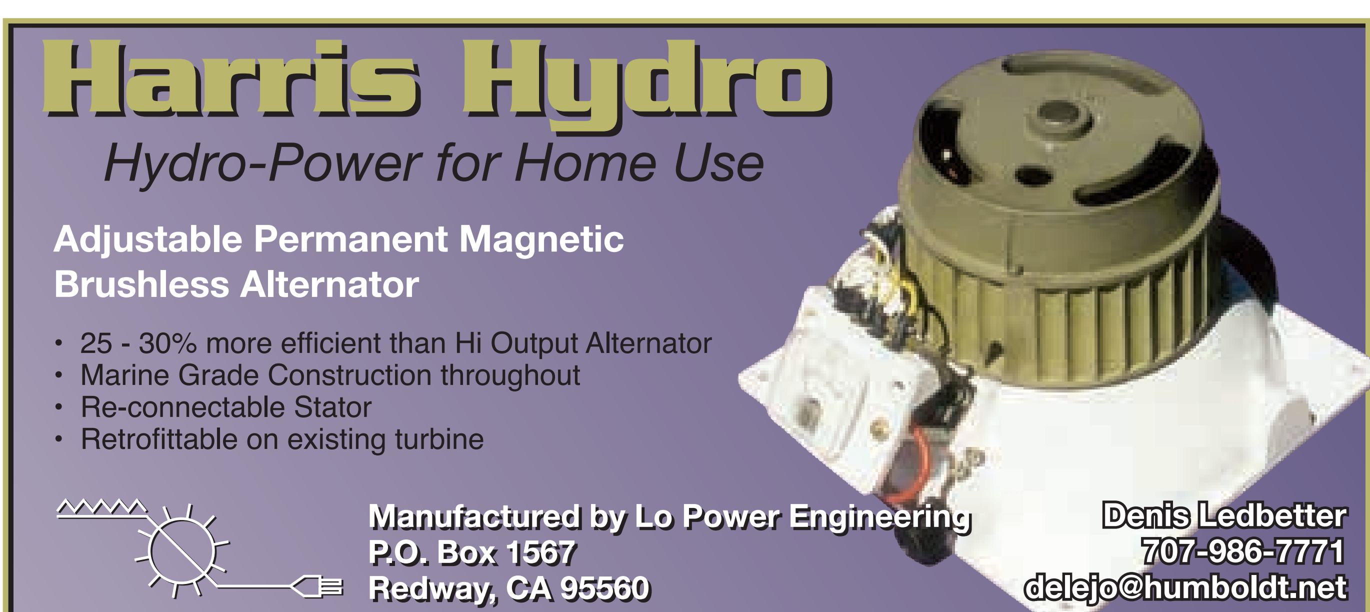
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Oct. 6, '07. National Tour of Solar Homes. Tours in most states. Info: American Solar Energy Society • www.nationalsolartour.org

CALIFORNIA

Oct. 18, '07. Berkeley. NorCal Solar Energy Assoc. annual membership meeting & solar party. Share camaraderie & industry contacts. Info: NorCal Solar • www.norcalsolar.org

Nov. 7–9, '07. Sacramento. Behavior, Energy & Climate Change Conf. National conf. on behavior & decision-making to help accelerate transition to an energy-efficient & low-carbon economy. Info: see ACORE listing under Washington, DC.

Nov. 13, '07. Winters, CA. Smart Energy Management in Agriculture. RE & energy efficiency for farmers, dairies, ranchers & wineries. Info: Ecological Farming Association • 831-763-2111 ext. 4 • jasmine@eco-farm.org • www.eco-farm.org/energy

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

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

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

FLORIDA

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

INDIANA

Oct. 1–3, '07. Indianapolis. Conf. on RE from Organics Recycling. For project managers, policy makers, investors, technology providers, utilities, consultants, etc. Info: BioCycle • biocycle_magazine@vresp.com • www.biocycle.net

IOWA

Feb. 20–22, '08. Des Moines. Forum on Energy Efficiency in Agriculture. Info: ACEEE • 202-429-8873 • agforum@aceee.org • www.aceee.org

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

MASSACHUSETTS

Hudson, MA. Workshops: Intro to PV; Advanced PV; RE Basics; Solar Hot Water & more. Info: The Alternative Energy Store • 877-878-4060 • support@altenergystore.com • http://workshops.altenergystore.com

MICHIGAN

West Branch, MI. Intro to Solar, Wind & Hydro. 1st Fri. each month. System design & layout for homes or cabins. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

MISSOURI

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

MONTANA

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

NEW HAMPSHIRE

Dec. 1, '07. Manchester, NH. Home Energy Conference. Incorporating RE, efficiency, green building, geothermal, biofuels & other sustainable technologies into the home. Info: NH Sustainable Energy Assoc. • 603-497-2302 • nh.sustain.energy@tds.net • www.nhsea.org

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. NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NORTH CAROLINA

October 20–21, '07. Boone, NC. Small-Scale Wind Installation workshop. Info: Appalachian State Univ. • 828-262-2933 • wind@appstate.edu • www.wind.appstate.edu

Saxapahaw, NC. Solar-Powered Home workshop. Solar Village Institute • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OREGON
Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. 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/psea.htm

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

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

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

WASHINGTON, D.C.
Oct. 12–20, '07. Solar Decathlon. Twenty teams compete on the National Mall to design, build, and operate the most attractive & energy-efficient solar-powered home. Info: www.solardecathlon.org

Nov. 28–29, '07. RE in America: Policies for Phase II. Policy forum with U.S. legislators. Info: American Council on RE (ACORE) • 202-429-2037 • conroy@acore.org • www.acore.org

WASHINGTON STATE
Guemes Island, WA. SEI 2007 workshops. Oct. 6: Intro to RE; Oct. 8–13: Solar-Electric Design & Installation; Oct. 15–17: Grid-Tied Solar Electricity; Oct. 19–20: Successful Solar Businesses; Oct. 22–24: Solar Hot Water; Nov. 5–10: Electric Vehicle Conversion. Info: See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

WISCONSIN
Oct. 1–3, '07 (again Nov. 2–4, '07). Amherst, WI. Installing a Solar Water Heating System. Hands-on workshop on solar thermal closed-loop pressurized & drainback systems for domestic hot water and space heating. Info: Artha Sustainable Living Center LLC • 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

Custer, WI. MREA '07 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

INTERNATIONAL

AUSTRALIA
Feb. 17–21, '08. Adelaide, S. Australia. Intl. Solar Cities Congress. Support cities in UN energy & climate policies by stimulating interest in RE & energy efficiencies. Info: Plevin & Associates • 61-8-8379-8222 • events@plevin.com.au • www.solarcitiescongress.com.au

COSTA RICA
Jan. 21–27, '08. Pursical County, C.R. RE for the Developing World. Hands-on workshop. Info: See SEI listing for WA State • www.ranchomastatal.com

Feb. 2–10, '08. Palmital, C.R. Solar Electricity for the Developing World. Hands-on workshop. Info: See SEI listing for WA State • www.durika.org

ITALY
Nov. 11–15, '07. Rome. Wind Expo 2007. International conf. for commercial wind industry. Info: Artenergy • info@windexpo.eu • www.windexpo.com

NEW ZEALAND
Jan. 26–27, '08. Canterbury. Sustainability Expo. PV, wind, Solar hot water, energy efficient building design, housing & transport, & other sustainable technologies. Info: Solar Electric Specialists Ltd. • 027-457-6527 • www.sustainabilityexpo.co.nz

WALES
Aberystwyth. RE workshops. Oct. 19–21: Wind & Solar; Oct. 23–24: RE for Planners; Oct. 26–28: Intro to RE. Info: Green Dragon Energy • 49-0-30-486-249-98 • info@greendragonenergy.co.uk • www.greendragonenergy.co.uk

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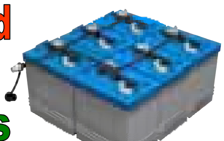

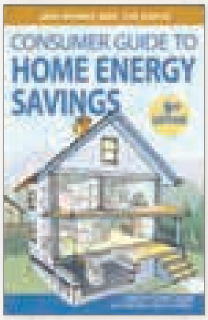

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RE People

Debbi & Bill Lord, solar pioneers.

Who: Bill & Debbi Lord
Where: Cape Porpoise, Maine
When: 1995 to present
What: Solar-electric & solar hot water systems
Why: Social & environmental responsibility

Over the years, Bill Lord has turned up in *Home Power's* pages several times. In 1997, we first covered his crusade for sensible net metering in Maine. Two years later, Bill and his wife Debbi's home graced the cover of *HP70.*

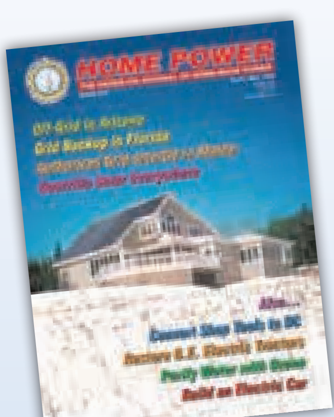
According to Bill, the *Home Power* cover story put their home "on the publicity map." Since then, the Lords have had numerous articles written about their "Maine Solar House," and television coverage has included spots on HGTV, The History Channel, and, most recently, *Nova.*

With 31 years at ABC News as an executive producer of *Nightline* and *World News Tonight*, Bill is no stranger to the powerful influence of mass media. Now a journalism professor at Boston University, he merges his professional expertise with his environmental convictions, providing information about renewable energy through a personal Web site (www.solarhouse.com). Here, visitors can learn about the home's solar energy systems, listen to Bill's solar podcasts, and even participate in an online solar forum.

"When we constructed our home, the issue of treading lightly on the environment was uppermost in our minds," says Bill, "though my wife suspected that the gizmos in the basement—inverters, pumps, and controllers—had a certain attraction to my male mind."

Despite its high-tech bent, the Lords' very normal-looking, contemporary-styled saltbox home has all the amenities and conveniences of a typical American home. "We basically live like everybody else,'' Debbi says, ''but the sun is providing our energy.''

Solar thermal collectors, which provide water and space heating, cover half of the Lords' south-facing roof. The other half harvests the sun's free energy for electricity: The 4,200-watt PV array generates approximately 4 megawatt-hours annually, completely meeting the home's electrical needs. Bill says that their utility bill—a $7.47 monthly connection fee for being hooked up to the grid—is "a pleasure to pay."



Even during Maine's legendary winters, the home shines. Passive solar design and the solar thermal system keep the home warm. Bill reports that "interior temperatures rise above 75°F if a window isn't kept open. Our feet are greeted in the morning by the welcoming warmth of our radiant floor."

"There is a free lunch and dinner with solar energy, as long as you can afford the breakfast," says Bill. The up-front costs are "not to be scoffed at, but they are an investment in a lifestyle that is personally rewarding, financially beneficial in the long run, and socially necessary. Do join the solar generation. It is worth the effort."

—Ian Woofenden

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1) March 2006, SANYO R&D Labs. 2) Single c-si cells. 3) Compared to industry average.

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