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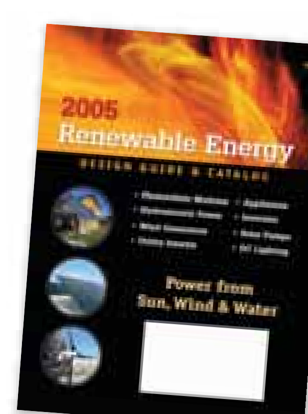

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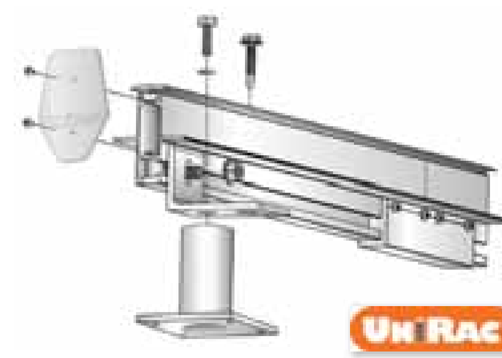

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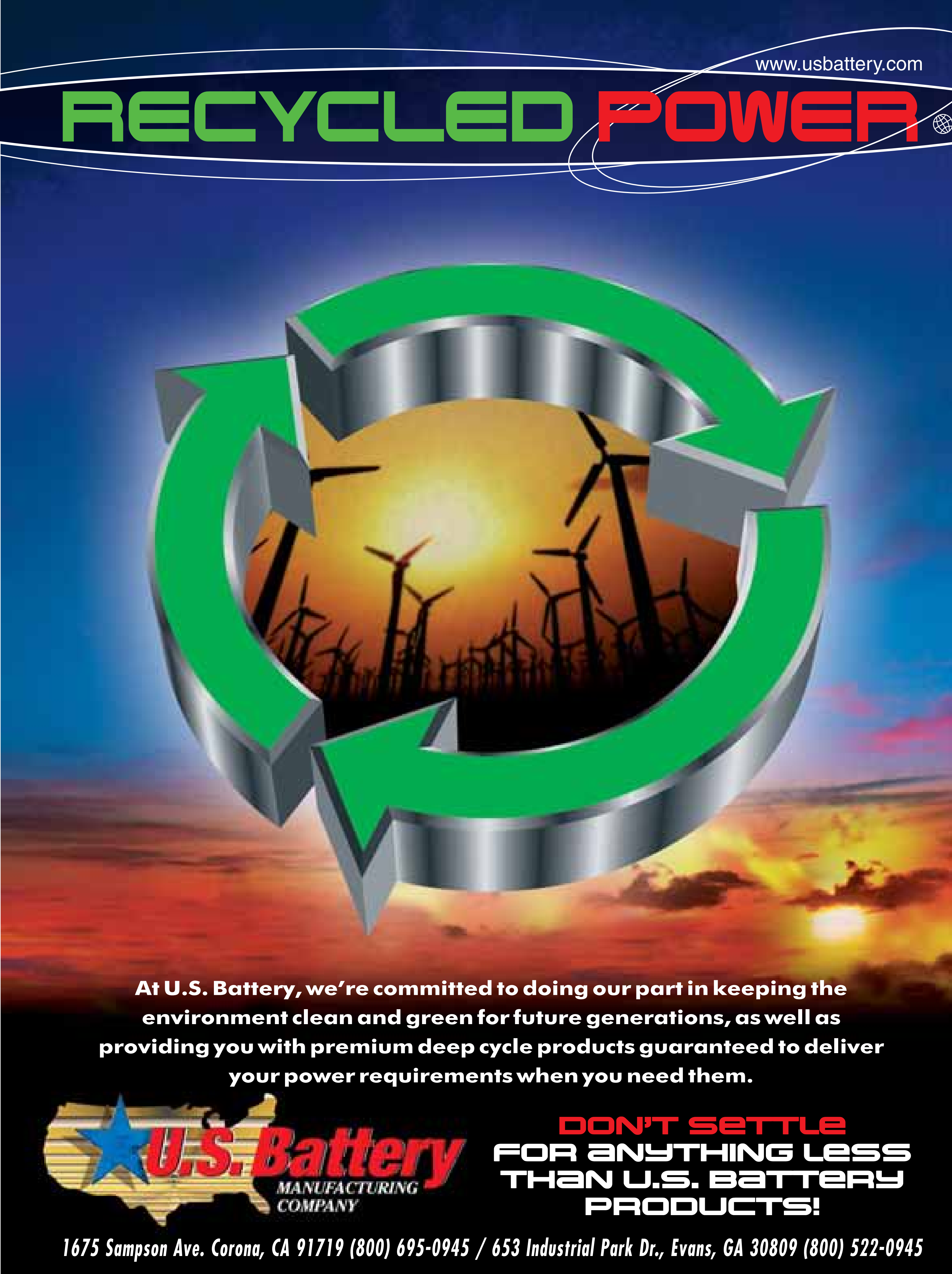
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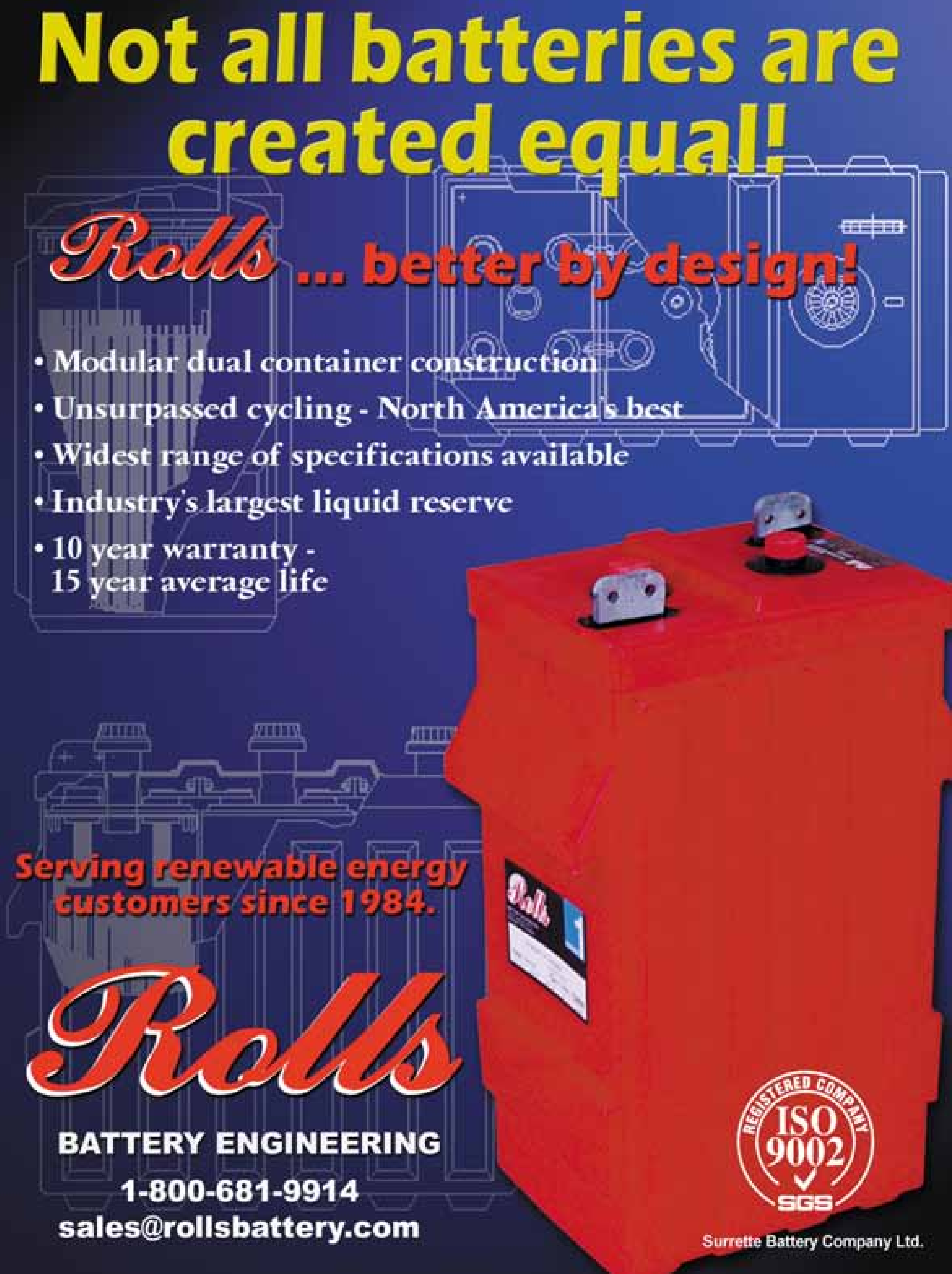

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The 2005 U.S. Energy Bill

A Few Points of Light

Optimism and perseverance are two personality traits that most renewable energy (RE) advocates have honed over the years. They're survival skills, really. In early August, President Bush signed into law the first comprehensive U.S. energy legislation since 1992. While the overwhelming majority of the bill's provisions are sure to challenge even the steadfast optimism of seasoned RE supporters, the following new tax credits could help bring RE and efficiency into more U.S. homes and businesses:

Solar-electric and solar water heating systems. Homeowners can receive a tax credit for up to 30 percent of their solar equipment and installation costs, with a maximum credit of US$2,000. The current solar tax credit for commercial systems was increased from 10 percent to 30 percent, with no cap on credit amount.

Hybrid gas-electric vehicles. The current federal US$2,000 tax deduction for hybrid vehicles was changed to a tax credit of up to US$3,400 (bigger credits will go to hybrids that save the most fuel compared with 2002 models). This credit takes effect January 1, 2006—but you'll have to hurry to take advantage of it. Only the first 60,000 hybrid vehicles sold by each automaker will qualify.

Efficiency upgrades for existing homes. This new tax credit covers 10 percent (up to US$500) of your home energy improvements, such as adding insulation, installing more energy efficient windows, or buying a high efficiency central air conditioner, heat pump, or water heater.

The Solar Energy Industries Association (SEIA) worked tirelessly and succeeded in their efforts to have solar credits included in the bill. While these credits are short-lived as written, one of SEIA's main goals this fall will be the extension of both the residential and commercial solar credits. We can all help in this effort by using the credits, and installing solar-electric and solar water heating systems. If public demand is high, it will send an unmistakable message to our representatives that the people in this country want renewable energy to be part of our collective energy future.

—Joe Schwartz for the *Home Power* crew

Think About It...

We don't have to wait for some grand utopian future. The future is an infinite succession of presents, and to live now as we think human beings should live, in defiance of all that is bad around us, is itself a marvelous victory.

Howard Zinn, historian

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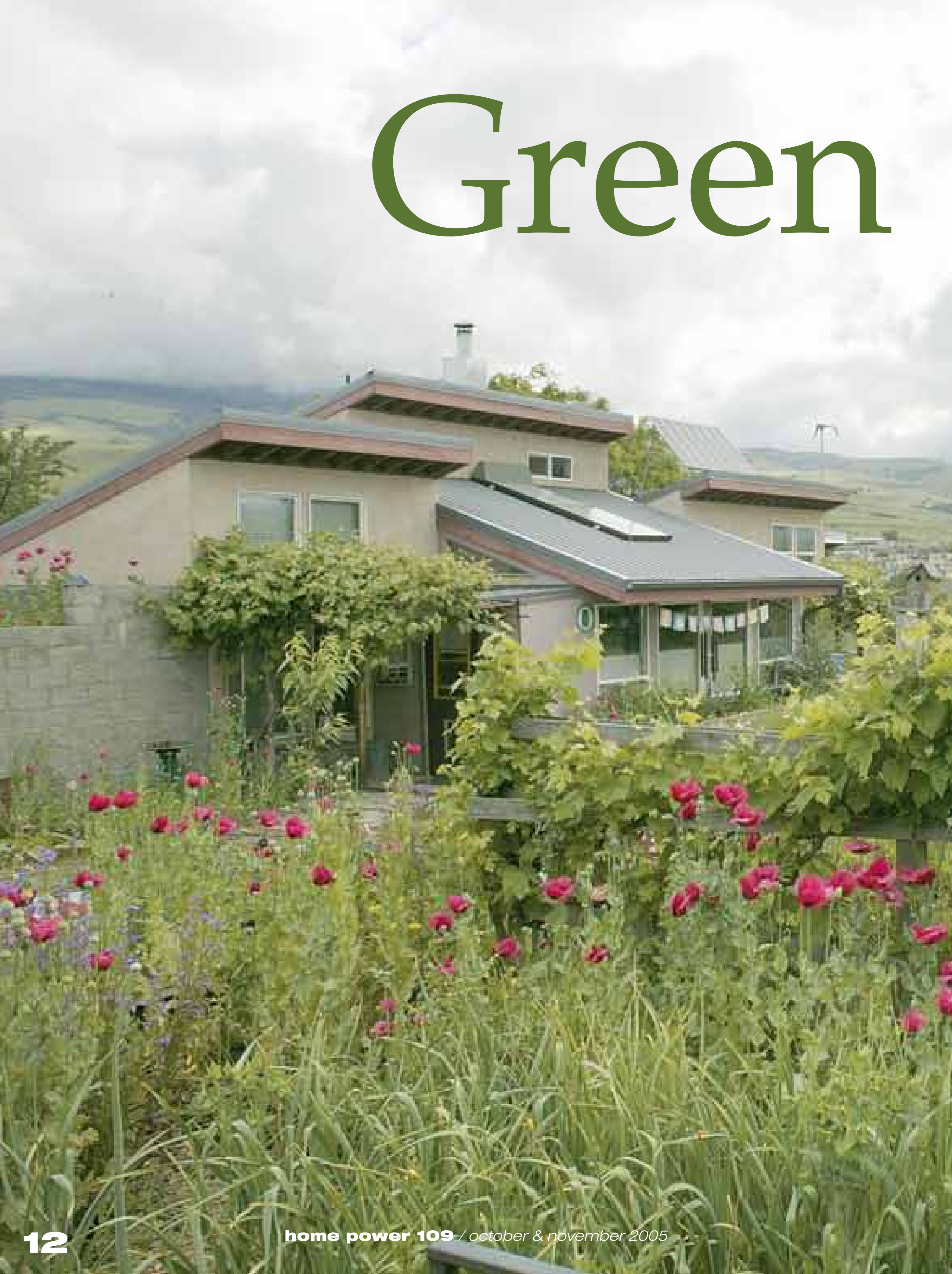

Half-Acre

Off-Grid Country Living—In the City

Risa Buck
Photos by Pam Lott

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Fourteen years ago, I moved to Ashland, Oregon, hoping to settle in and create a more permanent place to call home. I was very fortunate to have bought a 1950s house and an old shed on a half-acre of land with two friends. When our circumstances changed, I remained the sole caretaker of this land. I wanted to move out of the original house and build a smaller, passive solar home. I knew that I wanted to create a place that was efficient and sustainable. Since I was several screws short of being a builder, it was obvious that I had a lot of homework and networking to do.

In the mid '80s through the early '90s, I lived in a five-person vegetarian cooperative in Davis, California. There, I was first exposed to permaculture concepts, which include nurturing the relationships that exist between the land, animals, and people. Wise use of resources and integrating different systems (composting, plant diversity, seed collecting) also play an important part. What began with the pleasures and necessity of eating fresh, local food, traveled full circle to include every aspect of my life—from what I consume and where it comes from, to how it was created and what the costs are (human, environmental, economic, political, and spiritual). I built my house the way I did because it expresses (in part) the way I want to be in the world.

Since that time, I've created a place to live that's become not just a home, but a way of relating with the world around me. The off-grid home designed for one person a decade ago has blossomed into a "sustainable urban homestead," which I now share with my partner Pam and dog Ahlyo. Other developments include a wind generator, straw bale studio, water catchment systems, and extensive gardens.

This off-grid, passive solar homestead uses wise design to achieve thermal comfort, energy efficiency, and sustain its occupants. On the roof, a solar thermal collector heats the home's water, and a solar-electric array provides electricity. A small wind generator supplements the solar electricity during winter months. Below the middle, front windows, a raised cinder-block bed provides a perfect place to grow greens in winter and heat-loving vegetables in the summer. Fourteen years ago, this homestead was a barren lot, with a dense peppering of star thistle and foxtail weeds.

I worked with architect Ryan Langemeyer, who had been one of my housemates in the original house (now a rental home) on the property. Ryan is a great problem-solver, and there was no shortage of challenges and opportunities during this project.

With good southern exposure, the long, rectangular lot lent itself well to building a passive solar home. To maximize solar gain into the house, most of the windows face south. A south-facing roof allowed a place to mount solar hot water and solar-electric panels. A dense dirt mound (berm) along the north side of the house creates additional insulation and thermal mass, which helps keep the house cooler in the summer and warmer in the winter. The passive solar design was a natural choice that allows the flexibility to change with the seasons. In the summer, we use window shades and grape arbors to shade the house. During wintertime, the grapevines die back, and we open the shades to let in as much light and heat as possible.

Each year that passes, the thermal comfort of the house and surrounding area improves, especially in the summertime. As the grapes and trees mature, more shade is generated, cooling the entire area. It is tricky planting very large trees because we don't want to shade the rooftop PV panels or solar hot water panel.

On summer evenings, when outside temperatures become cooler, we open windows to lower the indoor temperature. In the morning, as temperatures rise, we close windows and shades to retain the coolness.

A south-facing, cinder-block raised bed allows winter gardening with freeze protection due to its close proximity to the house. In addition, the reflective heat from the windows, the overhang, and the masonry block create a heat sink. During the summer months, the bed really heats up and makes for happy tomatoes, eggplant, basil, and peppers. I can extend the growing season on both ends without a greenhouse.

Straw Bale Studio

When I first considered the design possibilities for my home, I was very interested in straw bale construction and energy independence. I chose to pursue off-grid living, although I regretted not building a straw bale home. Five years later, I got my chance to build with straw, when I needed to replace the shed that was deteriorating.

Above: Large south-facing windows admit an abundance of sunlight, eliminating the need for artificial lighting during the day, and providing heat during the winter. In the summertime, drawing the shades prevents the rooms from overheating.

Top: Smart design in this passive solar house means maximizing small spaces and "stacking functions." Here, a loft above the kitchen serves as a storage area for the water heater tank, which is connected to a rooftop solar collector. This arrangement allows water from the tank to be delivered to the kitchen and bathroom below by gravity, instead of an electric pump.

Above: Risa gets her gloves muddy applying the first layer, or scratch coat, of earthen plaster on the straw bale studio's exterior walls.

Middle: One hundred straw bales, purchased from a local farmer, were used to construct the studio.

Top: The completed studio.

Building code dictated that the walls of the straw bale studio be non-load bearing, although that building code has now been revised. We poured the concrete floor and constructed the framework first. Once that was complete, I organized a three-day work party. A couple of experienced "strawpenters" guided the 30-person crew to stack bales, attach chicken wire, and apply stucco.

The straw bale design is very simple. The 17-by-17-foot building has an open floor plan, with a toilet and small sink enclosed in one corner. A couple of truth windows—small cut-aways in the walls—reveal the straw and chicken wire behind the plaster.

The coolness inside the straw bale studio in the summer is comparable to air conditioning. Similarly, in the winter, once the space is heated, it takes very little energy to keep the space warm. The insulating qualities (2-foot-thick; 61 cm walls) of the straw bale studio far surpass any other kind of building I have been in. It has a unique aliveness and character with its undulating walls.

Trash to Treasure

Whenever possible, we use salvaged materials. When the local co-op built a new store, I scored the bakery shelves and adapted them as a multi-use cabinet for food storage on one end and the stereo and music collection on the other. An old fire escape ladder, with wheels welded on the bottom for mobility, provides access to the loft above the kitchen. We extended one of the grape trellises by using an old metal bed and various other collected metals. We converted a newspaper recycling bin from the local Lion's Club into a garden shed. Besides being more cost effective and usually higher quality, an additional benefit from reusing materials is reducing waste (items slated for the landfill get a new lease on life). An incredible abundance of resources are available because one person's discard is another's asset. The satisfaction from obtaining these materials is priceless—it keeps life going as one gigantic treasure hunt.

at a glance

Location: Ashland, Oregon

Property Size: 0.5 acres

Main House: 800 sq. ft.

Studio: 289 sq. ft.

Energy Systems: Off-grid, wind and solar-electric; solar hot water system with propane, on-demand backup water heater. Average daily electricity production: 1.6 DC KWH

Water System: Rainwater harvesting and catchment for irrigation. Capacity: 3,000 gallons (ferro-cement tank); 10,000 gallons (pond)

Space Heating: Masonry stove; Annual wood use: 1 cord of a hardwood, like oak or madrone

Cooking & Refrigeration: Propane cookstove and refrigerator

Food Production: Extensive gardens that include raspberries, 'Concord' and 'Red Flame' grapes, fig, kiwi, apple, persimmon, almond, olive, Asian pear, plum, peach, cucumber, garlic, sugar snap peas, greens, squash, tomatoes, basil, eggplant, peppers, and okra; Winter food production: 5 percent; Summer: 66 percent

Transportation: By foot and by bicycle (85 percent); by biodiesel-fueled car (15 percent)

What We Love Best: "We get the best of both worlds. We're close enough to town to walk or bike, and we have the space to live with greenery, critters, and Ashland's surrounding beauty."

Special Challenges: "The ferocious unsustainable development happening in the valley. In the last several years, overinflated real estate prices have made it difficult or impossible for households with 'regular' incomes to live here.

"Also, when we need a technician to work on our various systems, it is still tough to find someone who can problem-solve the solution. We thank the heavens for Joe Schwartz, *HP* tech editor and CEO."

Risa, Pam, and Ahlyo dine alfresco on the patio they constructed using concrete salvaged from two neighborhood construction jobs. Originally destined for the dump, the neighbors were happy to find a home for it (and avoid the disposal fee). The concrete was broken into smaller pieces, and transported across the yard, one or two pieces at a time—tough work, but a great payoff for the sweat equity.

Above (left): On the middle roof—a solar thermal collector preheats the household's water. An array of solar-electric panels on the upper roof meets the majority of the home's electrical needs. An Air 303 wind turbine also contributes to the home's energy production and keeps the batteries charged during winter months, when there is typically less sunshine and more wind.

Above (right): Living in town lets Risa and Pam walk and bike to many places. For longer trips, they use Risa's Volkswagen Golf TDI. They fuel her car with biodiesel, a plant-based, renewable fuel, making this car, which averages 48 mpg, an even cleaner, greener vehicle.

Below: The fuel-efficient masonry stove does double duty as a home heater and clothes dryer when the laundry is hung in front of it on a retractable clothesline. Combining passive and active strategies like these maximizes the house's energy efficiency.

Energy

My house still is the only city-sanctioned, off-grid home within the city limits. Initially, the City of Ashland was concerned about my energy independence. They were concerned that if I provided my own electricity, I might be at risk of "running out." I believe they feared a mini-revolution of wannabe, off-gridders following in my footsteps. But this fear was unfounded. The energy needs for an average household are considerably greater, and an off-grid system to meet those needs would be more costly than the very modest system that sustains us.

The 370-watt solar-electric (photovoltaic; PV) system works year-round. In the winter, when there is less sunshine, a wind generator supplements the charging of the system's batteries. With two of us using a system originally sized for one, we are mindful (some might accuse me of being hypervigilant) of our energy usage.

Our house takes advantage of several efficient 12-volt appliances. A 12-volt car stereo system offers the best sound for the lowest electrical use and cost. I chose a 12-volt television for the same reasons. My laptop computer runs on 12-volt DC and 120-volt AC. And, in summer, a 12-volt ceiling fan runs constantly to circulate air in the house.

We don't have the luxury of ignoring the bigger picture before making changes. If a grid-tied home adds a new appliance, the consequence shows up in the form of a bigger monthly electric bill. Our consequences would likely drain the six Trojan deep-cycle batteries, eventually rendering them worthless. Purchasing a new bank of batteries for my small system would run about US$1,000. It is not a mistake I want to make even once.

In the winter, we use about one cord of hardwood in the masonry stove. The fire heats air chambers inside the stove, which absorbs the heat and radiates it to the surrounding space. This clean-burning, efficient heater only requires one fire a day for about 90 minutes. Once the vent and flue are shut, the stove radiates heat for the next 24 hours, maintaining indoor temperatures between 67°F and 70°F (19–21°C). Raising the window shades on sunny winter days also maximizes any solar gain and helps heat the home.

A rooftop solar collector heats household water. In the summer, the sun heats the water between 140°F and 160°F (60–71°C). In the winter, the sun only heats the water to about 80°F (27°C). I learned the first winter that you cannot comfortably wash dishes and bathe at that temperature. Now, a propane, on-demand heater supplements the solar water heater.

Food & Water

An important part of our homestead is creating a balanced landscape that helps support itself, and works with where and how we live. As a small household, we grow a fair amount of food, relying more heavily on the garden during spring, summer, and fall. We pay particular attention to building good soil, which helps with water conservation, and makes for happy earthworms and other critters. A diverse mix of fruit and shade trees, shrubs, perennials, herbs, and veggies are planted in multistoried layers, which help support one another by shading or by providing mulch. We also group plants with similar needs together and locate them according to the attention they require (plants that need more tending are closer to the house). One special consideration is solar access, and making sure to plant accordingly to avoid blocking solar gain to the house.

The grounds have changed dramatically over the years, and have been further enhanced by Pam's garden design expertise. Fourteen years ago, the backyard had an English walnut tree, pampas grass, and 'Red Flame' grapes, but the dominant species were star thistle and foxtail weeds. When it rained, water rushed toward the end of the property and eroded the hillside below. Today, the walnut and grape are in an expanding community with trees, bushes, vines, veggies, herbs, and flowers. The erosion has ceased.

Each area of our landscape has a specific function and purpose, whether it's growing veggies or providing shade for us to hang out. As the garden gets more established, it becomes more self-sustaining. Besides enjoying the seasonal and annual changes, there's nothing like stepping out the front door and picking a fresh salad or filling a cereal bowl full of raspberries.

Above: A luscious crop of peaches was only a small sampling of the delicious harvest from Risa and Pam's front yard garden. This year's bumper crop has been quarts and quarts of raspberries.

Top: In bloom—a wide assortment of perennials and annuals grace the gardens, providing wonderful color, sweet fragrances, and plenty of special nooks and crannies for wild creatures.

At right (upper): A ferro-cement cistern, built on site, contains up to 3,000 gallons of rainwater that washes from the rooftops of the main home and straw bale studio. The tank was constructed by workshop participants in 1996. With the addition of the pond, the tank now serves as standby storage for times when the pond dips below the 3-foot mark. Both are used for irrigation.

Right: A rainwater catchment pond acts as the homestead's primary reservoir, storing between 8,000 to 12,000 gallons of water. It also hosts a variety of wildlife. *Gambusia* (mosquito larvae-eating fish) share the pond with tadpoles, snails, *Anacharis* (a submerged aquatic plant that oxygenates the water), and water lilies. Since the pond was built, a great blue heron and two ducks have visited, as well as fox, deer, raccoon, gophers, ground squirrels, and skunks. Future plans include raising fish for food, so an aeration system was recently installed (powered by excess solar-electricity generated on site), to ensure adequate oxygen to the plants and animals living in it.

A work in progress—the half-acre 14 years ago, and today.

Home, Sustainable Home

I feel very grateful to be on this adventure of creating a sustainable urban homestead. The unfolding of what a half-acre of land can become is well underway. It has been my palette for integrating beauty (building stuff) with the natural surroundings. The support and participation of friends and family over the last decade have helped make it possible.

This article has provided some snippets of accomplishments and highlights since 1995, but I consider my evolving homestead a lifelong journey of creating and re-creating, figuring out what works and what might work better. I believe it is possible as an individual to make a positive difference with how we *impact* our environment. It is because of that belief that I feel encouraged and hopeful.

We can all do more with less. Although I strive to consider, as much as possible, the many-layered consequences from my choices, I am not, nor have I tried to be, a purist in any sense of the word. I am a consumer, and I want to be a conscientious consumer.

My chosen lifestyle connects me closely with my environment. It is a daily relationship that I cherish. From the food we grow to eat and the food we purchase (local and organic), to the various scavenged materials, the energy generated by the sun and wind, and the used cooking oil collected from local restaurants for making biodiesel to fuel my diesel car—all of these things and more are decisions we make every day. The lifestyle we have chosen is not for everyone. It is a conscious choice to live here in this way. It feels so luxurious to be able to have an integrated connection with my surroundings and then be able to go up the street to the co-op, the movies, or the public swimming pool. That's a pretty good life.

And last but not least, I now get to officially thank CJ Banner and Tracy Wood—two dear friends who have participated in *so* many projects in the last thirteen years. Hardly an endeavor has occurred successfully without their consult, creativity, and hard work. When they aren't around and there's a challenging situation (a need to move something way too heavy), I imagine how they might approach it, and this helps me see it through. Thank you! Thank you!

Pam, Risa, and Ahlyo.

Access

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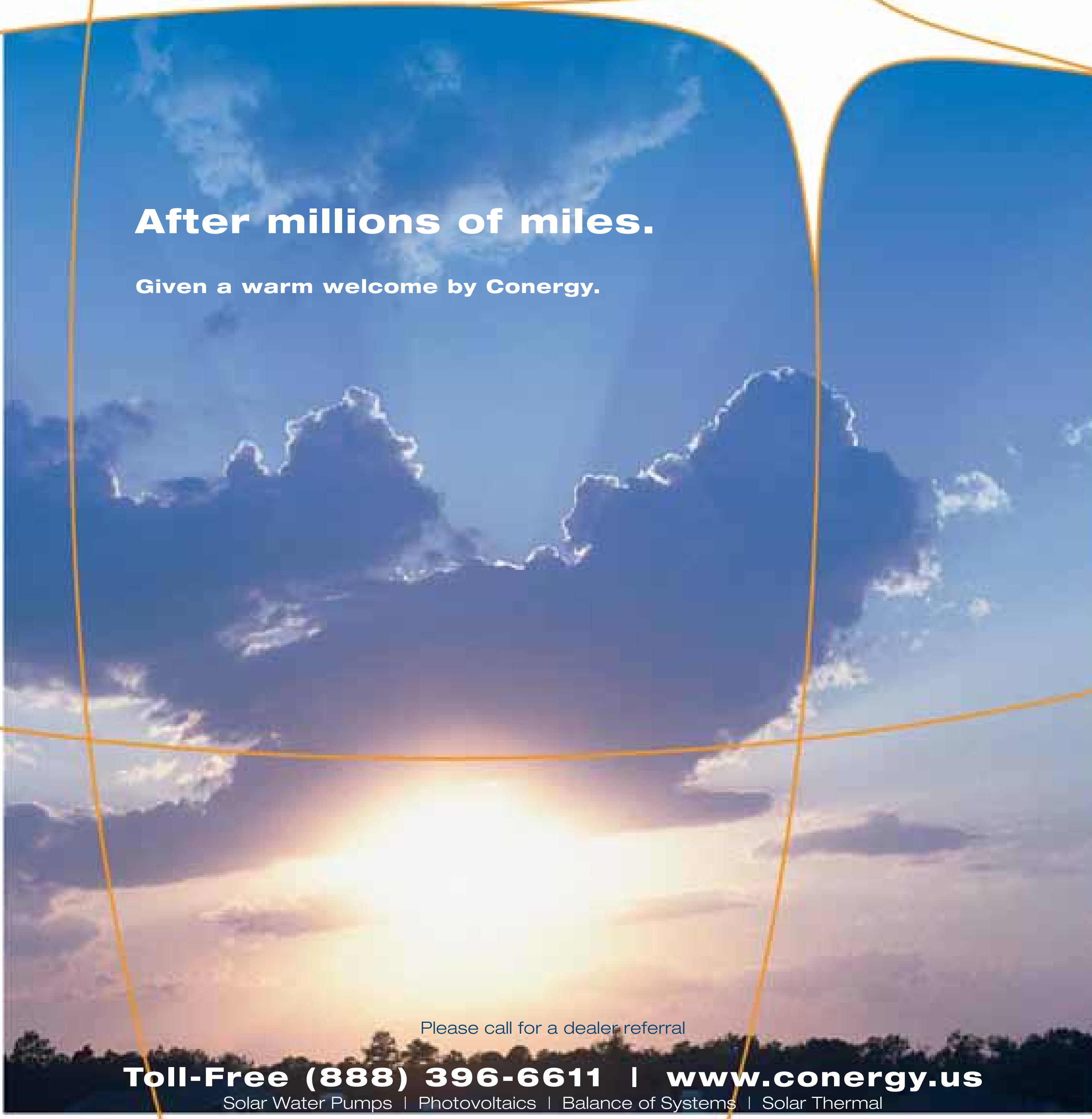

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Making $ense

of Solar-Electric System Costs

Scott Russell

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As *Home Power's* marketing director, I spend a lot of time at fairs and other events aimed at getting people interested in renewable energy. Without a doubt, the question I get more than any other is, "What does a solar-electric system cost for an average home?" Understandably, these folks are looking for the sticker price of a grid-tied solar-electric system, something to walk away with and compare to other home energy or greener living "investment" possibilities.

The truth is, it's not much easier to answer, "How much will a solar-electric system cost me?" than it is to answer, "How much will it cost me to build a house?" In either case, the answer has to start with two words—"It depends…"

That's because several variables influence the cost of a grid-tied solar-electric (photovoltaic; PV) system. Although there's no pat answer to the price question, the guidelines and examples here will help you estimate your costs, and get you started on your path to energy independence.

How Hungry Is Your Home?

The average American home uses roughly 830 kilowatt-hours (KWH) of electricity each month. But basing system costs solely on that number would most likely give you an inaccurate and unhelpful result. Your electrical use may vary wildly, depending on the season, what kind of appliances you use, and your usage habits.

So how can you gauge your electrical appetite? For a quick snapshot of your electrical usage, check out your monthly electricity bill. Most bills will include KWH usage figures for the last twelve months; this will give you a good idea of how much electricity your home uses each year.

Once you've got a handle on your electrical appetite, taking steps to improve the efficiency of your home will be your next best move. This can have a tremendous impact on the cost of the system you install. Every dollar you spend on making your home more efficient decreases the cost of your system by approximately US$3 to $5. (For more information, see "Calculating Your Energy Appetite," in *HP102*.)

A huge disparity exists between home sizes, efficiencies, and personal electrical appetites, and there's also a similar gap in the efficiency potential of different homes. If you live in an efficiently built, well-insulated home, with modern appliances, compact fluorescent lighting, and high performance windows, you may only be able to reduce your average electricity use by 5 or 10 percent. But if you're on the other end of that spectrum, by implementing efficiency measures you may be able to reduce your use by 40 percent or more, shaving several thousand dollars off the cost of your system. For example, just replacing an older model refrigerator with a modern, more efficient one could reduce your electrical usage by 50 KWH per month. Combine this with household-wide efficiency strategies and you can make a pretty sizeable dent in your system cost.

A Sharp 175-watt solar-electric module, 62 x 32.5 inches. The author, 66.25 x 18.5 inches.

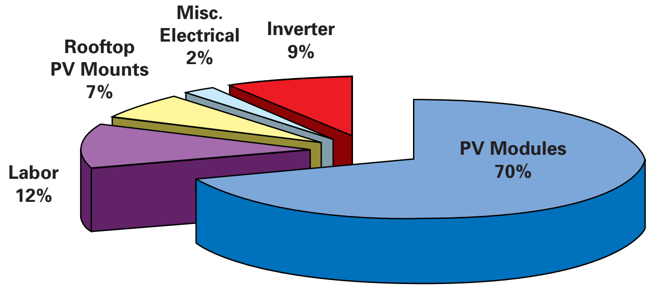
Location, Location, Location

Where you live also affects your system costs. Less sunny locales will call for larger systems to generate the same amount of electricity that a smaller system in a sunnier spot can produce. In the solar world, sunlight is measured in units called "peak sun hours." Phoenix, Arizona, receives an annual average of 6.5 peak sun hours per day, while Seattle, Washington, only gets 3.7 peak sun hours per day. To determine the peak sun hours in your region, visit the Renewable Resource Data Center's Web site (see Access).

Besides the number of peak sun hours in your region, average annual temperatures where you live also affect your system size, and its relative cost. In colder regions, you may use lots of electricity for space heating and water heating. In warmer regions, air conditioning can dramatically amplify your electricity use.

Climate and other site-specific variables will also determine your solar-electric system's size and its production. PV panels operate more efficiently in cooler climates and less efficiently in hot ones. Some locations regularly receive morning fog or afternoon thunderstorms. In dry, dusty climates without regular rains to clean the panels, accumulated dust and dirt will reduce the output of the system. All of these variables need to be considered when sizing a system and estimating its annual production.

Sample Grid-Tied PV System Costs (%)



A Place in the Sun

Even the sunniest regions won't guarantee you good system performance unless you have unobstructed solar access at your site. This daily access to the sun is called your "solar window." You'll need a location on your rooftop or elsewhere on your property that:

- Ideally faces south, but east- or west-facing arrays make sense in some cases;
- Provides enough space for the number of PV panels needed, possibly including room for expansion;
- Enables the entire array of modules unshaded exposure to the sun between the hours of 9 AM and 3 PM, year-round.

Compromising any of these three conditions can mean having to increase the size of your system, which increases its cost.

A Nibble or a Bite?

One of the best features of solar electricity is its scalability. With a little foresight, you can start small and build your system gradually if that better suits your budget.

A starter system can be designed to meet just a portion of your home's daily electricity needs. This is one great benefit of a grid-tied system—the remainder of your electricity can be purchased from your electric utility, just as before. And, if you plan your design for future expansion, adding more modules to your array as your pocketbook allows is relatively simple.

Estimated System Costs Comparison

	San Diego, CA				Seattle, WA			
Average monthly electricity use (KWH)	500		1,000		500		1,000	
Portion of electricity from solar energy*	25%	75%	25%	75%	25%	75%	25%	75%
Average sun hours per day	5.7	5.7	5.7	5.7	3.7	3.7	3.7	3.7
Approximate system efficiency	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Number of 175 W modules needed*	6	18	12	36	10	28	19	56
Total system size (W)	1,050	3,150	2,100	6,300	1,750	4,900	3,325	9,800
Roof space needed (sq. ft.)	85.9	257.8	171.8	515.5	143.2	401.0	272.1	801.9
Estimated system cost per KW (US$)	10	8	9	6	9	6	8	6
Price of installed system (US$)	10,500	25,200	18,900	37,800	15,750	29,400	26,600	58,800
State rebates (US$; excludes tax incentives)	2,940	8,820	5,880	17,640	0‡	0‡	0‡	0‡
Cost after rebates (US$)	7,560	16,380	13,020	20,160	15,750	29,400	26,600	58,800

* Module counts are rounded up, since it's not possible to install "fractions" of a module. The result is that all of the examples will produce more than this nominal percentage.
‡ Washington State is currently implementing production-based incentives up to US$2,000 per year.

Free Money

Perhaps the most powerful impetus behind the exploding popularity of grid-tied solar electricity is the availability of generous financial incentives. In some states, rebate programs refund as much as 60 percent of the system's installed cost to the homeowner! Illinois residents can recoup from 25 to 50 percent of their costs; New York's PV incentive program pays up to 60 percent of total installed costs; and Oregon homeowners can receive up to US$10,000 in rebates. Add to that state tax credits and exemptions, and low-interest state loans, and the picture gets brighter still. You can get up-to-date information on financial incentives at the Database of State Incentives for Renewable Energy Web site (see Access).

DIY or Go Pro

Whether to install your solar-electric system yourself or hire a professional is a decision not to be taken lightly. Doing it yourself can cut 15 to 25 percent from the total cost, but be sure to realistically gauge your ability to design and install an efficient, code-compliant, and safe system, and don't forget to consider what your time is worth. If you're adept at wiring and home improvement projects, and have the considerable time required to learn the specialties of solar-electric installation, you can join the ranks of homeowners who successfully self-install. (For a list of recommended tools, see "Tools of the Solar-Electric Trade," in *HP105.*)

The vast majority of grid-tied systems are quickly and competently installed by licensed professionals who bring with them the experience to ensure a system design that provides safe, maximized performance. Some rebate programs require that a pro installs your system; be sure to inquire. (For a directory of professional installers, see Access.)

Even a small system can reduce your utility bills while producing clean energy.

Estimating Installed Costs

The U.S. Department of Energy (DOE) estimates that a 2 KW (2,000 watt) system costs US$8 to $10 per watt to install, while a 5 KW (5,000 watt) system can cost US$6 to $8 per watt installed. The actual cost of an installed system may vary widely depending upon installation complexity, location, component availability, and the size of the installed system.

Rated System Size (W)	Cost Per Installed Watt (US$)
1,000 to 4,000 W	$8 to $10
5,000 W+	$6 to $8

Duluth, MN				Atlanta, GA				Boston, MA			
500		1,000		500		1,000		500		1,000	
25%	75%	25%	75%	25%	75%	25%	75%	25%	75%	25%	75%
4.4	4.4	4.4	4.4	5.1	5.1	5.1	5.1	4.6	4.6	4.6	4.6
0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
8	24	16	47	7	21	14	41	8	23	15	45
1,400	4,200	2,800	8,225	1,225	3,675	2,450	7,175	1,400	4,025	2,625	7,875
114.6	343.7	229.1	673.0	100.2	300.7	200.5	587.1	114.6	329.4	214.8	644.4
10	7	8	6	10	7	9	6	10	7	8	6
14,000	29,400	22,400	49,350	12,250	25,725	22,050	43,050	14,000	28,175	21,000	47,250
2,800	8,000	5,600	8,000	0	0	0	0	4,200	12,075	7,875	23,625
11,200	21,400	16,800	41,350	12,250	25,725	22,050	43,050	9,800	16,100	13,125	23,625

Next Steps

It's easy to see why there's no such thing as a "one-size-fits-all" sticker price for a solar-electric system, but a little homework and understanding your options both go a long way toward reliable planning and budgeting. To give you an even better idea of the costs involved, check out the Estimated System Costs Comparison table above, which compares the energy production, efficiency, and costs of two sizes of solar-electric systems in five U.S. cities.

To take a first pass in estimating costs yourself, consider each of the variables discussed above and determine the:

- Average KWH used by your home each month
- Peak sun hours for your location
- Quality of your solar window
- Financial incentives, if any, available in your state

Use this information to fill in the worksheet on the right to figure your approximate system size in watts. Finally, project your costs based on the sliding scale that specifies total cost per installed watt. This will give you a rough cost projection from which to work.

To get a better picture of what such a system might cost you, two options exist: phone a local professional for a quote or work through the calculations yourself. (Before you call, gather a

Calculate Your Costs

Use this easy worksheet to figure out what a professionally installed solar-electric system might cost. If you have last year's electricity bills handy, grab them and your calculator, and get started!

1. First, figure the daily output needed from your PV system:

Average Monthly Electricity Use ___________ KWH

x 1,000 [converts KWH to Watt-Hours] = ____________ WH

x Percent (_____ %)* of Monthly Electrical Use from PVs = ____________ WH

÷ 30 days

= Daily PV Output Needed ____________ WH

(*Example: for 25%, multiply by 0.25)

2. Then, calculate the minimum system size [in watts]:

Daily PV Output Needed [from Step 1] ____________ WH

÷ Average Peak Sun Hours (______ hrs.) Per Day = ____________ W

÷ 0.7 [for 70 % System Efficiency Factor]

= Minimum System Size ____________ W

3. Next, determine the number of PV modules you'll need:

Minimum System Size [from Step 2] ____________ WH

÷ Wattage Rating (_______ W) of Chosen Module

= Number of Modules Required _____ Modules

4. Now you can figure the size of the system:

Number of Modules Required [from Step 3; round up] _____Modules

x Wattage Rating (_______ W) of Chosen Module [also from Step 3]

= System Size [in Watts] ____________ W

5. Last, find the approximate system cost:

System Size [from Step 4] ___________ W

x System Cost Per Watt [from sidebar opposite] $____________

– Rebates & financial incentives $__________

= Approximate System Cost $__________

few of your recent electric utility bills for easy reference.) The pros know what questions to ask and the relevant data for your geographic location, and should be able to provide a preliminary estimate by phone. An on-site visit will be necessary before they can give you a firm quote, and get you on your way to making some or all of your electricity with clean, renewable energy.

Access

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Database of State Incentives for Renewable Energy • dsireinfo@ncsu.edu • www.dsireusa.org

National Renewable Energy Laboratory (NREL) • http://rredc.nrel.gov/solar/pubs/redbook • Solar insolation data • http://rredc.nrel.gov/solar/calculators/PVWATTS • PVWATTS calculator

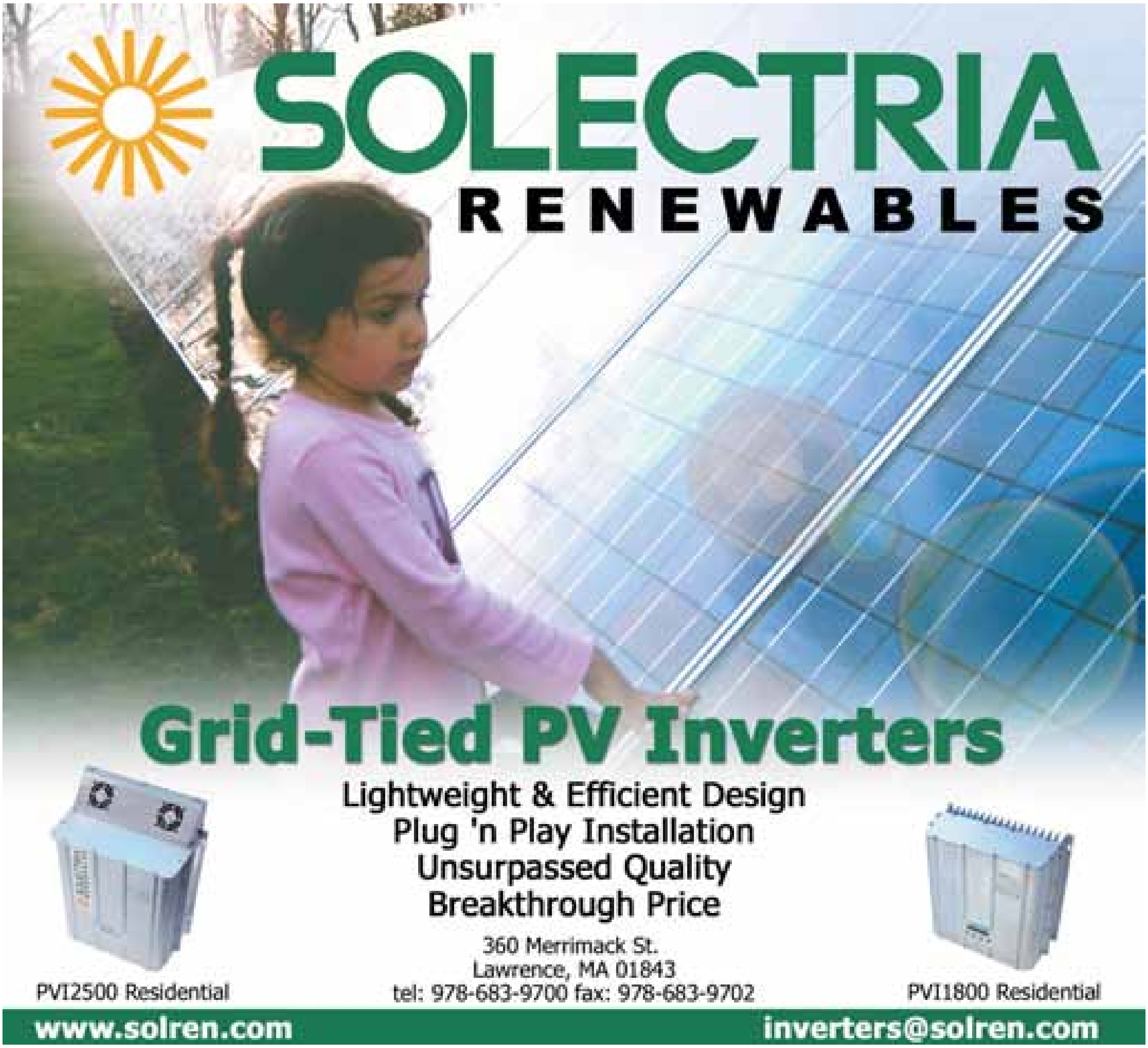
Directories of Solar-Electric System Installers:

Home Power's Installers Directory, see page 124 or visit www.homepower.com/resources/directory.cfm

www.renewableenergyaccess.com/rea/market/business/home

www.seia.org/about/statechapters.asp

Renewable Resource Data Center • http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/



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POWERING YOUR FUTURE

Build a Solar Heater for $350

Gary Reysa

©2005 Gary Reysa

Gary Reysa's shop is heated by this inexpensive and easy-to-build solar hot air collector, installed on the building's south face.

After walking into our new workshop one December morning and finding the inside temperature to be a bone-chilling 10°F (-12°C), I decided that it was time for a heating system! Given the rising costs of propane and our environmental concerns about using nonrenewable fossil fuels, a solar solution seemed fitting.

I reviewed many solar collector concepts, and finally decided to install a thermosiphon air collector on the south wall of the building. The concept is elegant and simple. A thermosiphon design uses only the buoyancy of heated air to circulate air through the collector, eliminating the cost, maintenance, and energy consumption of fans, sensors, and controllers commonly used in other collector designs. On a sunny day, in a cold climate like ours here in Bozeman, Montana, this simple system can produce the heat equivalent of burning about 2 gallons (8 l) of propane.

To minimize material use, I integrated the collector within the building's structure. I also tried to make the collector easy to construct using readily available materials. In fact, making this collector should only take one trip to the hardware store and US$350. Set aside two or three days to complete the project.

How It Works

The thermosiphon collector consists of clear, corrugated polycarbonate panels fastened to vertical 2 by 6s. The clear panels, on the building's south face, admit sunlight. An absorber—in this case, two layers of black metal window screen—suspended inside the collector captures the sun's heat energy. The air around the mesh expands and rises as it warms, creating a convection current. Vents located at the top and bottom of the collector allow air to circulate and become heated. Cool air enters the lower vent, is heated by the absorber, and rises through to the upper vents that exit into the building's interior. This circulation of air continues as long as the sun shines on the collector.

Materials used to construct the thermosiphon collector can be found at most lumberyards and hardware stores.

At night, as air in the collector cools to outside temperatures, airflow tries to reverse. Air in the collector sinks through the bottom vents and attempts to pull the warmed air from the building through the top vents. Use of flapper valves on the top vents helps prevent this reverse circulation and keeps the heat inside.

Nuts & Bolts

The collector is 20 feet wide by 8 feet high (6.1 x 2.4 m) for an overall area of 160 square feet (15 m^2). The collector is 6 inches (15 cm) deep. In most cases, make the collector as large as your south wall allows (see sidebar). The top vent and bottom vent areas should each be at least 50 percent of the collector's horizontal cross-sectional area (again, more is better).

The collector frame is constructed from wood, and consists of six vertical members, a bottom sill, and a top sill. The six vertical 2 by 6s divide the collector into five, 4-foot-wide (1.2 m) bays. A 2 by 6 is used for the bottom sill. A 2 by 8 is used for the top sill, which should be sloped at about 10 degrees to shed rain. The collector frame attaches to the building by lag bolts from the inside.

The collector is glazed with clear Suntuf corrugated polycarbonate panels (see Access). These panels have an ultraviolet light-resistant coating on their sun-facing side to extend their life. Each panel is 26 inches (66 cm) wide by 96 inches (244 cm) high. There are ten panels. Pairs of 26-inch-wide panels are joined over a 1- by 1-inch (2.5 x 2.5 cm) vertical wood strip to make the 4-foot-wide panels for each bay. Two, 1- by 1-inch horizontal members provide additional support for the glazing.

The absorber is installed on battens placed about halfway between the glazing and siding. After measuring the thermal performance with one, two, and three layers of window screening, I found that two layers work best.

Sizing the Collector

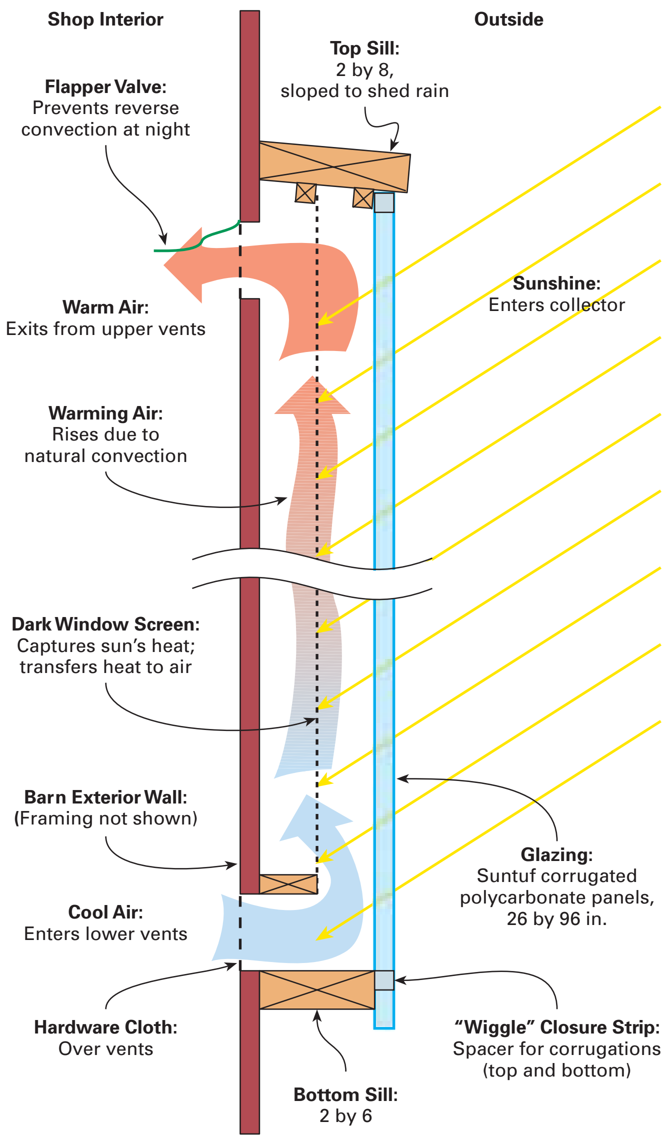
Usually, the bigger the collector, the better. The reasons for this are:

- Most outbuildings suffer high heat losses due to high infiltration rates and a lack of adequate insulation. The heat a large collector generates can be put to good use.
- With this collector design, overheating is usually not a problem. Upper vents can be easily closed off or thermal mass, such as water containers or PVC pipes mounted on the ceiling near collector exit vents, can be incorporated. This has the added benefit of reducing nighttime interior temperature swings.
- More collector area provides some allowance for partly cloudy and thinly overcast days.
- The added time and material cost to build a collector that uses the full wall versus part of the wall is small.

Exceptions to using the full south wall for the collector include locations with mild climates, well-insulated and well-sealed buildings, or buildings that are much longer along their east-west axis than their north-south axis. If the full south wall is not available, using a portion of the wall still pays off.

The simple design of this thermosiphon collector makes for easy construction and installation.

Solar Heater Construction & Function



Each of the ten top vents and ten bottom vents measures 4 by 18 inches (10 x 46 cm). These are simply holes cut into the building. Inside the building, ten flapper valves made from light plastic sheeting prevent backflow through the upper vents at night. Half-inch (1.3 cm) hardware cloth is installed under the plastic sheets to prevent the flappers from being sucked into the vent at night. In the summer, blocking off the top vent openings helps prevent the building's interior from overheating. I just staple a piece of cardboard over each top vent, but you could install hinged vent doors. Shading or covering the panels during the summer might also be effective. In the spring and fall, you can close some vents and leave others open to control the temperature inside.

Construction Tips

It took me about three, eight-hour days to build and install the collector. Follow these suggestions and you may be able to do it in less time!

First, measure your building's south wall to determine what changes you will have to make to the collector design. Pay particular attention to the vertical height available and to stud spacing. Next, lay out the vent locations. They should be offset enough from the wall studs to allow the verticals to be lag-bolted from *inside* the building. Mark the vent locations on the inside and outside of the building to ensure no conflicts exist. After you are certain the layout is correct, take a deep breath, and cut all of the vents.

For the frame, cut the top sill long enough to lap over the end verticals by at least 1 inch (2.5 cm). Bevel the back of the top sill so that it slopes about 10 degrees when fitted against the siding. Next, cut all the verticals, noting that the two end verticals are longer because they extend below the lower sill. The tops of the verticals must be cut to match the slope of the top sill. Gang the verticals together and cut the notches for the two, 1- by 1-inch horizontal glazing supports.

Prime and paint everything. Although you do not need to repaint the siding under the collector, painting it a dark color will improve the collector's efficiency slightly. Keep in mind that a muted version of this color will show through the collector screen, so be sure it meets your aesthetic sensibilities.

After the paint has cured, mount all of the verticals to the siding. Take care to keep everything level, plumb, and straight—this will save you a lot of four-letter words later. I fastened the verticals to the wall sheathing and siding from the inside using lag bolts. If your siding is not strong enough for this, consider mounting the verticals from the outside, using lag screws through the verticals and into the wall studs.

Next, attach the top and bottom sills. Use flashing above the top sill if desired. Then, seal the collector frame with silicone caulk. Mount the battens that will support the

The frame is mounted on the outside wall after the vents are cut.

Horizontal support strips run along the back side of the corrugated panel sections. Vertical strips inside the corrugations tie the panel sections together.

screen absorber. Staple the window screen onto the battens. You can fold the edges of the screen to make it fit in the slightly less than 48-inch (122 cm) bay widths.

Make five 4- by 8-foot (1.2 x 2.4 m) glazing panels by joining pairs of the 26-inch-wide by 8-foot-long corrugated panels. Overlap the panels by one corrugation, and apply a light bead of silicone between the overlapped sheets. Fasten the overlapped corrugations to a 1- by 1-inch wood strip using screws with EPDM washers.

A close view of the lower sill, lower vent, left end's vertical glazing supports, and screen absorber. "Wiggle" closure strips secured to the sill plates help seal the glazing panels.

Hot Air Collector Pros & Cons

Pros:

- Simple (not much to go wrong or watch over)
- Easy to build
- Long life and little maintenance (so far)
- Low initial cost (one-tenth the cost of most commercial panels)
- Good economic return on the initial investment
- Operation produces no greenhouse gases
- Output can be adjusted by opening and closing vents—summer output can be made zero
- Does not impact use of building (I can still pile stuff against the interior wall, but now it's not junk—it's thermal mass)
- Does not require changes to the building structure
- My wife doesn't think it's ugly (or at least not *too* ugly!)

Cons:

- It hurts a bit to cut holes in the wall (but you get over it)
- The building might require additional thermal mass and insulation to keep inside temperatures from dropping too much at night

Install the horizontal 1- by 1-inch glazing support strips to the collector frame. The surface of the strips should sit flush with the surface of the collector's frame when installed in the notches of the 2 by 6s. Do any cleanup, caulking, or other work you need to do inside the collector frame now! You won't be able to get to the inside after the glazing is applied.

Next, mount the glazing panels. Install the "wiggle" closure strips, which fill in the contours of the corrugations, on the top and bottom sills. Run caulk beads on the first set of verticals and mount the first glazing panel section. (You'll quickly find out how square your frame is.) Fasten the panel sections to the frame using screws with EPDM washers. Install the rest of the sections in the same way. Overlap each new section over the last section by one corrugation, using a bead of caulk in the overlap.

Make the flapper valves for the ten inside top vents. I used two thicknesses of plastic garbage bag for each flapper. Before attaching the flapper, attach $^{1}/_{2}$-inch hardware cloth over each vent. Then, staple the flappers along the top edge of the vent, just above the vent opening.

The author inspects the thin plastic flapper valve that prevents reverse airflow and helps keep heat inside the building.

Performance

On sunny winter days, the collector raises daytime interior temperatures to between 60 and 75°F (16–24°C), providing a comfortable workspace. In my neck of the woods, that's 25 to 35°F (14–19°C) above the outside temperature. The workshop temperature rises about 10°F (6°C) for each hour the sun hits the collector. Warming the workshop from 35 to 65°F (2–18°C) usually takes about three hours. Through the night, and by morning, the building typically cools to about 8 to 15°F (4–8°C) above the outside temperature. On heavily overcast days, the collector does very little heating, but on partly cloudy days or with a thin overcast it does provide some useful heat.

For optimal heating performance, be sure to provide adequate insulation and to control air infiltration. No solar collector will do a good job of heating a workshop that is drafty and uninsulated. With the walls and roof insulated to R-19, my 576-square-foot (54 m^2) workshop has a heat loss of about 190 Btu per hour for each degree Fahrenheit difference. So, if it's 60°F inside and 30°F outside, the heat loss is: (60°F - 30°F) x 190 Btu/hr = 5,700 Btu/hr. During periods of full sun, the collector will gain heat at a rate about three times greater than this.

The graph shows my collector's typical heating performance on a mostly sunny midwinter day. Although outside temperatures never rose above 40°F (4°C), the collector heated the building from 38°F (3°C) to almost 70°F (21°C) during the day. At night, when the collector isn't working, the building's temperature drops quite a bit. In the morning, it takes a few hours of sun to raise the temperature inside the workshop to a comfortable level—a good excuse to sleep in! If you are determined to start work early, more insulation, more thermal mass, or an early morning blast from a backup heater would be in order.

One of the advantages of having a relatively large collector is that once the sun is on the collector, the heat gain rate is several times the heat loss rate. This excess heat raises the temperature of the building's thermal mass fairly quickly. At midday, under typical sunny winter conditions, the collector provides a 50 to 60°F (28–33°C) temperature rise from the lower vent to the upper vent, and an average upper vent velocity from 110 to 120 feet per minute (34–37 m/min). The total gain on a sunny day is about 130,000 Btu (38 KWH). This is equivalent to burning about 2 gallons of propane at 70 percent efficiency.

Heat gain estimates are based on measurements of the collector temperature rise and the vent exit velocity. Combining these with the density of air at temperature and the specific heat of air gives the collector's heat output. I consider these estimates to be approximate, but solid enough to get a good feel for how well the collector works.

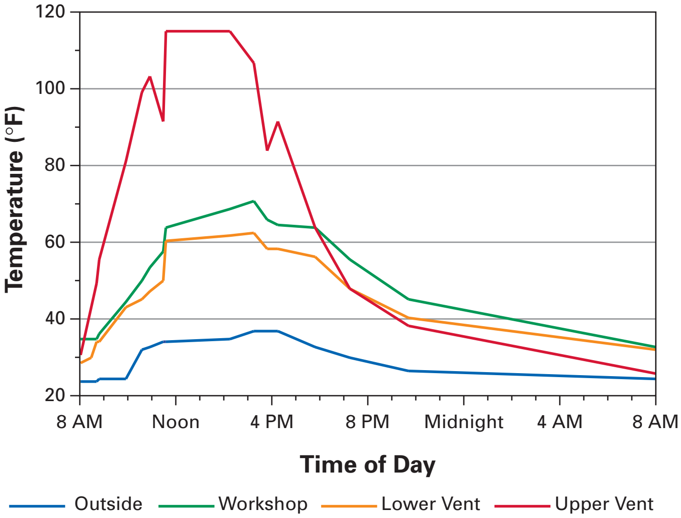
The rate of heat gain was estimated using the following equation:

$$G = A \times V \times D \times (T_u - T_l) \times H$$

Where G is the heat gain rate; A is the vent area; V is the velocity of air through the vent; D is the air density; T_u is air temperature at the upper vent; T_l is the air temperature at the lower vent; and H is the specific heat of air.

I measured the temperatures with several US$2 Taylor thermometers from the hardware store. The vent exit velocity was taken using a Kestrel wind meter. Although this instrumentation might not meet Sandia National Laboratories' standards, I believe it does provide a solid estimate of the collector's performance.

Typical Sunny Winter Day Performance



Economics

Our only alternative would have been to heat the workshop with propane. And, although the cost of a propane heater would have been a bit less than the cost of building the solar collector, the ongoing cost of propane over our five-month heating season would have been US$150 to 200 per year.

Solar Heater Costs

Item	Cost (US$)
10 Suntuf corrugated polycarbonate panels, 2 x 8 ft.	$160
Black window screen, 4 x 70 ft.	70
Lower sill & studs, 2 x 6s, 68 ft.	42
Paint, caulk, lag screws, etc.	25
Upper sill, 2 x 8s, 22 ft.	18
Glazing 1 x 1 in. supports, 130 ft.	15
Suntuf "wiggle" closure strips, 40 ft.	10
200 Screws with EPDM washers	10
Total	$350

The simple payback period of the collector is a couple of years on materials cost. You also can consider it as an investment of US$350 that's reaping the benefits of an inflation-protected, tax-free return of 50 percent per year. If the collector has a life of 20 years, you are in effect paying in advance for all the heating the collector will produce in a lifetime—at fractions of a penny. Because I use the workshop intermittently, I can usually wait for a sunny day to warm the building. I haven't needed to buy a backup heater, which is an additional savings.

Collector Variations

With a bit more investment of time and money, a couple of variations could be made to improve the system's performance. Substituting dual-wall polycarbonate glazing in place of the single sheet of corrugated glazing would help reduce thermal losses through the glazing. This type of glazing, which provides two layers of polycarbonate sheets separated by support webs, also simplifies the glazing installation, since it requires less support and doesn't require sealing the corrugated edges. Buildings in cold climates will benefit the most with this change. Using this glazing may increase the cost of the collector by 50 percent or more.

Keep in mind that temperature fluctuations and solar exposure can reduce the life of the polycarbonate glazing to between ten and twenty years. Substituting tempered glass instead of polycarbonate glazing is another strategy, although it is more expensive and will require some design modifications.

Alternating collector and window panels on the south wall is another design option. This method would allow more light into the space and some direct gain through the windows, without the glare, high losses, and overheating problems that accompany full window walls. You can use the same concept to heat a house or cabin. With some refinement to integrate the vents with the finished wall, the same basic design can be used to provide daytime heat to living spaces.

A word of warning, though—the *National Mechanical Code* prohibits circulating conditioned air of more than 120°F (49°C) in wooden stud spaces. While this may not pose a problem for outbuildings, in buildings used for human habitation, consider constructing the collector with metal, rather than wood studs. As an extra measure of safety, wood areas immediately surrounding exit vents also can be flashed with sheet metal.

In making changes to the collector, keep in mind that a thermosiphon collector must provide low resistance to airflow. Make sure that any changes you make do not violate these guidelines:

- The depth of collector should be at least 1/15th of the height;
- The absorber must have low resistance to airflow;
- The vent area should be at least 50 percent of the collector's horizontal cross-sectional area; and
- The air path through the collector should be as shown in the diagram on page 32.

Build It!

Building a solar hot air collector into new construction or adding one onto an existing building can be an easy and inexpensive heating solution. Following the simple principles and the plan outlined here will allow you to heat your workshop, barn, or even your home with free heat supplied by the sun. If it works here in Montana, it's bound to work wherever you are. Here's to your warmth and comfort.

Access

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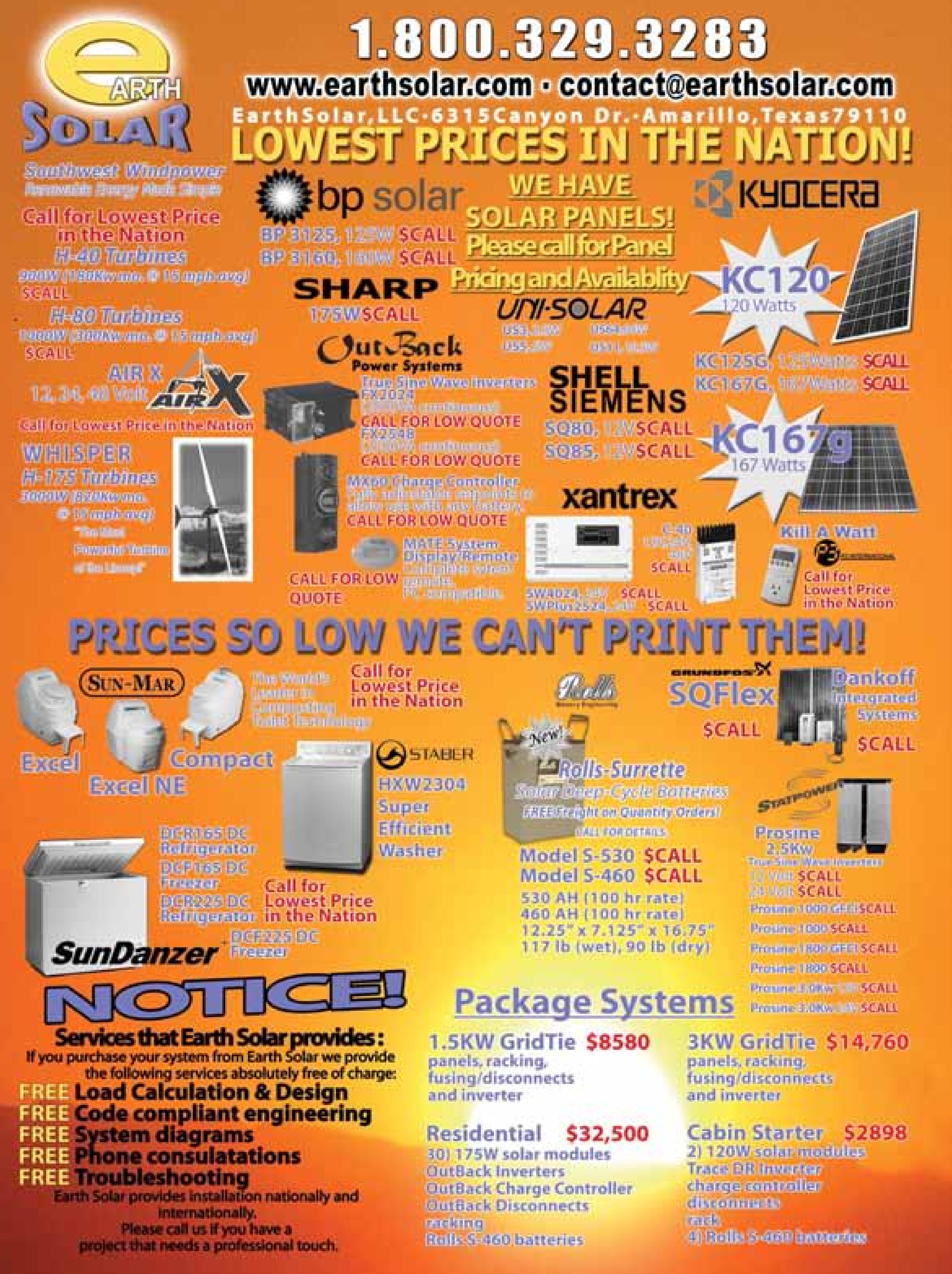
Kestrel Meters, 3225 Lyndale Ave. S., Minneapolis, MN 55408 • 800-891-8493 • Fax: 612-827-0582 • info@kestrelmeters.com • www.kestrelmeters.com

Palram Americas, Arcadia West Industrial Park, 9735 Commerce Cir., Kutztown, PA 19530 • 800-999-9459 or 610-285-6968 • Fax: 610-285-9928 • suntuf@suntuf.com • www.suntuf.com/Suntuf-Panels.htm • Suntuf corrugated polycarbonate panels

Usenet newsgroup • http://groups-beta.google.com/group/alt.solar.thermal

Thanks to the crew at the Usenet newsgroup and Nick Pine in particular for making many helpful suggestions.



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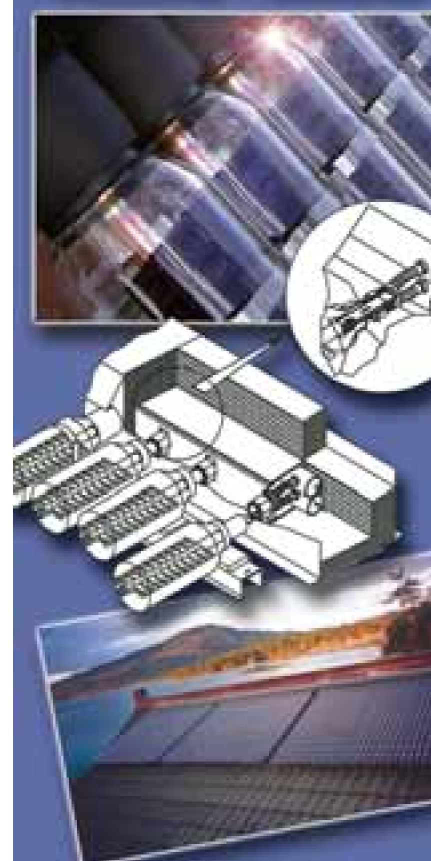

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designing with daylight

Chris Herman

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Large windows such as these provide an abundance of natural light during the day.

Daylighting is the art and science of using natural light to illuminate indoor spaces. It saves energy, and can make living and working areas more attractive and comfortable. Daylighting in homes is typically accomplished using windows, translucent doors, skylights, light pipes (tubular skylights), and clerestories. A well-designed daylit home on a sunny lot can get by without any electric lighting between dawn and dusk.

Benefits

Daylight is sunlight that is direct or reflected. Sunshine provides us with vitamin D, and also combats seasonal affective disorder, or winter depression. Natural light doesn't change the character of colors the way artificial lights can and, with its subtly changing intensity, daylight is much more interesting. It can make us feel more connected to nature and supports our natural biological rhythms, which contribute to restful sleep.

Using sunlight in your home can decrease heating and cooling loads through passive solar design techniques, as well as eliminate most lighting needs during the day. Its use has been proven, in commercial settings and schools, to decrease absenteeism and increase productivity and test scores. Also, people who work in naturally lit buildings report a sense of well-being.

System Types

When daylighting design is done properly, its goals are easily realized. When it's not, glare, overheating, and increased energy use for artificial lighting, heating, and cooling can result. The guidelines that follow can help you achieve your daylighting goals with ease.

Windows. Windows are the most common daylighting tool. Natural light is mandated for homes built under the International Residential Code, and windows also fulfill requirements for natural ventilation and emergency exits.

Glazing recommendations and percentages vary by climate. There are many kinds of glass and coatings, so you can tailor your choices to your climate's demands. In the Pacific Northwest, double-glazing is required by code, and low-E coatings, which selectively filter the sun's energy and reduce radiant heat loss, are recommended. In the summer, low-E^2 coatings let in visible sunlight, while blocking ultraviolet rays and infrared solar energy, helping to decrease cooling costs. In the winter, these coatings can help reduce heating costs by reflecting room-side heat back into the room.

For south-facing windows in climates with heating loads, a solar heat gain coefficient (SHGC) of 0.76 or greater is recommended. This can be achieved with hard-coat low-E or clear glazing. SHGC is expressed as a number between 0 and 1. The lower a window's SHGC, the less solar heat it transmits. Large west-facing windows should be coated with low-E-squared (SHGC less than 0.6) to prevent overheating the home. In hot climates where cooling loads dominate, select windows with a SHGC of 0.5 or below, and size overhangs appropriately.

Well-placed skylights can be useful in achieving daylighting design goals.

Cliff and Nancy Herman (the author's parents) enjoy the diffuse natural light of this clerestory.

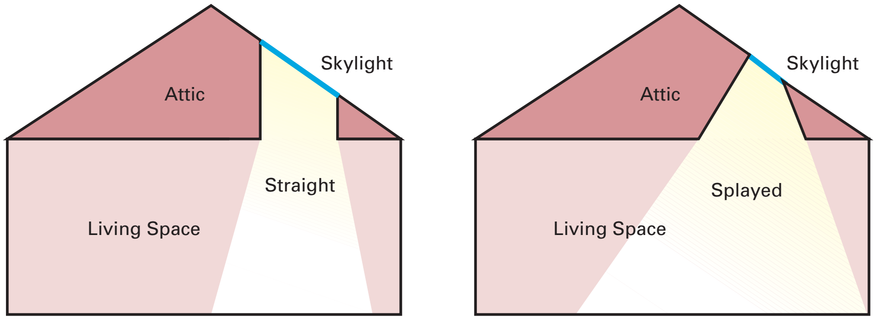
Photo by Chris Herman, Winter Sun Design

In an energy-efficient home, window area should be equal to no more than 25 percent of the home's floor area, and half of that glass should be located on the south side, if shading is not a factor. In the winter, windows in a house are much more vulnerable to heat loss than walls. Closing blinds can help stop the radiant loss, and using insulating curtains can reduce conductive and convective losses significantly. Just be sure that night insulation fits snugly in the window frame. Curtains with open valances can actually increase heat loss from a window by setting up a convective loop—the cold air against the glass falls to the floor and pulls warm air from the ceiling to replace it.

Skylights. Skylights and roof windows are used extensively to bring overhead light into areas in the middle of the home (hallways and closets), where privacy is needed (bathrooms), or where accessible wall space is limited (kitchens). People also like them for sky gazing, and operable units aid natural convective cooling, helping to flush heat from a home's interior.

Skylights are helpful if used very sparingly. Problems can occur with overheating the home in the summer, when the sun is high. And even a north-facing skylight on a low-pitched roof or in northern latitudes will admit heat. Shading a skylight should be done from the outside, with greenhouse shade cloth. Blinds inside skylights don't stop the heat gain effectively and can actually damage the seals of the insulated glass units by increasing heat in the air space between the panes of glass.

Straight vs. Splayed Skylight Well



A smaller skylight paired with a splayed lightwell (right) can provide the same amount of light, with fewer thermal disadvantages.

Skylights also lose lots of heat in the winter. Compared to a code-compliant roof that's insulated to R-30 or R-38, skylights are big losers. The warmest air in the home ends up against the skylight's glass, which has only a minimal insulating capacity between R-2 and R-3. In this case, smaller is better: Instead of buying a skylight that measures 2 by 4 feet (61 x 122 cm), consider installing a 2- by 2-foot unit and splaying the light well (see illustration above).

Light pipes. Light pipes (also known as tubular skylights and light tubes) are inside-mirrored "stovepipes" capped with a clear plastic dome that admits sunlight. A special lens on the bottom of the tube helps spread out the light. Transmitted light enters the room through a ceiling fixture that is virtually indistinguishable from a conventional light fixture. Light tubes fit easily between roof framing members, admit little heat gain during the summer, limit heat loss in the winter, and don't transmit glare. Well suited for kitchens, bathrooms, closets, hallways, and stairwells, they can even be ordered with an electric light or an exhaust fan. Unlike skylights, light tubes don't collect dirt you see when you look up. Of course, you also can't look up and see the blue sky or a full moon through them.

Clerestories. Clerestory windows are placed on an outside wall that rises above an adjoining roof. They are an effective way of supplying diffused light to a building's interior. With their vertical orientation, they stay much cleaner than skylights, and may be left open during mild rain showers. Awning windows are preferred for ease of operation and rain-shedding ability.

A light-colored roof in front of the clerestory bounces more light into the windows, and light-colored walls inside the home increase their effectiveness. Clerestories can transmit glare with low winter sun angles, and can admit unwanted heat during the spring and fall. Translucent curtains hung over the windows can mitigate this seasonal glare, and north-facing openings deliver a low but constant source of sunlight with little or no glare.

South-facing clerestory windows can help passive solar heating in the winter. In the summer, a fixed overhang can prevent heat gain through the windows. Vaulted ceilings associated with clerestories contribute to temperature stratification (warm air up high; cold air down low). For increased winter comfort, a ceiling fan placed in the clerestory roof can push warm air down into the rooms. In the summer, operable windows allow natural convective cooling by helping exhaust hot air that accumulates at ceiling level.

Design Tips

Designing a daylit home can be very simple. In most regions, provide a long south wall of windows and locate the main living spaces along the south side to take advantage of direct solar gain in the wintertime. In the summer, adequately deep, fixed overhangs will block heat gain but still allow indirect light to enter the windows.

First, arrange rooms based on your preferences. Morning people tend to like their bedrooms located in the southeast corner of a home. Kitchen and breakfast rooms may compete for that corner. Night folks usually don't mind a bedroom on the west; by the time they retire, the room will have cooled off. Artists, especially painters, usually locate their studios on a home's north side to take advantage of the uniformity of northern light.

A row of clerestory windows on this home in Shoreline, Washington, provides ventilation and admits additional daylight into the home's interior.

Photo by Chris Herman, Winter Sun Design

Next, select your daylighting strategies. Start with windows for almost every room. Consider light, heat gain, ventilation, views, aesthetics, and emergency exits when making your choices of window sizes and types. Add a clerestory for overhead, private light; increased ventilation; and desirable heat gain. A small operable skylight with a flared light well can provide sky-gazing opportunities and overhead light, with privacy and increased ventilation. Light pipes are a great choice for naturally lighting small interior spaces and dark corners.

Daylight is extremely variable in intensity and duration, changing throughout the day and year. These characteristics can make it challenging to deliver consistent lighting. Light sensors can control artificial light sources, on dimmers, to maintain minimum light levels.

Glare is a potential problem for many systems. Controlling reflected sun by using light shelves (interior "overhangs") or wide windowsills is effective, and using sheer fabrics to filter incoming light can also help.

Living with natural light helps us feel less isolated from nature, and being indoors seems more like a temporary condition, rather than a permanent sentence. With thoughtful daylighting design incorporated into your home, you'll find that from dawn to dusk, the best things in light are free.

Courtesy of Solatube (2)

Light tubes, which fit easily between roof framing members, are a straightforward solution to lighting interior spaces.

Light tubes are well suited to interior rooms with no window access and where privacy is desired.

Access

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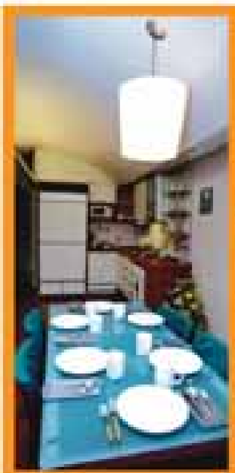
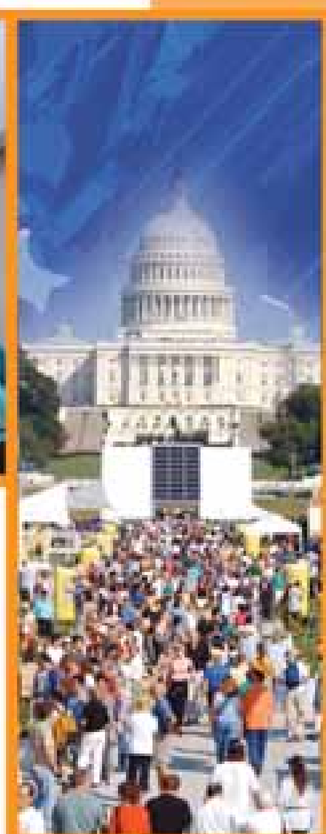
The Solar Decathlon is a competition to design, build, and operate the most attractive and energy-efficient solar-powered home. Eighteen teams from colleges and universities from the United States (including Puerto Rico), Canada, and Spain bring their competition houses to the National Mall in Washington, D.C., October 7–16, 2005. The teams assemble a "solar village" and compete against one another in ten contests.

The team houses are living demonstrations of the latest in energy efficiency and renewable energy designs and products, and the best in home design. The public is invited to this free event to meet the students and tour their solar-powered houses. Visitors are also welcome to experience educational exhibits and attend consumer workshops on energy efficiency and solar energy.

For more information or to follow the competition on line: *www.solardecathlon.org*





The University of Colorado house won the first Solar Decathlon competition in 2002.

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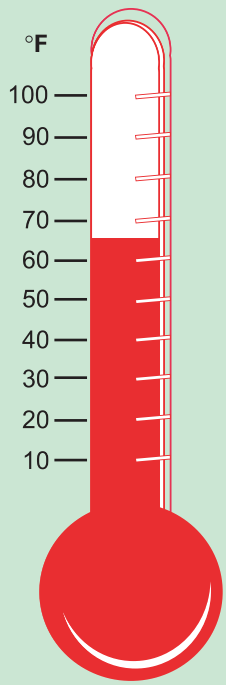
What the Heck? 20

Degree Day



Used In: Calculating heating or cooling loads of buildings and the amount of insulation needed in various locations

AKA: Heating degree day (HDD) and cooling degree day (CDD)

What It Is: A measurement of climate used to help determine a building's heating and cooling requirements

What It Ain't: The day happy students don black gowns and wear funny-looking, flat caps

Want to know how cold or hot some place is? You need to know the yearly degree days of that location. The difference between a day's average temperature and 65°F (18°C) is the number of degree days for that day. If a day has an average temperature of 50°F (10°C), that day would be rated at 15 heating degree days, indicating that supplemental heat might be needed to maintain a comfortable indoor temperature. If a summer day has an average temperature of 90°F (32°C), that day would be rated at 25 cooling degree days. An average temperature of 65°F on any given day would be recorded as zero degree days.

Degree days are used for home design, insulation value requirements in codebooks, and anyone who wants to quantify how cold or hot it is. If you want to heat your home with solar energy, you'll need to know the heating degree days to accurately predict how much of your home's heat load the sun will provide.

Annual Degree Days

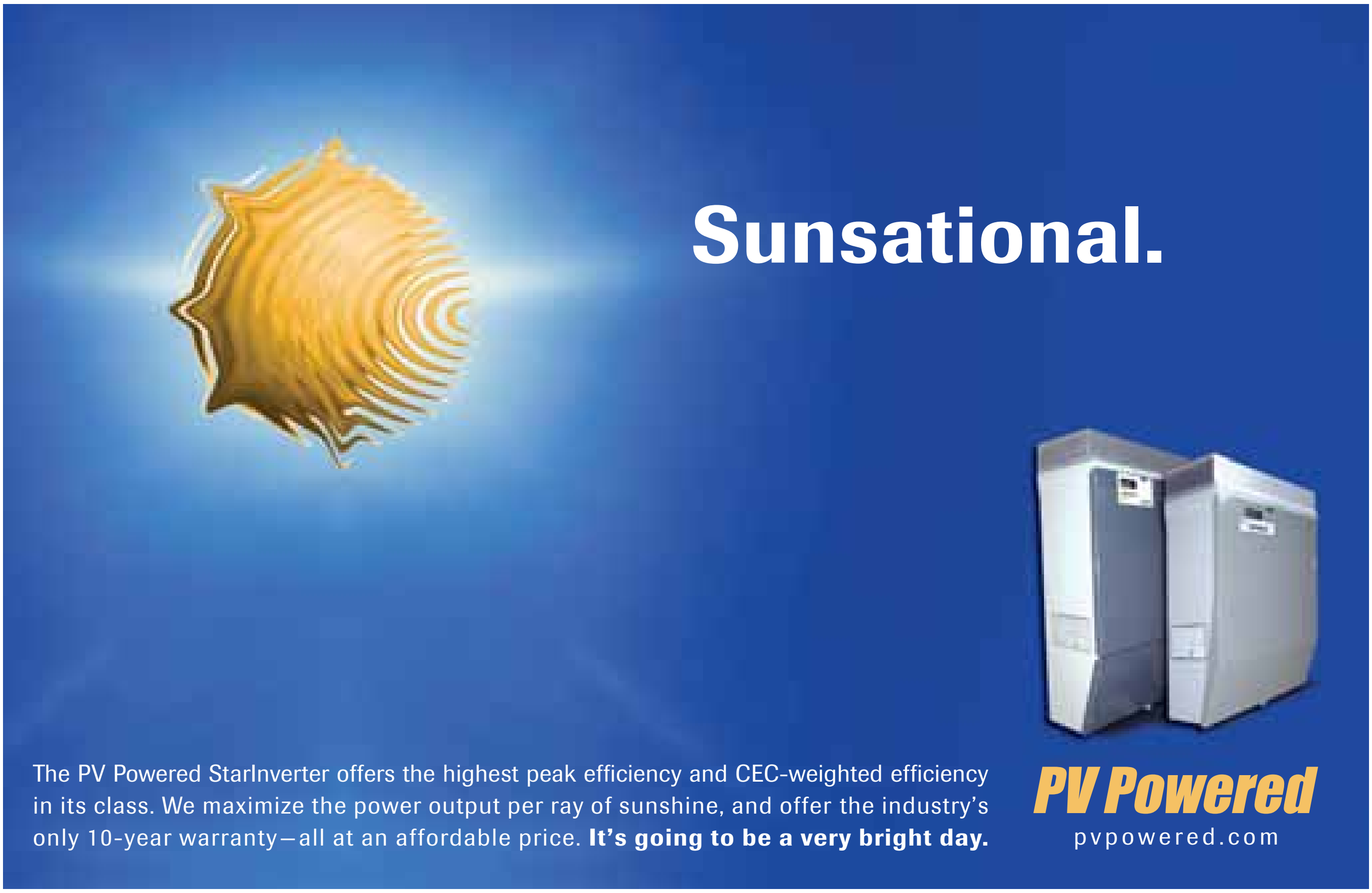
City	HDD	CDD
Barrow, AK	20,370	0
Bismarck, ND	8,932	499
Hilo, HI	0	3,134
Kansas City, MO	5,326	1,388
Key West, FL	68	4,820
Yuma, AZ	983	4,244

Source: *USA Today*, Weather Almanac

How many degree days require you to put a log on the fire or turn on the air conditioner to be comfortable? Relative humidity and infiltration heat losses (or gains) due to wind affect human comfort, and this data isn't reflected in degree-day information. Thermal comfort varies with each individual and home, but homes that are well insulated and energy tight are more resistant to degree-day changes.

The National Climatic Data Center's Web site offers HDD and CDD information for more than 250 U.S. cities. Go to www.ncdc.noaa.gov/oa/ncdc.html, click on "Free Data," and then select "Comparative Climatic Data," to find information for a city near you.

Chuck Marken • chuck.marken@homepower.com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AC Mini-Grids

The Future of Community-Scale Renewable Energy

Dana Brandt

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This 3,600-watt photovoltaic array is part of a groundbreaking "AC mini-grid" system in Bulyansungwe, Uganda.

For decades, nearly all small-scale renewable energy (RE) installations have been DC-coupled systems. These DC-based systems are just like you read about in *Home Power*—where one or more DC sources like photovoltaics (PVs) and/or wind generators are used to charge batteries that, in turn, power DC loads directly, or AC loads via an inverter. Each charging source requires a controller to regulate the power from the RE source to the battery. While DC coupling is still the state of the art in most of the world, a method of AC coupling (connecting several charging sources together on the AC side of the system) has been developed that offers significant benefits for certain applications.

AC coupling uses batteryless inverters networked to one or more centralized battery-based inverters. This configuration allows AC to either go directly to AC loads, bypassing the batteries, or to charge the batteries via the battery-based inverter. Regulation is done on the AC side of the system by limiting the output of the batteryless inverters when the batteries are fully charged.

I had the unique opportunity of working with this new technology for my thesis project while doing graduate studies in renewable energy in Germany. My project was the design and installation of a PV and engine-generator hybrid system with an AC mini-grid. The system powers a rural boarding school complex in the village of Bulyansungwe, Uganda, where there are no utility lines within several miles. The people of Bulyansungwe are primarily subsistence farmers who grow bananas and coffee as cash crops. Bulyansungwe Secondary School is considered the center of the village because there is no conventional village center of houses and shops.

The school complex includes a girls' dorm, boys' dorm, classrooms, a convent, and a social center. The German organization, Together: Assistance for Uganda, has provided funding for its construction and operation. Previously, the only source of electricity was a small, gasoline-powered generator used on special occasions.

Hybrid Systems & Mini-Grids

Hybrid renewable energy systems have proven to be an excellent solution for providing electricity to areas with no utility service. Hybrid systems combine multiple sources to supply steady and reliable energy to consumers. Common system configurations often include one or more renewable energy sources (PV, wind, etc.), battery storage, and an engine generator for backup.

The majority of existing hybrid systems are DC-coupled, where all the electricity sources are connected to a single battery bank. The loads are then either powered directly from the battery bank or via AC from inverters. Recently, however, pilot projects and new installations have shown the technical feasibility of AC coupling.

An AC mini-grid is expandable and modular with standardized system components. Every system component (energy sources, consumers, and storage) is connected to a single AC grid. This allows the use of established residential AC standards for interconnection of the different devices. This is in contrast to DC-coupled systems, where there is no such standard and a wide variety of system voltages are common.

Adding more PV or battery to an AC-coupled system is as simple as installing that new component and connecting it to the grid without any modification to the original system. In the case of DC-coupled systems, modifications (sometimes significant) will need to be made to the original system.

Comparison of AC- & DC-Coupled Systems

This AC mini-grid concept is also often referred to as modular system technology. Since each component is connected to the grid, a sort of modular power plant can be constructed. A major advantage to such a system is that it can easily grow to meet increased consumption demands simply by adding more producers to the grid.

Estimating future electrical needs can be extremely difficult (especially for large systems), and often leads to underdesign or overdesign (poor supply or poor economics). Modular system technology is potentially a great solution because the supply can more easily grow with the demand.

Another attribute of AC mini-grids is their ability to be interconnected. Since they operate under common parameters, multiple systems can easily be combined simply by connecting their AC lines. In this way, small individual systems can be connected to form village grids, and village grids can be connected to form regional grids. Interconnection of systems results in greater overall security of supply because of the redundancy of suppliers.

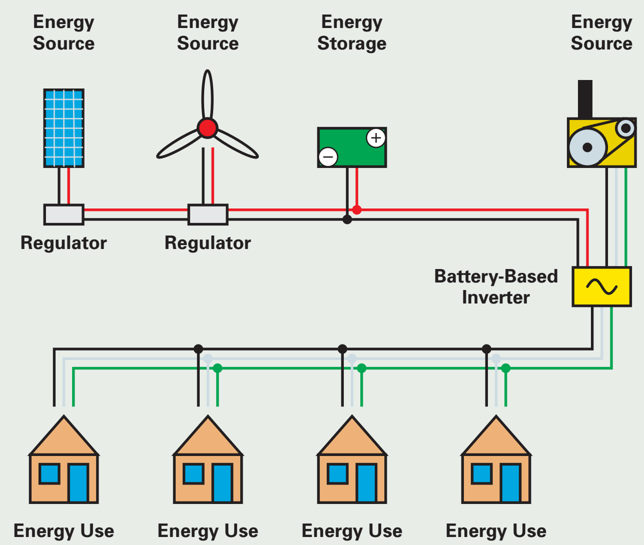
AC mini-grids can also be incorporated into a utility grid at any time simply by connecting directly to the utility lines. This can be an important advantage in many areas where rural utility grids are expanding

Courtesy Franz Kininger

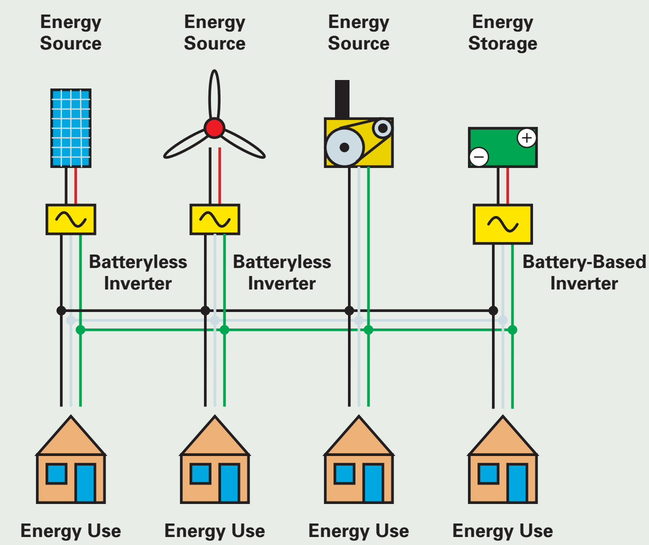
The author on the completed PV array, with the Sunny Boy, batteryless inverters visible in background. This array is 75 feet (23 m) from the battery bank.

A view of the completed PV installation above the large school compound. An AC mini grid allows optimal placement of system components without the proximity restrictions inherent in DC-coupled systems.

DC-Coupled System



AC Mini-Grid System



rapidly. It's important to note that mini-grids are not dependent on the interconnection, and can continue normal operation in the event of line failure.

A potential disadvantage to AC mini-grids as opposed to DC-coupled systems is a slightly lower system efficiency. This is a result of more frequent conditioning of the electricity because all energy stored in the batteries must be rectified during charging and inverted during discharging. This effect is greatest in systems where a large percentage of the consumption is at a different time than the production (such as in PV systems with high consumption at night) because more of the energy must be stored in the batteries.

The SMA Sunny Island inverter, battery bank, generator connection box, and two AC distribution boxes.

System modeling suggests, however, that this is a minor influence in system performance, and less important than engine-generator operating time and precise sizing of the energy producers. One set of simulations had slightly more than 50 percent of the PV energy flowing through the batteries. The end result was a PV array performance ratio of 0.54 for the DC-coupled configuration and 0.51 for the AC-coupled configuration.

Implementing the Technology

The most important technical challenge of AC mini-grids is coordination of the different components, especially the battery-based inverters because they are generally the grid-forming units. The inverters must have exactly the same phase and frequency, and share the charging and discharging equally. Traditionally, this has been done through high-speed, hard-wired communication—one master inverter dictating the operation of the other inverters through a separate communication network.

While this can allow for expandability in localized systems, it is not sufficient for interconnection of multiple systems without considerable reconfiguration of the components and communication network. In addition, this system concept has little redundancy because it is completely reliant on the operation of the master unit.

Through a cooperation of German organizations, a method has been developed for multi-master operation. This new technology uses the grid frequency and voltage as a communication medium. The resulting characteristics are quite similar to those of rotating generators and motors. Known as "drooping," the frequency drops slightly from nominal with loading and rises slightly during battery charging. Reactive power information is exchanged in the same way through slight variations (drooping) in the voltage. In other words, the multi-master inverter is able to regulate the output, based on communication between the inverters in the system.

This new technology allows for a completely modular system configuration and enhanced security through parallel multi-master operation. Each battery bank is controlled by its own master inverter, and PV arrays are connected using standard, batteryless string inverters. This technology has been integrated into some of SMA's Sunny Island battery inverters for the European market. However, the multi-master technology is not yet included in the Sunny Islands recently released in the U.S. market. The Sunny Island 4248U has AC-coupling technology, but is not capable of multi-master operation.

Generator Connection

Engine-generators can also be easily incorporated into the AC mini-grid. With proper control electronics, a generator can be directly connected to the AC grid and operate autonomously within the system. However, these control electronics are currently prohibitively expensive for most systems, so the generator is commonly controlled by the battery-based inverter.

A close-up of the SMA Sunny Boy inverters and a junction box that combines their AC output.

Tech Specs

Overview

System type: Off-grid PV & engine-generator hybrid system

System architecture: AC mini-grid, 230 V, 50 Hz

Location: Bulyansungwe, Uganda

Solar resource: 5.0 average daily peak sun hours

Production: 485 AC KWH per month

Photovoltaics

Modules: 48 Shell Solar S75, 75 W STC, 17.6 Vmp, 12 VDC nominal

Array: Four, 12-module series strings, two parallel strings feed each inverter, 3,600 W STC total, 211.2 Vmp

Array installation: Locally constructed steel frame tower, facing north with a 15-degree tilt angle

Energy Storage

Batteries: 30 Exide Sonnenschein, type 6 OPzV 360, gel, lead-acid, 2 VDC nominal, 360 AH at 100-hour rate

Battery bank: 60 VDC nominal, 21.6 KWH total

Balance of System

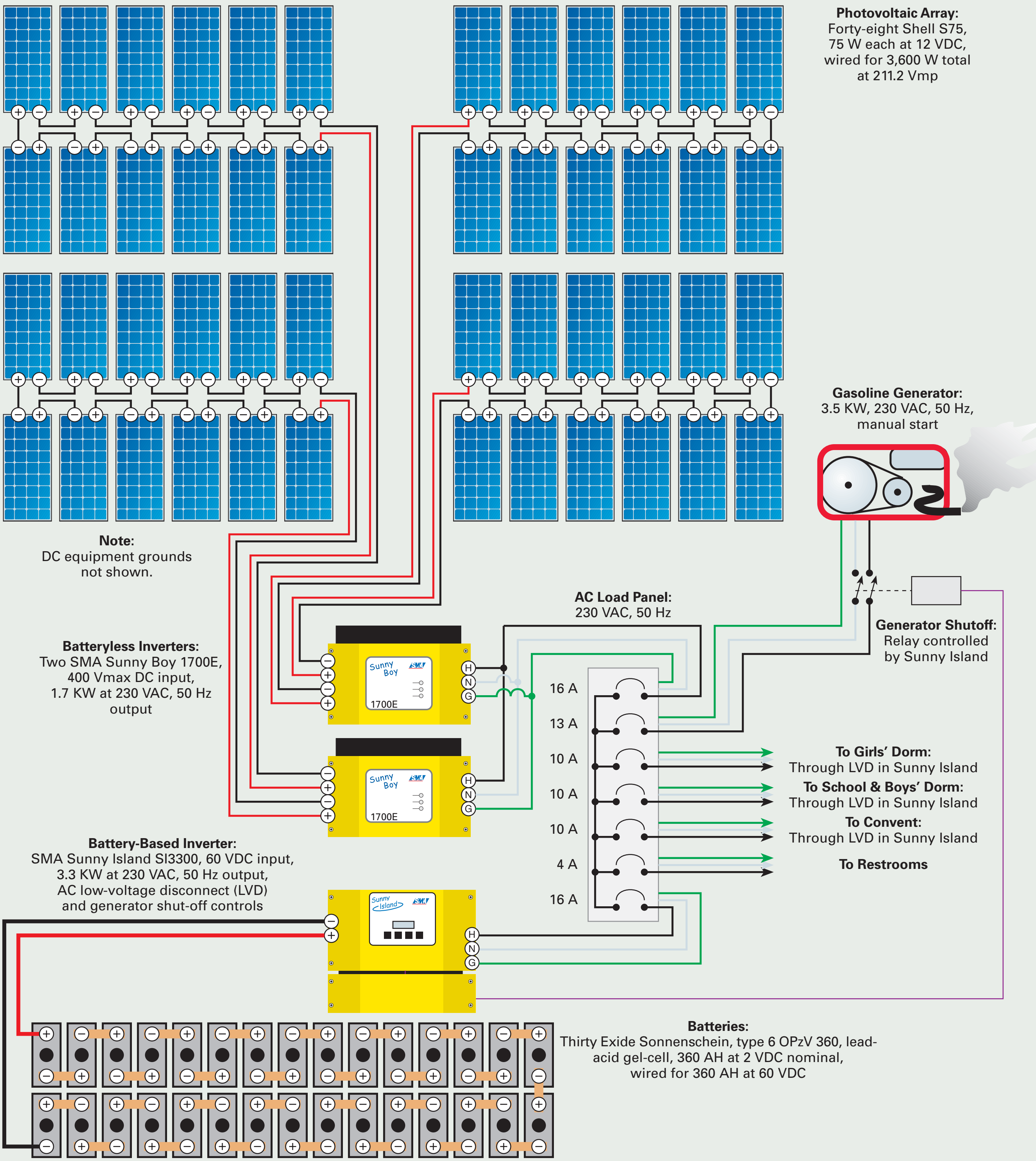
PV inverters (batteryless): Two SMA Sunny Boy 1700E, 1.7 KW, 400 VDC maximum input voltage, 139–400 VDC MPPT window, 230 VAC, 50 Hz output

Battery-based inverter: SMA Sunny Island SI3300, 3.3 KW, 60 VDC nominal input, 230 VAC, 50 Hz output

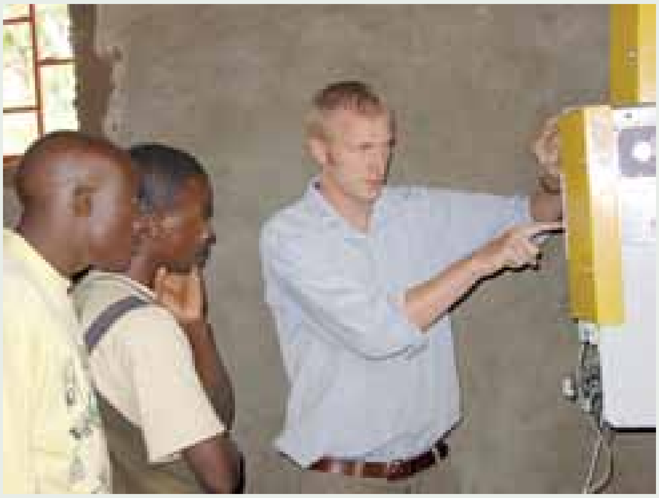
Engine generator: 3.4 KW, 230 VAC, 50 Hz, manual start, gasoline fueled

Once connected, a generator works naturally with the voltage and frequency droops. Excellent load sharing among SMA's battery-based Sunny Island inverters and a diesel generator have been demonstrated in the HYBRIX (hybrid system) demonstration plant in San Agustin, Spain. It is common for island inverters to switch into a grid-supporting mode when a generator is connected. This is not necessary with the variable voltage and variable frequency operation of the Sunny Island units, so the inverter remains in grid-forming mode. This allows the system to provide the sum of the peak powers of the inverter and generator.

Bulyansungwe School's AC Mini-Grid System



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



The author trains Julius, a local technician who is now responsible for the operation of the system. The financial director looks on—both are alumni of the school.

Bulyansungwe System

The Bulyansungwe system is an AC mini-grid. The installation consists of PV and gasoline hybrid generating capacity with an integrated ultraviolet water purification and pumping system. It supplies both electricity and clean water to the school complex.

The primary electricity is supplied by a 3.6 KW PV array, which is connected to the mini-grid through two SMA Sunny Boy 1700E inverters. Energy is stored in a 21.6 KWH battery bank. The connection of the battery bank to the mini-grid, as well as the general control and orchestration of the system, is performed by a 3.3 KW SMA Sunny Island inverter (European model SI3300).

The Sunny Island communicates with the Sunny Boys via grid frequency similar to the droop system described earlier. If the batteries are fully charged, the Sunny Island will instruct the Sunny Boys to derate their power output so that the batteries will not be overcharged. Backup is provided by a 3.5 KW pull-start gasoline generator that was already owned by the school. There are plans for a self-starting diesel generator when funds are available.

The first phase of the system is now in full operation, supplying electricity and water to the girls' dorm, boys' dorm, classrooms, and convent. The primary use of the electricity is lighting. The dining room is open in the evening for studying, and hall lights are a huge help for midnight visits to the restroom. Another important use is kitchen appliances, such as blenders and mixers. However, the stereo is by far the students' favorite use of their new energy.

Bulyansungwe's social center was left unelectrified because it is presently only used during the day. However, plans to establish a health center and basic hospital that will require electricity are in the works. This is one of the reasons an AC mini-grid is so appropriate for this location.

Three years before we installed the AC mini-grid, the sponsoring organization installed a small, DC water pumping and purification system in the social center in Bulyansungwe. This separate, DC system is powered by twelve, 75 W PV panels, with two, 130 AH batteries for storage.

When the health center is realized, the existing DC system will be converted to AC and connected to the current mini-grid. More PV panels will be erected and the combined PV array will be connected to the mini-grid through a Sunny Boy inverter. Another Sunny Island inverter, which will allow the two systems to function together, and a battery bank will also be installed in the social center. The system will operate as a multi-master, frequency-coordinated AC mini-grid.

Expandable & Modular

The AC mini-grid topology of the Bulyansungwe system will also make future expansion of the system to meet growing energy demands easier. For example, if the school were able to acquire a few computers for classroom use, the daily energy demand would increase. This might necessitate more PV generating capacity, but not more battery capacity, since the computers are used during the day.

With the AC mini-grid, a small PV array could be added to the system by using a standard, batteryless, grid-tie inverter and connecting its output anywhere on the grid. The PVs could be mounted near the school building, which is a couple hundred yards from the current PV array and battery bank in the girls' dorm. Mounting the supplemental system near the school building would reduce line losses over that distance. This is in contrast to DC-coupled systems, where more significant reconfiguration of the system might be necessary for expansion.

AC mini-grids that are equipped with multi-master operation are an exciting new advancement in off-grid PV technology. This new technology opens the door to interesting new possibilities in hybrid system design. The plans for expanding the Bulyansungwe project highlight expandability as a primary benefit to AC mini-grids.

Access

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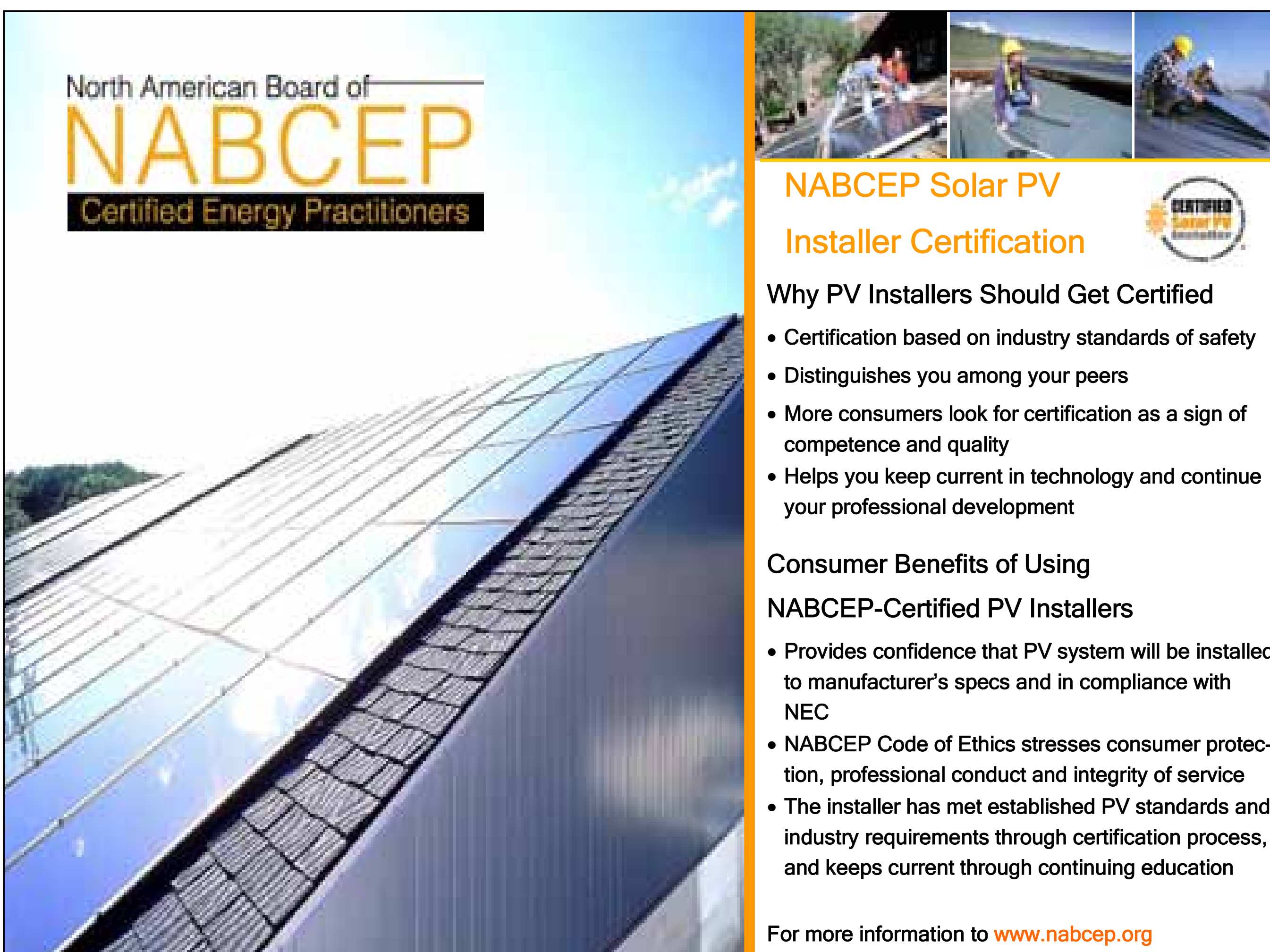

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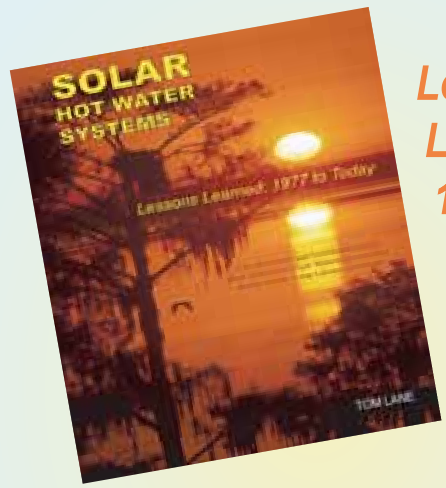

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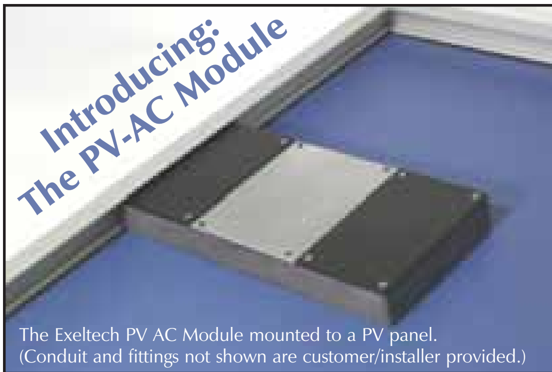

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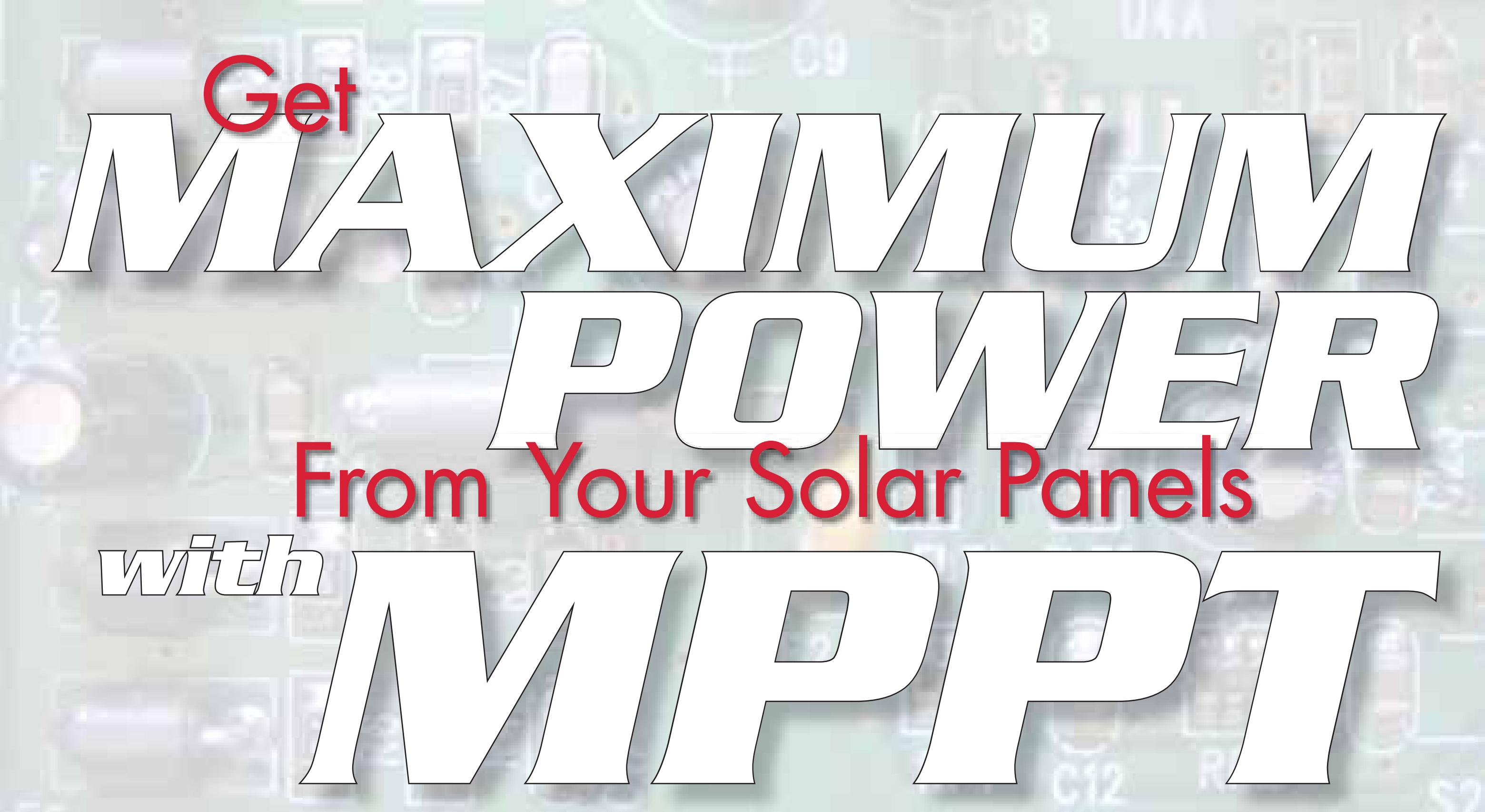

Get MAXIMUM POWER From Your Solar Panels with MPPT

boB Gudgel

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Interested in increasing the output of your solar-electric array, without adding additional panels? A maximum power point tracking (MPPT) controller will allow you to harvest more energy from the sun under most conditions, and often substantially compared to non-MPPT designs. So if optimum system performance is your goal, take a closer look at the technology behind MPPT.

Commercially available maximum power point tracking controllers have been around since at least the 1980s. Now they're becoming standard equipment in all but the most modest solar-electric (photovoltaic; PV) systems. New controller designs with improved, lower cost electronic components, transistors, and microprocessors have made affordable and robust MPPT charge controllers a reality.

Simple PV Charging

When a PV panel is connected to a discharged battery and exposed to sunlight, the voltage (potential energy) of the PV will be higher than the battery voltage, and the PV will begin to charge the battery. Just as water flows downhill from a higher level to a lower level, energy flows from the higher voltage PV source to the lower voltage battery.

As soon as you connect the PV to the battery, the two voltages will be equal. The PV will still typically have a higher voltage potential, but the PV's operating voltage is clamped at the battery voltage. If the battery's state of charge is low, the charging voltage will initially be low too. As the battery is charged, the voltage will rise, and the charge rate (amperage) will decrease.

Typical flooded lead-acid batteries need to be held at a relatively high voltage (at least 14.4 VDC at 77°F for a 12 VDC nominal system with flooded batteries) for an hour or two to receive a full charge. This is called the "absorb" or "finish" charge stage. A few times a year, you'll want to equalize the battery bank. Equalization requires the battery to be charged and held at an even higher voltage (up to 16 VDC for a 12 VDC nominal system) for several hours. These are just two reasons why the actual operating voltage of a PV is higher than what is referred to as its nominal voltage. A 12 VDC nominal PV would actually spend much of its charging cycle at closer to 17 VDC, if the battery (or the charge controller) would let it.

The PWM Revolution

Simply connecting a PV to a flooded lead-acid battery can lead to overcharging and a radically decreased operational life if the charging process is not controlled. Overcharging sealed batteries will destroy them and possibly lead to explosions. So you can see why voltage control is necessary to both protect the battery and charge it properly.

A simple, on-off (or "slam-bang," as some call it) relay controller can provide basic protection. When the battery reaches a preset voltage, the controller turns the array off. When voltage drops below a predetermined lower set point, the controller turns the array back on. Controllers such as the old Trace C30 and mercury displacement relay (MDR) controllers operate in this manner.

A pulse width modulated (PWM) charge controller is the next step up in sophistication. It automatically disconnects and reconnects the PV array at a very fast rate, usually hundreds of times a second. This design approach allows the controller to hold the battery at a steady voltage during regulation, which results in higher quality battery charging, and longer battery life.

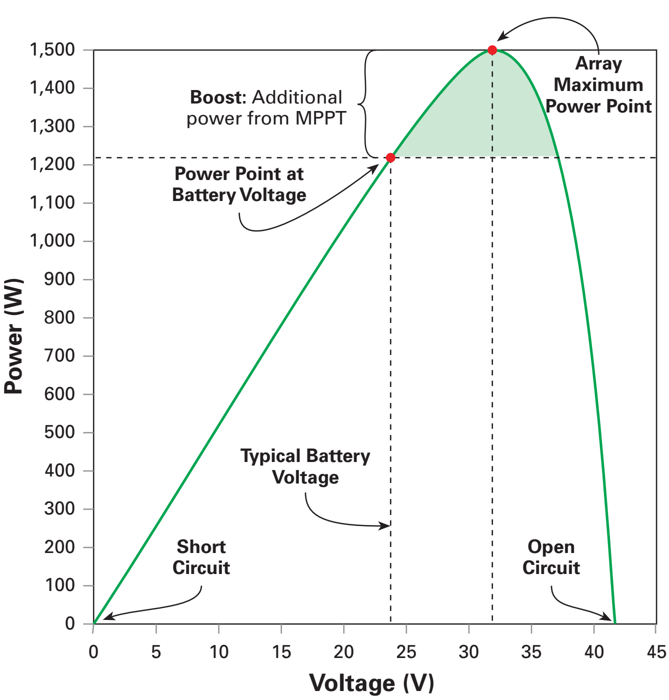
MPPT Is Better

If we look at a typical PV array's wattage versus voltage graphically (see the graph below), we can see how its output might be improved using maximum power point tracking. Power (watts) from a PV array can easily be calculated by multiplying array voltage by array current (amps).

Watts = Volts x Amps

If you look at the right side of the graph, where the wires are disconnected, there's open circuit voltage (Voc), but no amperage (current). Zero amps times any voltage is zero watts. At the left side of the graph, the PV wires are connected directly together, and although we have lots of amps (short circuit current), we have zero volts across this short circuit. Any current times zero volts still equals zero

Power Output of a Typical PV Array



Array Rated Wattage: 1,800 W
Array Nominal Voltage: 24 V
Battery Nominal Voltage: 24 V

How It Works

In a typical MPPT charge controller, the PV array is connected to the controller input terminals and the battery is connected to the output terminals. The controller monitors the PV voltage and amperage, battery voltage, and possibly other things such as battery temperature and load current. An internal microprocessor will make the decisions related to battery charging modes (bulk, float, equalize, track, sleep, wake up), take commands, and display information—everything needed to regulate the battery charging process and interact with the system users.

Assuming that the battery needs charging when the sun comes up, the MPPT controller will "wake up" and find the PV input voltage that will give the highest charge rate. This maximum power point voltage (MPPV) can be found, or "tracked," in several different ways. One way is to simply "sweep" the PV array input voltage from open circuit voltage (disconnected) downward towards the battery voltage.

The MPPT controller sweeps by adding an increasing load to the PV terminals. The load in this case is the battery. Connect the PV and the battery directly together (full load) and the PV voltage equals the battery voltage. A DC-to-DC converter in the controller can completely disconnect the PV from the battery (open circuit), connect them directly together, or anywhere in between. Somewhere in between the two extremes (open circuit and full load) lies the maximum power point voltage.

For example, on a typical 72-volt nominal array, the sweeping controller will move the PV array voltage from about 130 VDC to 65 VDC, looking for the voltage where the array will put out the highest power. As the voltage is being changed, the controller remembers what the maximum power PV voltage was, and keeps (regulates) its input voltage at that point.

Over the course of the day, the maximum power point voltage will change as conditions do (array temperature, sunlight intensity, etc.), and the controller will "track" this MPPV by periodically looking closely around the previously found MPPV. This nearsightedness ensures that it doesn't waste energy, which might happen if the controller had to restart from scratch every time.

When the battery is fully (or nearly) charged, when maximum power is not needed anymore, the controller will operate the PV input at whatever voltage is necessary to keep the battery voltage at the preset regulation voltage. At night, the MPPT controller will go to sleep, and the next day, it will wake up and start all over again.

B.Z. Products offers MPPT controllers in two amperage ratings.

watts. Somewhere in between the open and short circuit, we have a maximum power point (MPP), which is shown by the high peak. This is where the module will give us the highest output.

A maximum power point tracking charge controller operates the PV array at this maximum power point voltage, and efficiently translates that down to the lower battery voltage. It's like an automobile transmission, translating a high engine rpm down to a lower rpm at the wheels. This voltage-reducing circuit is technically called a "buck" converter. The idea is for this buck converter to operate efficiently and waste very little energy in heat, so we get as much energy out as possible. All controllers will get somewhat warm when processing any significant amount of energy, but high efficiency (less heat) is a good thing.

The Solar Boost 3024i is one of several MPPT controllers made by Blue Sky Energy Inc.

A good MPP tracking algorithm is also desirable. If the controller operates too far to the left or right of the peak, energy will be wasted. Although the maximum power point voltage will usually change slowly, it should at least be checked from time to time. Controllers can do this in many different ways. Normally, some energy will be lost in finding the maximum power point, but it's usually very small.

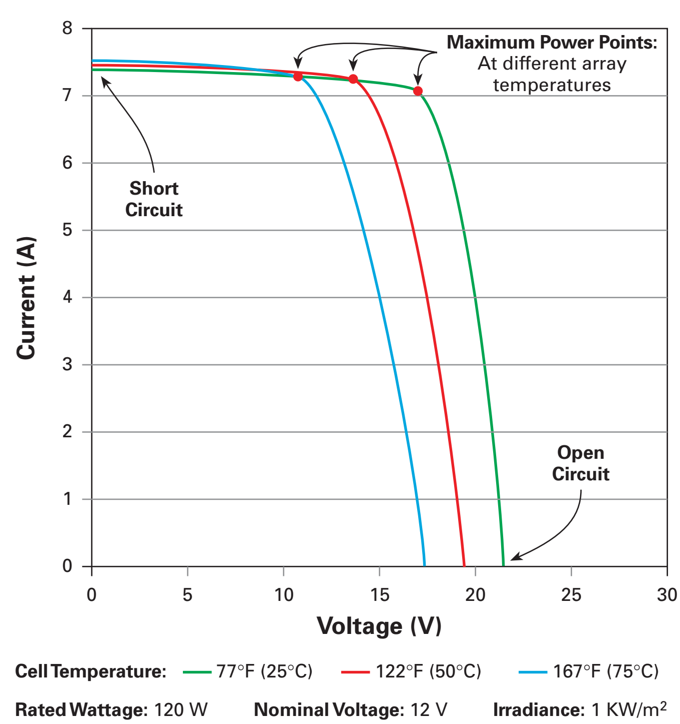
An MPPT controller will allow a solar array to generate more energy than a non-MPPT controller, at a lower cost compared to adding more modules to make up the difference. PV space limitations and wire loss may also be deciding factors in using an MPPT controller.

The increase in output above and beyond the direct PV connection is called "boost." The amount of boost achieved is not always easy to predict. Boost amount can depend on several factors, mainly temperature and battery state of charge. For example, high amounts of boost can happen on a cold sunny day in winter, after a storm, when your batteries are deeply discharged and you need the energy the most.

Maximum Power Point Voltage May Vary

PV module temperature plays a big part in determining how much boost you will get. The hotter the modules, the lower the maximum power point voltage and power will be. Of course, as soon as the sun shines on the modules, they will heat up. This can, at times, put the maximum power point at or even below the battery voltage. In this case, you will get no boost, and a PWM controller would work just as well as an MPPT controller.

Maximum Power Points of a 120-Watt PV Panel



In general, when the modules are cold, the output and maximum power point voltage go up, and a PWM-type charger will not be able to take advantage of the available power. Partial shading of an array will reduce the output and may also reduce the maximum power point voltage.

One way to be sure that the maximum power point voltage stays higher than the battery voltage, if the controller will allow it, is to simply wire more PV modules in series increasing the voltage of the array. Normally, wiring the PV one nominal voltage higher than the battery will do the trick, such as a 36-volt nominal array charging a 24-volt nominal battery. MPPT controller efficiency will generally go down slightly with higher input voltages, but the overall system gain will usually be more than the lower controller efficiency. Higher PV voltage can also improve early morning and evening low-light performance.

Reduce Your Losses

But wait! There's more! As long as we're raising the PV voltage a bit, why stop there? As mentioned before, power (watts) equals voltage times amperage. When we are talking about power lost in the PV wires, we use the equation:

$$P = I^2 \times R$$

Where P is power lost, I^2 is current squared (amps x amps), and R is wire resistance.

If we reduce the amperage by two (by doubling the voltage), we reduce the power lost by four. If we reduce the amperage by four, we can reduce the power lost by sixteen, etc. We do this by increasing the voltage by two or four times, respectively. For a very long wire run, this can add up to real savings very quickly!

Author boB Gudgel at the bench where he designs and tests MPPT charge controllers for OutBack Power Systems.

Let's say we need to place a 24 VDC nominal, 1,400-watt PV array 250 feet (76 m) away from a 24-volt nominal battery bank (500 feet; 152 m of wire, total). This situation comes up much more often than you might think. If we use #4/0 (107 mm^2) cable, we will have 3.3 percent loss (46 watts) in that length cable. From one RE dealer, 500 feet of #4/0 cable costs about US$1,200.

If we wire that same PV array for 48 volts nominal, we can use #2 (33 mm^2) wire for the same wire loss of 3.3 percent. The same dealer sells 500 feet of #2 for US$385. This example just saved US$815 in wire and paid for an MPPT controller with down-conversion capability, with change to spare. Depending on the MPPT controller capabilities, along with the voltage wiring versatility of the PV modules being used, you can save even more wire cost and power by wiring the array for 60 or 72 volts nominal. Utilities send electricity cross-country at a half a million volts or more for this same reason.

OutBack Power Systems makes the MX-60, an MPPT controller with a 60-amp capacity.

Here's the Point

Maximum power point tracking charge controllers come in varying amperage ratings, from just a few amps to 60 or 70 amps. The minimum wattage array to consider purchasing an MPPT controller for is about 250 watts. Of course, you may want to buy one even for a smaller array if you plan to expand your system later. The approximate maximum array size (in rated watts) that you can connect to a controller's input can be calculated by multiplying the battery voltage by the controller's output current rating.

Maximum power point tracking is an immediate way to increase system performance without going to the trouble or expense of adding extra PV modules. Often, you'll be throwing away part of your PV investment if you are not using an MPPT charge controller. Adding an MPPT controller will help you to charge harder, spin your utility meter backwards faster, and save money while the sun shines.

Access

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Other MPPT charge controller manufacturers:

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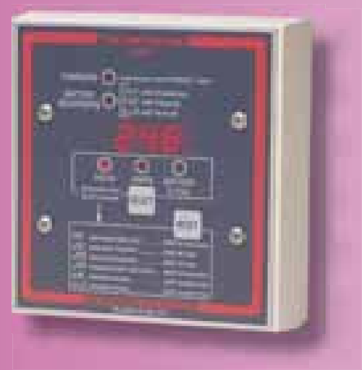

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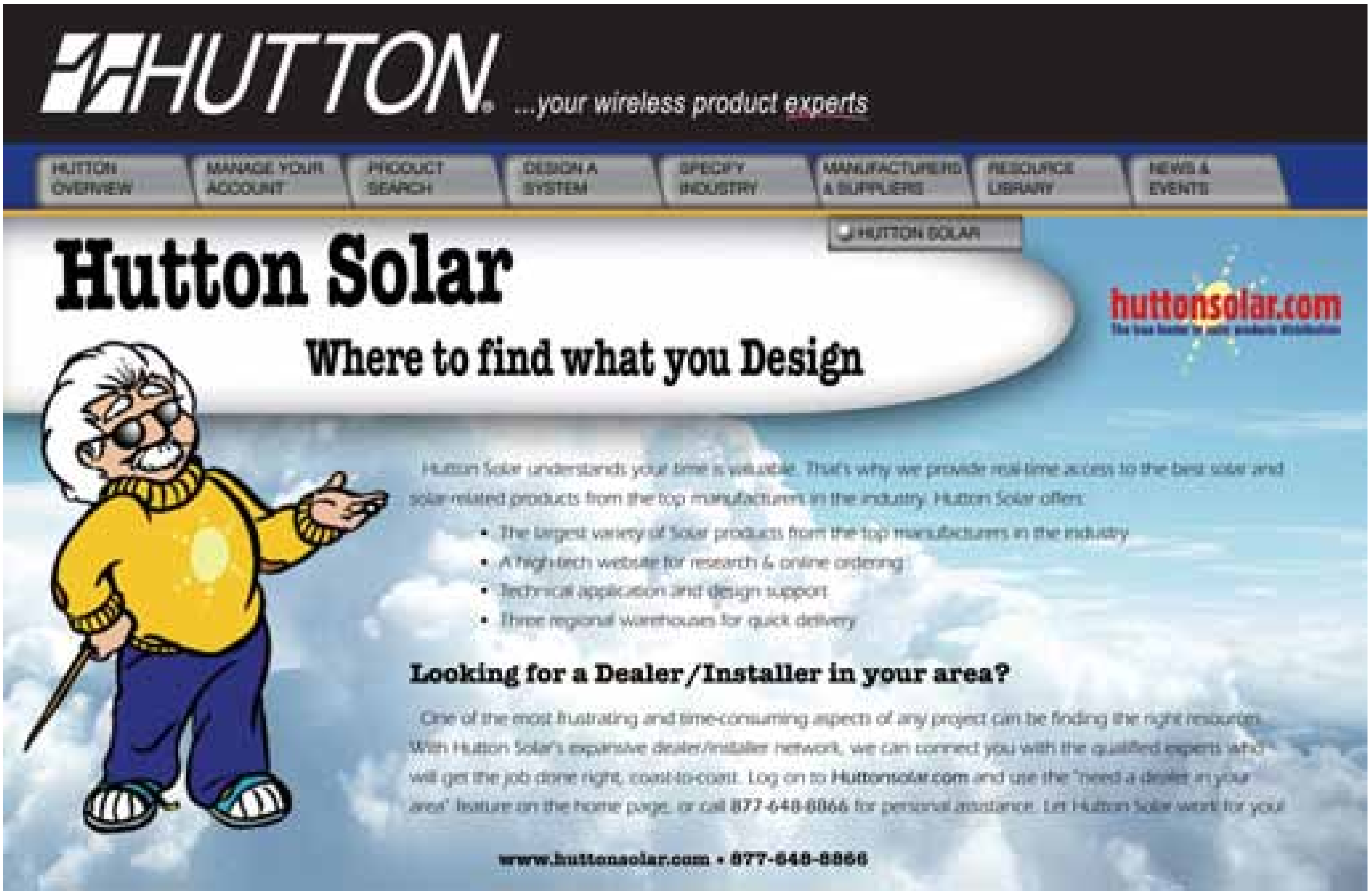
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Sharing the Road

Courtesy of Flexcar

Flexcar offers the fuel-efficient Honda Civic hybrid for car sharing.

Dan Chiras

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Adapted from *Superbia! 31 Ways to Create Sustainable Neighborhoods* by Dan Chiras & Dave Wann

Do you own your car—or does *it* own *you*? If you're like most people, you'll answer "yes" to both questions. You own a car that gets you where you want to go, but you're a slave to it, spending considerable amounts of money (and time) supporting your automobile and driving habit.

According to the American Automobile Association, Americans pay an average of US$700 each month to own and operate a car. Payments for a new car can easily run US$300 to $500 per month. Insurance adds from US$75 to $150 per month to the cost of car ownership, and then there's gasoline, costing another US$100 to $200, and maintenance expenses…But wait, that's not all. If you are like many Americans, you own not one, but two or three vehicles, which doubles or triples your monthly costs.

Fortunately, if you want the convenience of a car without the expense of ownership, there's an option for you—it's called car sharing.

The Wheel Deal

Popular in Europe for almost three decades, car sharing has finally begun to gain momentum in the United States. Today, two commercial ventures—Zipcar and Flexcar—offer car share programs in cities across the country, including Boston, New York, Chicago, Denver, Los Angeles, Seattle, Washington, D.C., and Portland, Oregon. Even universities, including the University of North Carolina–Chapel Hill, UCLA, and the University of Washington, are jumping on the wagon, saving students money, and helping curb campus traffic congestion and parking problems.

Most car share programs require a one-time application fee and charge an annual membership fee, which average about US$75. Once you join, vehicles are available for one hour to several days. (Special arrangements can be made to rent cars for long trips.) Businesses, families, and individuals can all participate. Car share programs screen applicants using age and traffic violation criteria to eliminate risky clientele. Qualified members are covered by comprehensive and liability insurance when behind the wheel.

Urban car share programs place their cars conveniently throughout the city, usually in reserved parking lots or spaces. Members pay a small hourly fee to use the car, typically under US$10, and a per-mile charge. San Francisco's nonprofit City CarShare program charges users US$4 per hour and 44 cents per mile. Some programs give members a certain number of free miles before charging for mileage.

Both Zipcar and Flexcar use online and phone reservation systems, which allow you to reserve a car in a few quick keystrokes or with a phone call. A computer tells you where the car is and its license plate number. You show up at the site, hold your membership card next to the windshield, where it is read by a scanner, and if you've reserved the car and the time is correct, the doors unlock. The car's onboard computer sends a signal to company headquarters, indicating your rental period has begun, and activates a billing record.

When you're done, you return the car to its parking space, lock it, and leave. Your credit card is billed monthly for any usage you incur. The program pays for gas, although members are responsible for filling the tank when the gauge drops below the one-quarter mark—using a company credit card. And what if you have a fender-bender? Neither Zipcar nor Flexcar charge a damage deposit. According to Flexcar spokesperson John Williams, members pay half of the deductible (US$500) if they caused the accident; otherwise, there's no penalty. (Policies vary among different organizations; be sure to inquire first.)

Car sharing programs make it easy to choose a vehicle to meet your needs by offering a wide range of vehicles, from small, efficient commuter cars like the hybrid-electric Honda Civic or Toyota Prius to larger vehicles for special uses, such as Ford pickups and SUVs. According to Zipcar, more than half of their members say that they tried the service for the opportunity to get behind the wheel of many different makes and models of cars, including hybrid-electric vehicles.

Is Car Sharing for You?

Yes, If You...

- Rely solely on mass transit or other car-free alternatives (like biking or walking), but occasionally need a car for special trips
- Own a car, but need to use a second car, truck, or van periodically
- Own two cars, but don't use the second vehicle very often
- Are interested in saving money and reducing your environmental impact

Probably Not, If You...

- Need a car to drive every day of the week
- Only use a car for long trips, like vacations (renting a car would probably make more sense)
- Drive more than 10,000 miles annually

Adapted from the Boulder Car Share Web site at www.carshare.org

Speedy Savings

How much you save depends on your driving habits and needs. According to a recent customer survey, Zipcar members state they save an average of US$435 per month when compared to car ownership. Williams says that most of Flexcar's customers report savings of at least a couple hundred dollars each month.

To determine whether a car sharing program makes economic sense for you, Zipcar offers an online savings calculator. Just click on "Run the Numbers" on their Web site and enter the current or projected costs of your vehicle, including monthly payments, insurance premiums, fuel costs, parking fees, and maintenance costs. The program calculates the monthly and annual costs of car ownership, and computes car sharing savings.

Beyond your pocketbook, car sharing also offers some environmental savings. Personal vehicles produce a large portion of the nation's annual emissions of carbon dioxide and other pollutants, contributing to global warming and localized smog. Accommodating the growing fleet of vehicles as we pave the planet also results in the loss of huge amounts of open space, farmland, and wildlife habitat.

According to Zipcar research, the company alone has been responsible for removing more than 10,000 cars from U.S. city streets and highways. Their survey also showed that car share members drive an average of 4,000 fewer miles (6,437 km) each year, compared to their habits before joining the program. Most people drive less when they have to pay a per-hour or per-mile fee, and studies have shown that car sharing folks are more likely to combine trips, take mass transit, bike, or walk when it's convenient. Combined with cities that have good mass transit systems, car share programs are highly effective at reducing congestion and pollution in urban settings.

Get Started

If car sharing hasn't come to your town, consider setting up a program yourself. Across the country, groups of friends, neighbors, and colleagues have established their own car share programs by using cars already owned by individual members of the group or by purchasing cars together.

To make a community car sharing program run smoothly, members should consider providing convenient locations to park the vehicles, and draft agreements on buying fuel, accessing keys, and servicing and insuring the vehicles. A booking system should also be established. The Eugene, Oregon, BioCarShare program uses Online Resource Scheduler free software as their scheduling tool. Members log on at the Web site with their user name and password to reserve a car. Set up as a cooperative, BioCarShare requires members to pay a joiner's fee, which is refundable, and a small monthly membership fee. Like most programs, they also require that drivers pay in proportion to their use, per hour or per mile. Car clubs such as these usually operate with standard insurance coverage—as long as the group or any of its members makes no profit. In most

Pass the keys, please. Many people are discovering that car sharing is convenient, cost effective—and fun.

states, car clubs apply for insurance in the club's name and can list four or five people on a single policy.

Access

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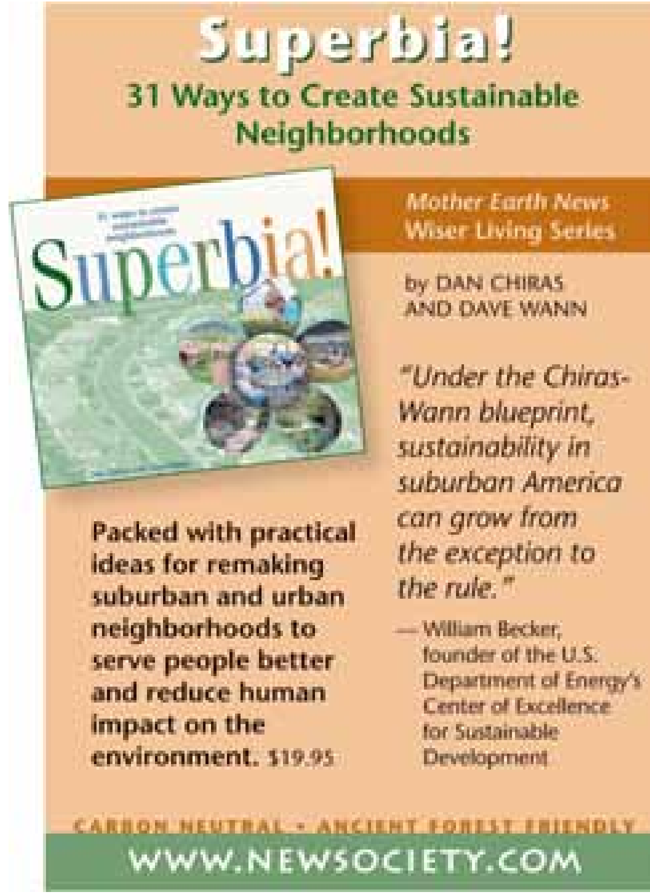

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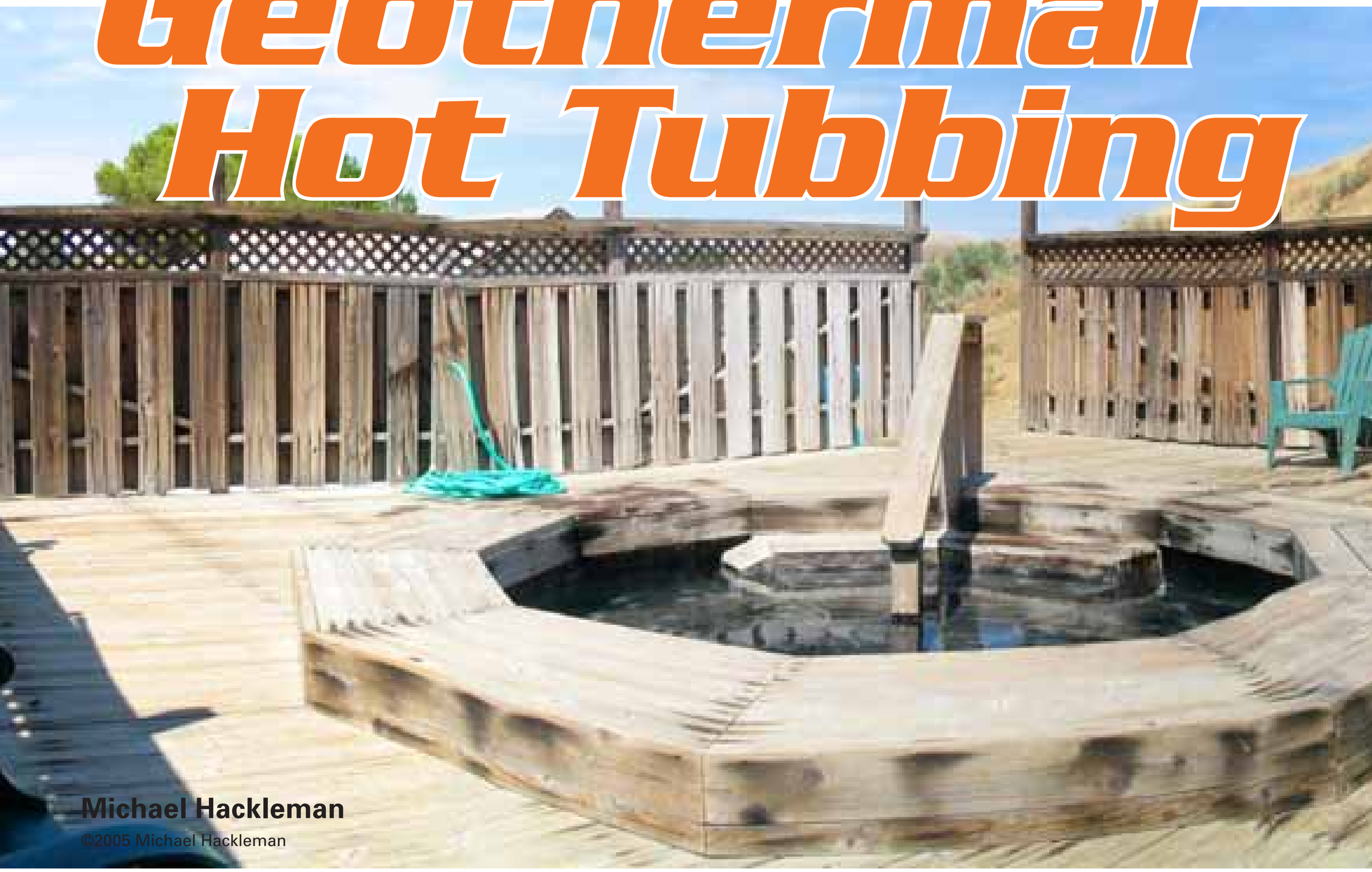

Michael Hackleman

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The 2,600-gallon (9,850 l) outdoor hot tub at Mercey Hot Springs is heated by a homebuilt heat exchanger plumbed through a natural 119°F artesian spring.

Geothermal energy heats the hot tub at Mercey Hot Springs, a desert oasis nestled in the hills west of the San Joaquin Valley of California. Since the nearest utility lines are 5 miles (8 km) away, electricity for the resort is generated from the wind, sun, and recycled veggie oil. Its swimming pool is heated by a solar thermal array.

While Mercey Hot Springs approaches 100 percent sustainability with regard to electricity use, it still relies on propane for heating the hotel and cabins in winter, supplying domestic hot water, cooking, and, formerly, maintaining the large outdoor hot tub at 104°F (40°C). Faced with monthly propane bills of US$300, owners Larry Ronneberg and Grazyna Aust were very interested in tapping the geothermal energy available onsite. Now, with the addition of a simple heat exchanger, geothermal energy reliably heats the large outdoor hot tub. Soon, geothermal energy will be heating buildings and domestic hot water for the resort.

Source

The first step toward using geothermal energy is assessing the source. The spring at Mercey Hot Springs is artesian, hot, and abundant. The exit temperature of the Mercey spring is 119°F (48°C) and the rate of flow is 7 to 8 gallons per minute (26–30 lpm). A flow rate of 7 gpm may sound small, but over a 24-hour period, the spring yields at least 10,080 gallons (38,183 l) of water.

Calculating the energy potential of a geothermal spring can be done in a number of ways. However, crunching a bunch of numbers is meaningless if you don't know what to do with the answers. See the Geothermal Calculations sidebar for some simple methods to help you assess geothermal potential.

Potential Applications

To what kinds of applications could the geothermal energy be applied? A temperature of 119°F (48°C) is not useful for cooking, refrigeration, or steam production directly. However, it is able to handle domestic hot water, room heating, dehydrating food, distilling water, and heating hot tubs. Mercey Hot Springs experiences a high number of solar days per year (335), so more direct methods of distilling water and dehydrating food using solar energy will be tried first.

To get the biggest bang for the buck, we looked at the energy usage for the remaining three applications—domestic hot water, room heating, and heating the hot tub—and their relative consumption of propane.

With a Hot Spring Heat Exchanger

After many calculations, it appeared that the hot tub was responsible for about 50 percent of the propane bill, or about US$150 per month. Heating the hot tub, then, offered the best cost-to-benefit ratio for tapping the geothermal potential of the spring.

A Geothermal Heat Exchanger

Heating water in a hot tub with the energy in a geothermal spring introduces several challenges. The first is the risk of contamination. The local county health department will be the first to point out that once spring water is introduced into the hot tub, it is considered "contaminated" and must not be circulated back to the source.

How, then, could we transfer heat from the source to the hot tub without risk of contamination? The solution was a fluid-to-fluid heat exchanger. This device permits the exchange of heat between two fluids while preventing a mix of them.

Manufacturers of heat exchangers offer hardware that is sized to satisfy virtually any application and specifications. Since the shop at Mercey Hot Springs has the tools to fabricate almost anything, we decided to design and build our own heat exchanger for the spring tank. How big it would be, where it would go, and how it would be plumbed were dictated largely by the existing spring tank and pumping hardware.

In the early 1900s, the artesian spring at Mercey Hot Springs was dug out to a depth of 8 feet (2.4 m) and surrounded by a foot-thick (0.3 m) wall of concrete measuring roughly 12 feet by 12 feet (3.7 x 3.7 m) in size. A foot-thick, convex shaped concrete cap has two, 30-inch (76 cm) square hatches on diagonally opposing corners for access.

Domestic hot water. One 80-gallon (300 l) water heater was in use, primarily for the kitchen sink and one private bath. All other showers, tubs, and sinks on site were plumbed to use the spring's hot water directly.

Room heating. The resort has five cabins, one mobile home, a massage room, the chapel (reception area), and five rooms in a hotel—two bedrooms, one office, a kitchen, and a dining room. All use propane for room heating. This usage is confined to the fall, winter, and spring, and disappears in the summer, when space heating is no longer needed.

Hot tub. The outdoor hot tub is 9 feet (2.7 m) in diameter and 5 feet (1.5 m) deep, and contains roughly 2,600 gallons (9,840 l) of water. Plumbing connects the hot tub with its circulation pump, filter, and chlorinator—all located some 200 feet (61 m) away. An in-line, propane-fueled demand heater was used to maintain a 104°F (40°C) temperature in the hot tub.

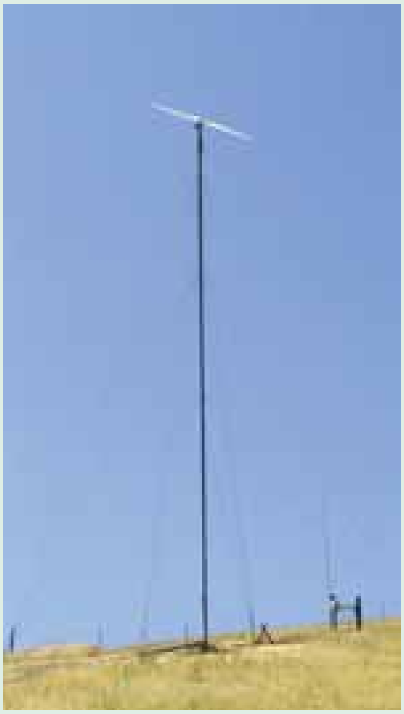
Estimating the percentage of propane usage for each of these functions—domestic hot water, room heating, cooking, and the hot tub—was mildly challenging. Propane usage during summer months is restricted to domestic hot water, cooking, and heating the hot tub. Mercey Hot Springs experiences relatively mild winters, so heating rooms is not a big load.

Mercey Hot Springs owner Larry Ronneberg (right) and author Michael Hackleman prepare copper coils for the heat exchanger.

Renewable Energy at Mercey Hot Springs

Tapping renewable energy is an ongoing event at Mercey Hot Springs. A 3,000-watt Whisper wind generator atop a 70-foot (21 m) tower faithfully cranks out electricity throughout the year. A 1,000-watt, solar-electric (PV) array tracks the sun, routing even more electricity into the resort's industrial-sized battery bank. A 15 KW standby diesel generator was converted last summer to run directly on filtered veggie oil recycled from nearby restaurants.

When the resort's usage exceeds the capacity of the battery bank, the generator fires up, takes over the load, and recharges the 48 V, 72 KWH battery bank at the same time. Twin 120 V inverters, each rated at 5.5 KW, handle both 120 V and 240 V loads from the battery bank when the generator is off. A 22-panel array of solar thermal (water heating) collectors supplements the energy grid further by heating the 25,000-gallon (95,000 l) outdoor swimming pool all year long.



Left: The 1,000 W PV array.
Right: The Whisper wind generator.

The heat exchanger was test assembled before installation into the spring tank.

County codes require a specific number of water exchanges daily for a public hot tub. To meet this requirement, the existing circulation system pumped water through the filter and chlorinator at a 50-gpm flow rate for 14 to 16 hours of each day. If we designed the heat exchanger to be plumbed in-line, we could use this flow to deliver heat from the spring tank to the hot tub. To minimize pressure losses in the circulation loop, the heat exchanger and related plumbing were sized around 2-inch PVC pipe and fittings, sweeps, and low-resistance diversion valves.

Using a flow resistance table for copper pipe, Larry confirmed that five coils of 1-inch copper pipe in parallel with each other would have less resistance to flow than one 2-inch plastic pipe. Since 1-inch (ID), thick-wall copper pipe was available from the refrigeration industry in 50-foot (15 m) coils, we elected to use these intact and to terminate the five coils in 2-inch PVC header pipes at each end.

We purchased the five coils of copper tubing and 2-inch PVC pipes, unions, elbows, and valves. Each coil had a diameter of 30 inches (76 cm). One coil was inserted into the larger of the two hatches in the spring tank to verify that it would go through. We included unions in the design at each junction of coil and header. We wanted to minimize the amount of assembly required inside the spring tank and avoid any risk of spilling glue into the spring water.

We spread all the parts of our heat exchanger on the ground, and tried various configurations of the heat exchanger itself. A low profile was important. Otherwise,

Connection to the manifold required a 2-inch tee, a reducer, a short PVC nipple, the union, and a PVC-to-copper adapter that was soldered to the end of a coil.

refilling the hot tub could drop the level of water in the spring tank to a level that would expose the coils to air, reducing their working efficiency.

Plumbed end-to-end, the five coils would not fit inside the length or width of the spring tank. However, we discovered that we could overlap and intermingle the coils

Intermingling adjacent coils saved space, separated the coils for efficient heat transfer, and allowed most of the preassembled heat exchanger to fit through the small hatch in the spring tank.

Geothermal Calculations

By definition, one Btu is the amount of heat it takes to raise the temperature of 1 pound (0.45 kg) of water by 1°F (0.56°C). Since a gallon of water (3.8 l) is about 8 pounds (3.6 kg), it takes 8 Btu to raise the temperature of 1 gallon of water by 1°F. Thus, it takes 80 Btu to increase the temperature of 10 gallons of water by 1°F, or to raise the temperature of 1 gallon of water by 10°F (5.6°C).

Heat seeks cold. At standard temperature and pressure, a heat source must be higher in temperature than the object itself if a transfer of heat between them is to work. Only the temperatures in a heat source above the application's likely temperature range (lowest temp and highest temp) are useful.

For example, Mercey's hot tub cools to 90°F (32°C) at night, and needs heating to achieve and maintain the desired temperature of 104°F (40°C) for 16 hours per day. There's a difference in temperature (ΔT, pronounced "delta tee") of 29°F (16°C) between the geothermal spring's exit temperature (119°F; 48°C) and the hot tub's lowest temperature (90°F). This ΔT is reduced to 15°F (8.3°C) as the hot tub reaches 104°F.

The Mercey Hot Springs hot tub uses 2,600 gallons (9,850 l) of water. How many Btu are needed to raise its temperature from 90°F to 104°F? The ΔT is 14°F (7.7°C). So, 14°F per pound of water times 8 pounds per gallon times 2,600 gallons equals 291,200 Btu.

How many Btu are available from geothermal energy to offset heat losses? The ΔT between the spring and the tub is 15°F (8.3°C). So, 15°F per pound times 8 pounds per gallon times 10,000 gallons per day equals 1.2 million Btu per day. Even when you factor in huge losses of heat in the hot tub, pipes, pumps, and heat exchanger, the spring is not heavily taxed in heating the hot tub.

Since radiant floors won't exceed 70°F (21°C), the inlet temperature to the tubing that serves a radiant floor system doesn't need a circulating fluid at more than 100°F (38°C). The geothermal source at Mercey Hot Springs is strong in this application, and future expansion of this system's output will likely move this way.

Steve Bain positions three of the heat exchanger coils on the cradle in the partially emptied spring tank. The two final coils were then lowered into the tank and connected to the preassembled ones.

for a more compact fit. By using unions at the in and out points of the heat exchanger, we were also able to eliminate the need to glue any PVC pipe inside the spring tank itself.

Assembly

Our mock-up of the way the heat exchanger would fit together saved mistakes, time, and material. It also gave us the measurements we needed to size the short lengths of 2-inch PVC pipe between the tees where the coils would attach in the header.

We used a tool that was designed to cut large PVC pipe, avoiding the uneven cuts you get using a hacksaw. The headers were glued together on a flat table in the shop. Mistakes tend to be cumulative, so we took our time building the headers to keep them straight. A reducer, a short nipple, and one side of a union were glued into each tee. The special copper fittings (1 1/8-inch ID) were soldered to each end of the copper coils. The coil ends were shaped by a tubing bender to get a perpendicular alignment of the fittings into the header tees.

Teflon plumbing tape handled the threaded ends of adapter-to-union joints near the tees. A cap was glued to one end of each header and a union glued to the other end for connection to the pipes that route water into and out of the exchanger. Sweeps were used at all turns to eliminate the flow resistance of 90-degree elbows.

A concrete-cutting blade in a standard circular saw was used to cut a 4- by 2-inch (10 x 5 cm) chunk in one corner of the 8-inch (20 cm) thick concrete hatch to pass the inlet and outlet pipes for the exchanger. We built a cradle to hold the exchanger assembly off the bottom of the spring, keep it level, and to separate and support the loops in the end coils. It was fabricated from PVC pipe and fittings. The finished unit looks like a monster in-line skate lying on its side, or a few bicycles that have crashed.

Pressure Testing

We were concerned about contaminating the spring tank, either from the hot tub water circulating through the heat exchanger or the materials used in making the heat exchanger. To mitigate the first possibility, the heat exchanger was pressure-tested at the shop as a unit, and again (along with interconnecting pipes) once it was installed in the spring tank. In both cases, the test pressure (80 psi) was twice that of the maximum pumping pressure (40 psi) in the system. A pressure gauge and a Schrader valve (like those used in tires) were permanently installed for periodic pressure tests of the exchanger while in operation.

While the mineral water at Mercey is only one-fifteenth the salinity of ocean water, it contains enough sodium and chloride to give it a slightly salty taste. It will eventually corrode or deposit scale on the copper coils, and may render them less effective at heat transfer over time. The effect of Mercey water on the PVC fittings or their glue is unknown.

Whether copper would be introduced into the spring water in detrimental amounts is also unknown but not suspected. Our design minimized the use of soldered fittings and only lead-free solder was used. To eliminate the chance of galvanic or electrolytic action from dissimilar metals, only PVC pipe and copper fittings were used in the heat exchanger and related fittings.

The modified plumbing sends the output of the circulation pump to a three-way valve, through the lower header of the heat exchanger, out the top header, through a ball valve, and back to the filter and chlorinator.

Installation

When it was time to install the heat exchanger, volunteers Steve Bain and Pat Kelly helped out. The spring tank hatches were lifted off with the resort's backhoe, and the tank was emptied, until only about a foot of water remained in the bottom of the tank. Steve slipped down into the tank as Pat and I lowered the cradle to him for positioning. Once it was level, the collapsed exchanger unit was maneuvered through the hatch and positioned on edge atop the cradle. Steve and I wrestled the coils apart, inserted the two remaining coils, and joined their unions to the headers.

Once the heat exchanger was in place, the prefabricated inlet and outlet pipes were lowered, positioned, and secured to it with union couplers. The aboveground plumbing was added, along with a three-way valve for the inlet and a ball valve for the outlet. With these valves positioned to isolate the exchanger's plumbing, we performed a final pressure check of the unit and all connections. Unistrut stands support the plumbing.

Heat from Mother Nature

We plumbed the heat exchanger into the system, including a bypass. Resetting both valves, we started the pump, brought the system online, and held our breath. With no discernable drop of pressure indicated on the system's gauges, we celebrated our efforts by taking cold showers and, later, with the propane heater shut off, we enjoyed a hot tub courtesy of Mother Nature and the in-spring heat exchanger.

The materials used to build the heat exchanger and plumb it into the existing system cost US$650. With propane savings amounting to nearly US$150 per month, this investment was recovered after 4 1/2 months of operation. The in-line flash heater sits idle now that the heat exchanger has taken over the job of heating the hot tub. Heating cabins and other buildings awaits system expansion. Insulation of the spring tank and hot tub and all plumbing is planned. This will ensure that there is enough geothermal heat to serve many more applications.

Access

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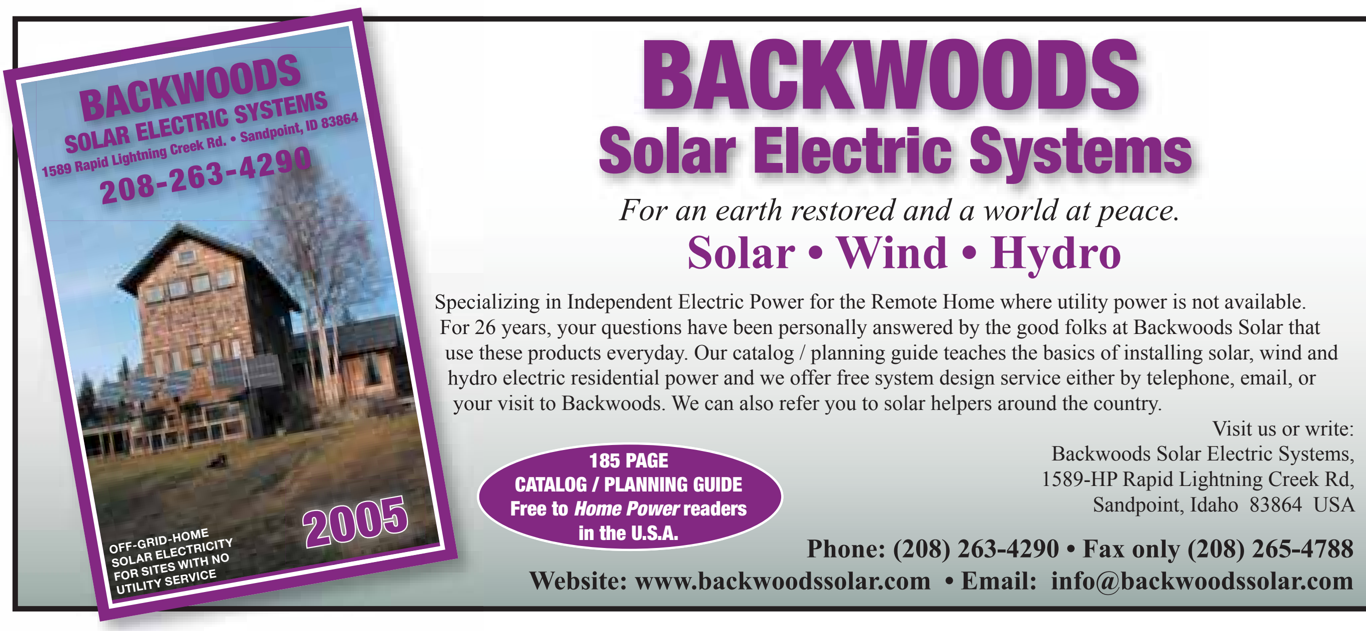
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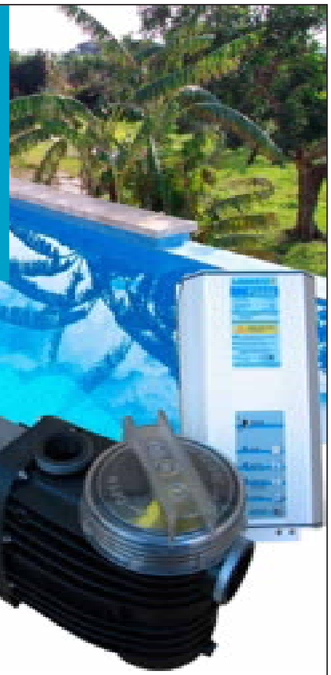

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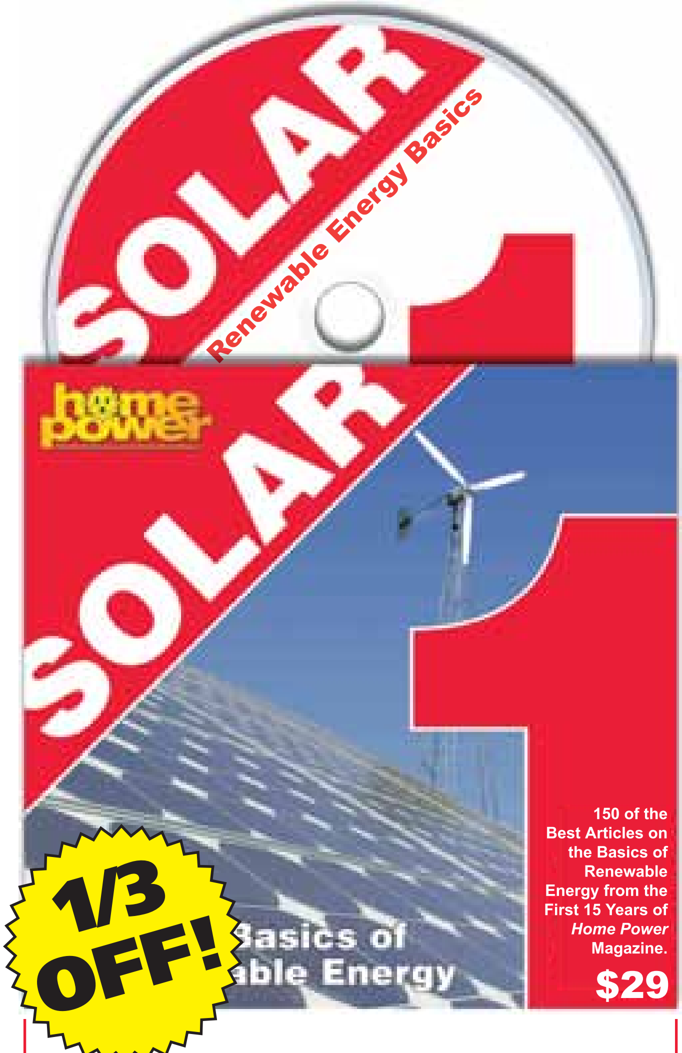

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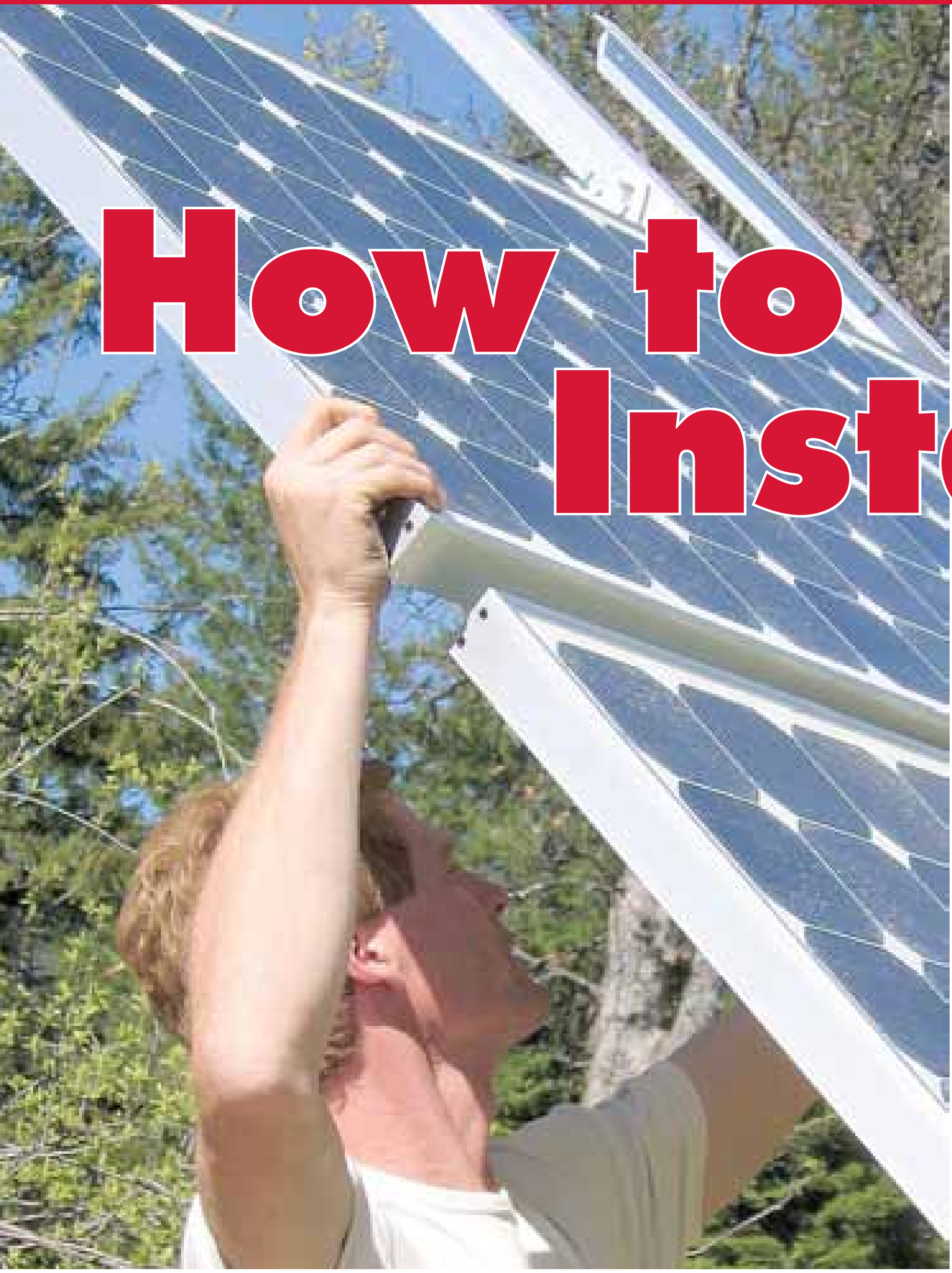

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Joe Schwartz

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Pole-mounted solar-electric (photovoltaic; PV) arrays are a great option for many sites. You don't need to worry about the orientation or angle of an existing roof, or about roof penetrations. Pole mounts allow easy, manual adjustment of the array's tilt angle, or you can choose automatic tracking mounts to optimize energy production. They provide great air circulation to keep PV temperature down and power output up during warm weather, and make clearing snow off the array a simple task in wintry climes.

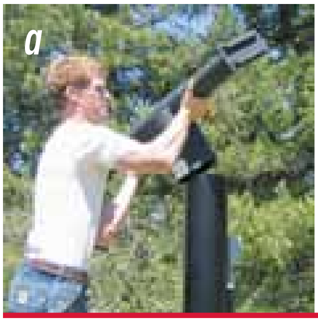
Last issue, I covered the groundwork—setting the pole. This time, I'll walk you through each step of the array assembly and wiring. Even if the equipment you use is different than mine, the information will be a useful installation guide for your own pole-mounted PV array.

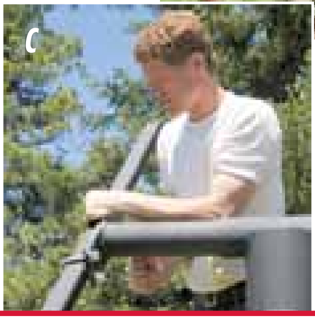
1 Assemble the Mount

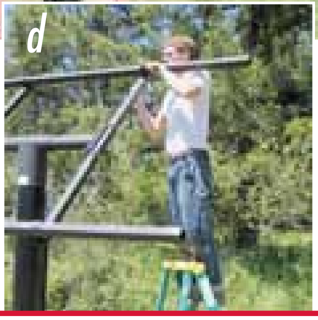
Most pole mounts are designed and manufactured for specific PV modules. When you contact your mount supplier, they'll need to know the brand, model, and quantity of PV modules planned for your system. Each mount will come with step-by-step assembly instructions. Getting your mount assembled on the top of the pole is as easy as following the directions, but I have a couple of tips that will help simplify the job.

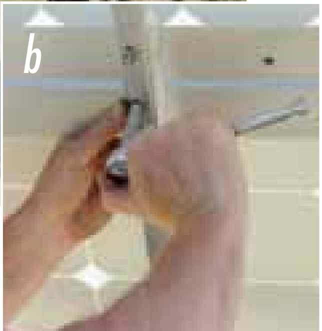
First, don't fully tighten the bolts that fasten the PV-mounting rails to the rest of the structure until all of the modules are in place. This will give you some wiggle room if any of the predrilled mounting holes in the rack are a little off. Don't forget to fully secure the rail hardware once the PVs are in place.

Second, pole mounts are designed to allow seasonal adjustment of the tilt angle of the array. While you're installing the array, it can be laid flat, at close to vertical, or anywhere in between. In general, I like to set the angle of the array at about 45 degrees. This limits the amount of uncomfortable overhead work. If the array is mounted on a tall pole, securing it in a horizontal position will make the whole array easier to reach.









2 Mount the PVs

Once the rack is assembled, it's time to install the PVs. If you're assembling the array while it's fixed in a tilted position, install the bottom row of PVs first. Then you can rest the next row of modules on the first row while you're positioning them, which makes the job faster and easier.

The mounting hardware for the PVs will be included with the rack, not the modules. This hardware should be stainless steel to resist corrosion, and include either lock washers or lock nuts that will not loosen over time. It's easier to work with the mounting hardware if you insert the bolts through the module mounting holes from the inside of the PVs, and then through the rack. This gives you better clearance to get the washers and nuts in place.

An open-end wrench used in conjunction with a ratchet and socket (usually 7/16 inch) will allow you to quickly fasten the PVs to the rack. If you have a big array, or several to install, a cordless drill fitted with a socket driver will definitely speed up the job. If you use this approach, make sure to set the driver's clutch to release before the hardware is overtightened. If you don't, you may snap off bolts.

3 Determine Combiner Box Conduit Fittings

The *National Electrical Code (NEC)* requires a dedicated breaker or fuse in line with each series string of PV modules (except with some high voltage inverters). To meet this code requirement, a combiner box is required in most pole-mounted array installations.

First, determine what conduit fittings you'll need to connect the combiner box to the conduit that runs up the pole. I typically run the conduit right against the pole. To make the transition from the conduit to the combiner box, you'll need a PVC female fitting, an offset, a nut, and a bushing.

Single-hole straps (clamps) are used to secure the conduit. Another channel and strapping system using Unistrut (not shown) is commonly used to secure the vertical length of conduit to the pole. This is a good approach, but requires a few more fittings.

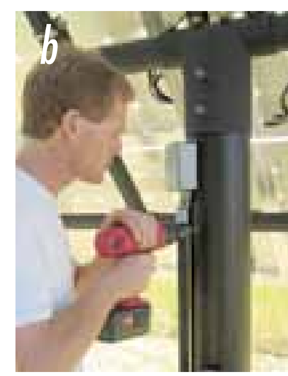
4 Mount the Combiner Box

Attach the conduit fittings to the combiner box finger-tight, and position the assembly on the conduit (no glue yet). Grab a marker and a torpedo (short) level. Adjust the offset until the back of the combiner box rests evenly against the pole, and then level the box. Now that everything is in position, mark the location of the mounting holes on the pole itself.

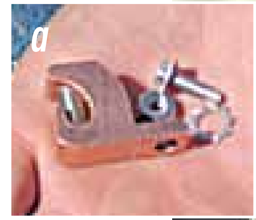
Depending on the size of the pole and the combiner box you're using, the box's predrilled mounting holes may not be positioned where you need them. If this is the case, line it up where you want it, and mark the back of the combiner box to predrill custom mounting holes. Then mark the location of the new holes on the pole.

Use self-tapping screws to fasten the combiner box to the pole (I prefer square-drive screws). Even with self-tapping screws, pilot holes are necessary when mounting to steel pipe. Make sure to choose a drill bit that is slightly smaller than the screws you use. The curve of the pole will typically cause your pilot bit to drift off your mark, so use a center punch to make a starting point for the drill bit. This will ensure that everything lines up when you fasten the box to the pole.

Once your holes line up, apply PVC glue to the conduit, and slide the combiner box/fitting assembly into place. Wipe off any excess glue and drive the screws. I always neatly apply some high-quality 50-year silicone caulk over the screw heads, and seal any unused, predrilled mounting holes in the back of the box. Finally, use straps to secure the vertical conduit to the pole.



5 Install the Array Equipment-Ground Lugs



All PV arrays need to be properly grounded per the *NEC*. Pole-mounted PV array equipment-grounding systems have three main components—lugs that attach the ground wire to the PV module frames, the ground wire itself, and a ground rod driven into the earth at the base of the pole.

Lay-in lug kits, available from solar energy equipment resellers, are appropriate for long-lasting, corrosion-free connections between the ground wire and the module frame. Lay-in lugs are designed to accept wire from the side, so the hassle of feeding the ground wire through successive lugs is eliminated.

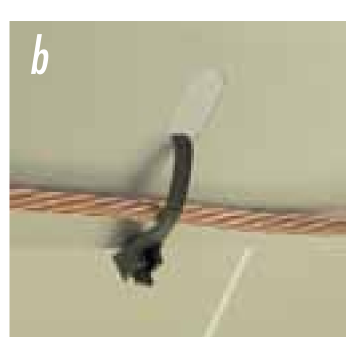
Lugs should be either bronze or stainless steel. They'll come with stainless mounting bolts or screws, and star washers that will cut through the anodizing on the module frame (ensuring a low-resistance connection). Low-cost aluminum lugs are not suitable, since the fastener will be exposed to weather in this application and corrosion will result.

Only the module grounding locations identified on the modules themselves should be used. Before you begin fastening the lugs to the module frames, plan the route the ground wire will run between each module, and then down to the combiner box. Use a cordless driver to fasten the lugs to the module frames.

6 Install the Array Equipment-Ground Wiring

Once the lugs are installed, it's time to run the ground wire from PV frame to PV frame, and then route it into the combiner box, where it will terminate at the box's equipment-ground lug. To ensure the lowest resistance electrical path, equipment-ground wire installed on PV arrays should be continuous.

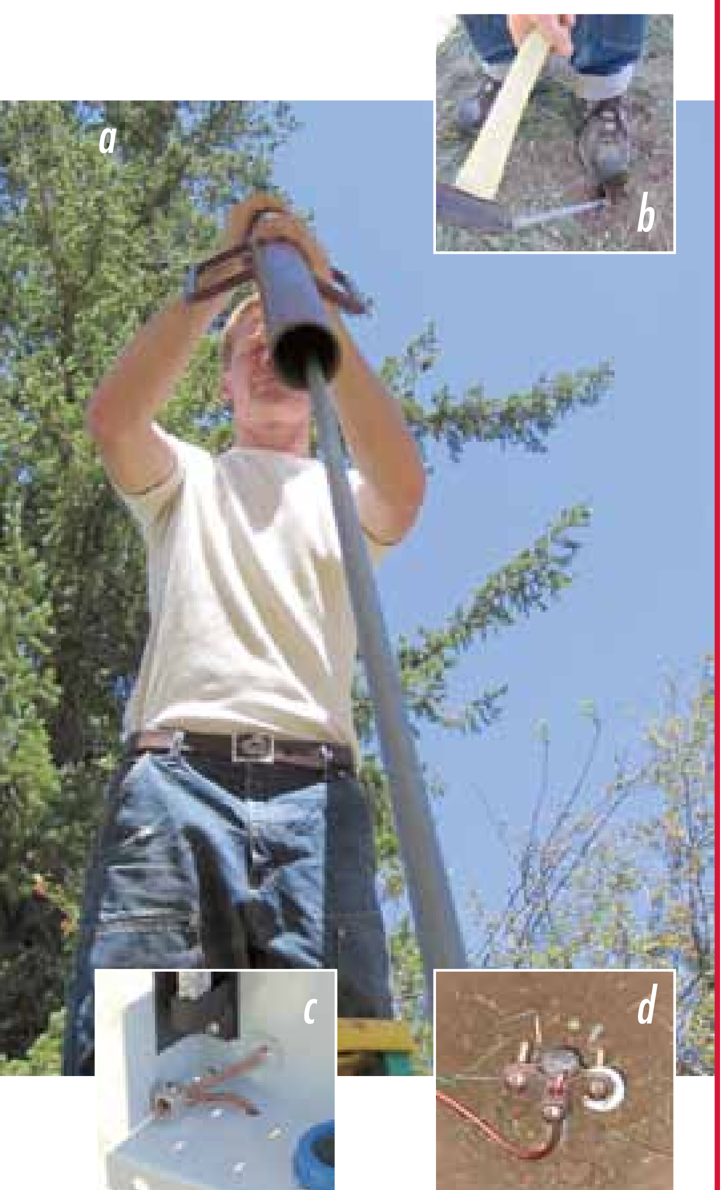
On the array, I always use #6 (13 mm^2) stranded, bare copper wire, which is more flexible than solid. Trying to bend #6 solid wire in the tight radiuses required when grounding module frames is not recommended. In some cases the *NEC* will allow smaller-gauge ground wire to be used, but I opt for #6 since it will better resist any physical damage.

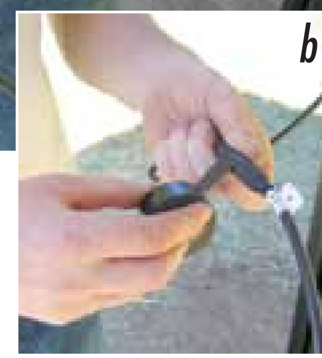


7 Install the Ground Rod & Wire

Next, pound a ground rod into the earth at the base of the pole, outside the edge of the concrete footing. Driving the ground rod at an angle can help you get it in all the way if bedrock is close to the surface.

Once the rod is driven, run #6 bare, solid, copper wire from the combiner box's ground lug, down along the vertical conduit, and then over to the ground rod. Where possible, I like to use a ground rod clamp approved for direct burial, completely bury the ground rod, and trench the ground wire in. This looks better, and won't trip people or animals if they pass by the base of the array.





8 Wire the PVs

When wiring the PVs, remember that they will generate electricity whenever the sun is shining, even in overcast conditions. So pay attention, and make sure you're qualified to get the job done right and safely. Some people even opt to cover the modules with an opaque material when wiring the array.

Almost all modern PV modules come with prewired, multicontact (MC) connectors. These connectors simply plug together, allowing fast installation and a low-resistance, weather-tight connection. MC connectors should be firmly pushed together and given about a quarter turn to make sure the seal is tight. Your system design will determine how many modules will be wired in series, and how many series strings your array will have. (See my article on wiring configurations for a PV array in *HP87*.)

Once the series strings are wired, the next step is to fully secure the wiring. All MC connectors should be either taped with high-quality electrical tape or sealed with heat-shrink tubing. While the connectors themselves are watertight, these methods will further weatherproof them, and provide some strain relief to keep them from being inadvertently disconnected. Finally, no PV wiring should be left hanging, since this looks sloppy and just invites trouble. Use UV-resistant (black) zip ties to secure the module wiring to the module frames or mount structure. Clips that attach to the module frame and hold the wires are available as well.


a


b


c


d

9 Install the Home-Run Wiring

Your array will require an additional MC cable to run from each series string of PVs to the combiner box. Purchase extra lengths of pre-made, MC cable that have a female connector on one end and a male connector on the other. When cut in half, these cables will need to be long enough to reach from the PVs to the combiner box. This wire is referred to as a "home run."

The ends of the home-run wiring destined for the combiner box should be taped off and handled carefully to avoid shock hazard and electrical shorting. To keep polarity straight, positive leads should be taped with red electrical tape and negative leads with white.

While working with this wiring, the safest approach is to leave one of the home-run conductors of each series string open (disconnected) at the PV arrays until the home runs are in place and terminated in the combiner box.

I like to put the home-run wiring running down the pole and into the combiner box in nonmetallic, watertight, flexible conduit for extra physical protection. The PV end of the conduit will not have a fitting on it, so make sure to seal it with silicone caulk to keep water from running down the wiring and into the combiner box.

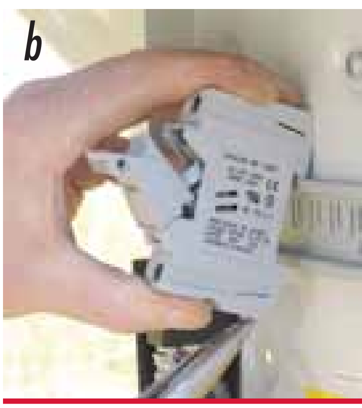
The flexible conduit can be secured to the pole using self-tapping screws with pilot holes, and heavy wall (HW) conduit straps. Finally, because pole mounts allow for seasonal adjustment for the tilt of the array, make sure to cut both the home-run wiring and flexible conduit to a length that will allow full adjustment of the array without placing any strain on the wiring.


e

10 Wire the Array to the Combiner Box

Breakers should be in the off position (or fuses removed) during combiner box wiring. Positive PV array home runs will terminate at series breakers or fuses, and negative ones at the negative bus (combiner) bar. Use a torque wrench to fully tighten all electrical connections inside the combiner box to the manufacturer's specifications.

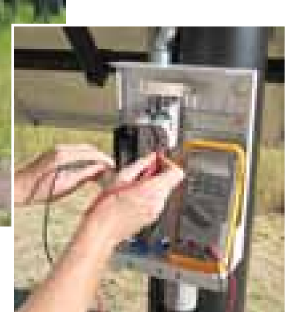
Once all the wiring in the combiner box is completed, double-check that the series breakers are in the off position, and then make the final connection in each series string's home-run wiring at the PV array. This strategy will ensure that you're not working with "hot" (energized) wiring during the installation. Use a digital multimeter to double-check that each series string's polarity is correct. The transmission wiring that runs between the array and the power room will also be terminated in the combiner box once it's pulled.



Done Deal

Once the pole is set and the concrete is cured, assembling and wiring a pole-mounted solar-electric array can be done in a single day, or over a leisurely weekend. One person can easily get the job done, but it's nice to have a second set of hands when assembling the rack and mounting the PVs.

If you want a solar-electric array, and your site is suitable for a pole mount, definitely consider it. Pole mounts are one of the most fun—and most productive—things you can plant in your backyard.



Access

Joe Schwartz, *Home Power*, PO Box 520, Ashland, OR 97520 • 541-512-0228 • joe.schwartz@homepower.com • www.homepower.com

Fixed pole-mount manufacturers:

Direct Power & Water, 4000-B Vassar Dr. NE, Albuquerque, NM 87107 • 800-260-3792 or 505-889-3585 • Fax: 505-889-3548 • info@power-fab.com • www.power-fab.com

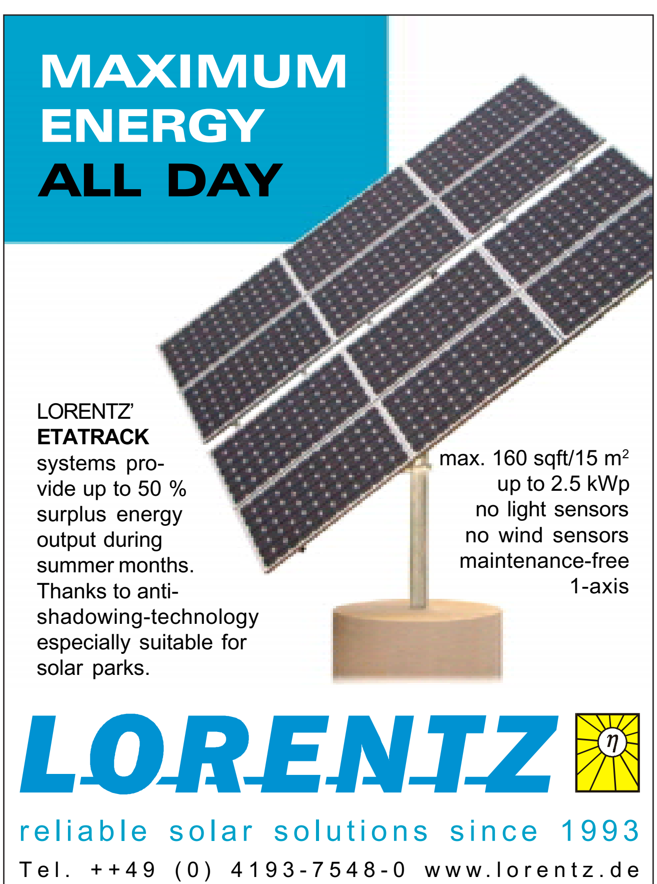
General Specialties, 206 N. 4th Ave., #200, Sandpoint, ID 83864 • 208-265-5244

UniRac Inc., 3201 University Blvd. SE, Ste. 110, Albuquerque, NM 87106 • 505-242-6411 • Fax: 505-242-6412 • contact@unirac.com • www.unirac.com

Zomeworks Corp., 1011 Sawmill Rd. NW, Albuquerque, NM 87104 • 800-279-6342 or 505-242-5354 • Fax: 505-243-5187 • zomework@zomeworks.com • www.zomeworks.com

Combiner box manufacturer:

OutBack Power Systems, 19009 62nd Ave. NE, Arlington, WA 98223 • 360-435-6030 • Fax: 360-435-6019 • sales@outbackpower.com • www.outbackpower.com



The 2008 National Electrical Code Part 2

John Wiles
Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

Proposals for the 2008 *National Electrical Code (NEC)* are due to the National Fire Protection Association (NFPA) in early November 2005. Last issue, half of the current proposals were presented in this column. The remaining proposals and their edited substantiations are outlined below. To see the entire list and keep abreast of any changes, the current proposals may be downloaded from the SWTDI Web site (see Access).

690.33(C) Type (Revised)

Proposal: Add a second sentence to this section as follows: Connectors that are readily accessible in circuits operating at over 50 volts (maximum system voltage for DC circuits or nominal voltage for AC circuits) shall require a tool to open and shall not present a shock hazard when opened under load.

Substantiation: Circuits with operating voltages above 50 volts (either DC maximum system voltages or AC nominal voltages) pose shock hazards when the energized conductors are exposed. Note the grounding requirement established at this voltage limit in 690.41. Connectors are allowed in PV systems (690.33) and they are commonly used in PV source circuits where the voltages typically range from 27 volts to 600 volts.

Most of the currently used connectors are of the latching type and may be opened by just pulling them apart. Although these existing connectors are manufactured as "touch safe," they are not designed to be opened under load. If inadvertently opened under load, the resulting arc (particularly on DC circuits) may disable the "touch-safe" feature by carbonizing the insulation.

Where these connectors are installed in readily accessible locations, they should be of a type that requires a tool to open. The "tool" may be a connector-specific opening device or merely the blade of a screwdriver or other pointed instrument. In some cases, the connector may consist of a latching connector with a locking shell that prevents the connector from being pulled apart. The connector must remain "touch safe" after opening under load and not present a shock hazard.

690.35(C)(3) (Revised)

Proposal: Revise the section as follows:
(3) Automatically disconnects the conductors or causes the inverter or charge controller connected to that portion of the faulted array to automatically cease exporting power.

Substantiation: Aligns the text for these ungrounded systems with the text in 690.5 dealing with grounded PV systems. Establishes that the faulted array may be isolated by disconnecting the conductors (typically done on low-voltage systems—12, 24, and 48 V) or by causing the connected inverter or charge controller to cease exporting power (typically done on higher voltage systems). Either of these methods serves the purpose of ceasing power production and providing an additional indication that something has happened that needs attention.

690.35(D) (New)

Proposal: Add the new exception as follows:
Exception: Conductors listed and identified as photovoltaic (PV) conductors may be installed as exposed, single-conductor cables in PV source circuits as permitted by 690.31(B).

Substantiation: UL has developed a new cable specification/standard for a cable type specifically designed for PV installations where exposed single-conductor cable is used. The cable is intended to meet the safety requirements associated with cables used in ungrounded PV installations permitted by 690.35. See the substantiation for the proposed revision to 690.31 in *HP108*.

690.35(F) Ungrounded Photovoltaic Power Systems (Revised)

Proposal: Revise the section as follows:
(F) The photovoltaic power source shall be labeled with the following warning at each junction box, combiner box, disconnect, and device where energized, uninsulated terminals or connections may be exposed during service:

WARNING: ELECTRIC SHOCK HAZARD. THE DC CONDUCTORS ARE UNGROUNDED BUT MAY BE ENERGIZED WITH RESPECT TO GROUND DUE TO LEAKAGE PATHS AND/OR GROUND FAULTS.

Substantiation: The section is modified to indicate that the label shall be required only where there are exposed, uninsulated, energized terminals. Pull boxes where there are no exposed, energized terminals would not require the label. The wording of the warning is simplified.

690.42 Point of System Grounding Connection (Revised)

Proposal: Add the new exception as follows:
Exception: Systems with a 690.5 ground-fault protection device, either as a separate device or built into the inverter, shall have the required grounding point (bond) made by the ground-fault protection device.

Substantiation: Section 690.5 ground-fault protection devices actually make the grounded conductor-to-ground bond for the entire DC system. It is important that no additional bond (as required by 690.42) be made in a system employing one of these devices. While many PV systems employ such a device, there are still numerous ground-mounted PV systems that do not require them. A proposal (690.5) has been submitted to require a ground-fault protection device on all PV systems.

690.43 Equipment Grounding (Revised)

Proposal: Add a second paragraph to the existing section as follows:

Equipment-grounding conductors for the PV array and structure (where required) shall be contained within the same raceway or cable, or otherwise run with the PV array circuit conductors where conductors leave the vicinity of the PV array.

Substantiation: This proposal is required because Section 250.134(B), Exception 2, allows DC equipment-grounding conductors to be routed separately from the circuit conductors. A proposal has been submitted to remove this exception, but there is no guarantee that it will be accepted.

With the resurgence of DC power systems (renewable energy systems, fuel cells, uninterruptible power systems, and various industrial processes), the routing of DC equipment-grounding conductors needs to be reconsidered. One of the many issues that *IEEE/ANSI Standard 1375, Guide for the Protection of Stationary Battery Systems* points out is the difficulty in getting proper overcurrent device operation as the circuit time constant goes above 10 milliseconds (the time constant limit of testing in UL Standards 198 and 489). Fuses and circuit breakers may not operate properly when inductance in the circuit results in a time constant exceeding 10 milliseconds.

Calculations shown in the IEEE Standard indicate that the normal circuit inductance in many DC systems results in time constants between 5 and 10 milliseconds. It wouldn't take much spacing between the equipment-grounding conductor and the circuit conductors to increase the fault-circuit time constant to greater than 10 milliseconds. If Exception 2 in 250.134(B) is followed, the routing of the equipment-grounding conductor away from the circuit conductors may allow the time constant under ground-fault conditions to exceed 10 milliseconds. These longer time constants, under ground-fault conditions, could prevent the DC overcurrent devices from functioning properly and possibly affect the operation of 690.5-required DC ground-fault protection equipment.

PV module frames are commonly large rectangles of aluminum that are generally grounded by equipment-grounding conductors at one point on the frame. In PV arrays with modules mounted side by side, the UL-designated grounding points on the modules allow one equipment-grounding conductor to be connected to a number of modules, grounding all at one time. The junction boxes on the modules for the DC power leads are some distance (1–3 ft.) away from the grounding points on the same modules. Since the grounded frames are in proximity to the junction boxes, the equipment-grounding conductors are effectively close to the circuit conductors throughout the array field. However, once the circuit conductors leave the vicinity of the PV array, the equipment-grounding conductor(s) should be routed with the circuit conductors to minimize the time constant described above.

690.45 Size of Equipment-Grounding Conductor (Revised)

Proposal: Revise 690.45 as follows:

690.45 Size of Equipment-Grounding Conductor. Equipment-grounding conductors in photovoltaic source and photovoltaic output circuits shall be sized in accordance with Table 250.122. Where no overcurrent protective device is used in the circuit, an assumed overcurrent device rated at 1.25 times the photovoltaic-originated short-circuit currents shall be used in Table 250.122. Increases in equipment-grounding conductor size to address voltage drop considerations shall not be required. The equipment-grounding conductor shall be no smaller than 14 AWG.

Substantiation: This proposal is a result of the proposed new ground-fault protection limits in 690.5 and 690.5(A). The language simplifies and clarifies the requirement. The ground-fault protective devices will interrupt any DC ground-fault currents that are in excess of a maximum value of 5 amps, no matter how large the PV array. This means that the equipment-grounding conductor will never have to carry more than 5 amps of circulating ground-fault currents on a continuous basis. Requiring the size to be based on Table 250.122 (or an assumed overcurrent device rated at 1.25 times the short-circuit current where there are no overcurrent devices in the circuit) will size the equipment-grounding conductors to an acceptable size that will minimize physical/mechanical abuse when being installed along with circuit conductors sized at 1.56 times the short-circuit current. Because even a 20 AWG conductor can carry the maximum 5 amps, there is no increase in size required by 250.122(B) where circuit conductors have been increased in size for voltage drop. Also, there are no overcurrent devices that need a low-impedance equipment-grounding connection for proper operation because the ground-fault device will activate at a significantly lower current level than any overcurrent device in the circuits. Typically, inverters up to about 10 KW are using 0.5 to 1.0 amp ground-fault trigger levels, and higher power inverters will use up to the 5-amp allowed maximum. Off-grid stand-alone systems are commonly using a 1-amp ground-fault protection device trip level.

690.47(D) Additional Grounding Electrodes (New)

Proposal: Add the new section as follows:

690.47(D) Additional Grounding Electrodes. Additional grounding electrodes for equipment grounding shall be installed in accordance with the methods described in 250.54 as modified by (1) and (2).

(1) A grounding electrode shall be installed at the location of ground-mounted PV arrays.

(2) A grounding electrode shall be installed at the location of any PV array that is mounted on a building or structure that is separate from the building or structure holding other power equipment in the system.

Substantiation: PV arrays may be mounted in locations that are some distance from the structure that holds the other power equipment in the system (inverters, batteries, interface equipment, etc.). To maintain the potential of the exposed metal surfaces as close to the potential of the local earth as possible, supplementary grounding electrodes are required at the remote locations where the PV arrays are located. These grounding electrodes do not have to be bonded directly to other grounding electrodes in the system since the equipment-grounding conductors indirectly connect them. The installation provisions of 250.54 are appropriate, but these grounding electrodes are required, not permissive.

690.53 Direct-Current Photovoltaic Power Source (Revised)

Proposal: Revise the section as follows:

690.53 Direct-Current Photovoltaic Power Source. A label for the direct-current power source indicating items (1) through (5) shall be provided by the installer at the PV disconnecting means:

(1) Rated maximum power-point current
(2) Rated maximum power-point voltage
(3) Maximum system voltage
(4) Rated short-circuit current
(5) Maximum rated output current of maximum power-point charge controller (if installed)

Substantiation: The basic paragraph is reworded to indicate that a label is required rather than a marking and to eliminate unnecessary words. The term "rated" is added to items (1), (2), and (4) to clarify exactly what values should be on the label. This term is not required on item (3) because maximum system voltage is defined in 690.7. Item (5) is added to identify the maximum rated output of the maximum power-point charge controller since that device, where installed, may significantly increase the current from the PV array.

690.54 Interactive System Point of Connection (Revised)

Proposal: Revise the section as follows:

690.54 Interactive System Point of Interconnection. All interactive system(s) points of interconnection with other sources shall be marked at an accessible location at the disconnecting means as a power source with the rated AC output current and the nominal operating AC voltage.

Substantiation: Clarifies the required marking to show the rated AC output, which is the current upon which conductors and overcurrent devices are based (690.8, 690.9). The existing text is sometimes interpreted as the maximum operating current for the installed system, which may be considerably less than the rated output current. Some installers were also marking a range of AC voltages. Both changes provide inspectors with better information to use in determining if code requirements have been met.

690.62 Ampacity of Neutral Conductor (New)

Proposal: Add the following second paragraph:

A neutral conductor connection to a single-phase or 3-phase utility-interactive inverter used solely for instrumentation or voltage or phase detection purposes and not for power transmission shall be permitted to be as small as 14 AWG.

Substantiation: Many utility-interactive inverters have a 240 V, 208 V, or 480 V output that requires no connection to a neutral conductor for power transmission. However, due to various IEEE standards and local jurisdiction requirements, a connection to the electrical power system neutral conductor is required to detect a loss of phase and/or to monitor unbalanced line-to-neutral voltages of the inverter. This neutral connection, used only for phase detection or instrumentation, carries no appreciable power and can safely be made very small. A minimum requirement of 14 AWG ensures that this conductor is physically robust enough to be pulled through conduits with the power conductors.

690.64 Point of Connection (Revised)

Proposal: Revise the section as follows:

690.64 Point of Connection. The output of a utility-interactive inverter shall be connected as specified in 690.64(A) or 690.64(B).

Substantiation: Over the evolution of article 690 since 1984, the definition of photovoltaic power source has referred to the DC output of a PV array. All of Part VII in 690 has always referred to the AC output of utility-interactive inverters. The terms "photovoltaic power source" was used incorrectly in this section.

690.64 (A) Supply Side (Revised)

Proposal: Revise the section as follows:

690.64 (A) Supply Side. The output of a utility-interactive inverter shall be permitted to be connected to the supply side of the service disconnecting means as permitted in 230.82(6).

Substantiation: See 690.64.

690.64(B) Load Side (Revised)

Proposal: Revise the first sentence of the section as follows:

690.64(B) Load Side. The output of a utility-interactive inverter shall be permitted to be connected to the load side of the service disconnecting means of the other source(s) at any distribution equipment on the premises, provided that all of the following conditions are met.

Substantiation: See 690.64

Proposal: Revise 690.64(B)(2) as follows:

690.64(B)(2). The sum of the ampere ratings of overcurrent devices in circuits supplying power to a busbar or conductor shall not exceed 110 percent of the rating of the busbar or conductor.

Substantiation: Since Section 690.64 was first placed in the 1984 *NEC*, significant changes have been made to the way overcurrent device ratings and conductor ampacities are used in the code. Load calculations including demand factors and other code requirements generally restrict the operation of overcurrent devices and conductors to continuous operation at 80 percent of rating. Therefore, there is 20 percent or more (depending on demand factors) additional capacity in the busbar of a load center than is currently being used. If 10 percent of the load center rating were allowed for a circuit from a PV inverter, there would still be, under the very unlikely, worst-case conditions of high loads on load circuits, a 10 percent safety factor. In nearly all installations under normal operating conditions, the addition of PV power to a load center will reduce the loading on the busbars and the loading on the main circuit breaker to the load center. Only in the unlikely situation where additional load circuits or increased loads were placed on the panel without complying with code requirements, would there be any possibility of even using the 10 percent extra designed allowance.

Proposal: Revise 690.64(B)(2) as follows by adding the following new second paragraph after the exception:

In dwelling units having no single main overcurrent protection device or service disconnect and having up to six main disconnects as allowed by 230.71(A), the sum of the ampere rating of overcurrent devices from the output of utility-interactive inverters supplying the busbar feeding the main disconnects shall not exceed 20 percent of the rating of that busbar.

Substantiation: In many areas of the country, residential service panels are installed that have no single main circuit breaker or disconnect. Up to six disconnects/circuit breakers are used to feed subpanels in other locations. It is not possible to apply the general rule and the exception of this section because a single breaker does not limit the contribution of current from the utility. Allowing a backfed PV breaker or breakers with ratings totaling 20 percent of the panel rating is consistent with safety requirements and the use of the exception in other dwelling unit installations.

Proposal: Delete the exception for 690.64(B)(3)

Substantiation: Ground-fault protection devices (5 mA GFCI receptacle outlets and circuit breakers, 30 mA equipment protection breakers, and 100–600 amp feeder protection equipment) will generally be damaged if tripped by a ground fault while being backfed. This damage will disable the ground-fault protection mechanism of the device while still allowing normal operation (circuit breaker operation and current flow). The damage may not be visible or obvious. Ground-fault protection equipment should never be backfed under any circumstances.

Proposal: Revise 690.64(B)(5) and add the Fine Print Note (FPN) as follows:

(5) Circuit breakers, if backfed, shall be identified for such operation. Dedicated circuit breakers backfed from listed utility-interactive inverters complying with 690.60 shall not be required to be individually clamped to the panelboard busbars. A front panel shall clamp all circuit breakers to the panelboard busbars. Main circuit breakers connected directly to energized feeders shall be individually clamped.

FPN: Circuit breakers that are not marked "Line" and "Load" are identified as suitable for backfeeding.

Substantiation: UL Standard 489 is the reference for testing and marking molded-case circuit breakers suitable for backfeeding. The limited distribution of the standard and the allowance for backfeeding based on the absence of a marking is resulting in many circuit breakers being used improperly for backfeeding. Conversely, the absence of the marking causes many inspectors to not allow backfed circuit breakers. Also see UL's *Molded Case Circuit Breaker Marking Guide.*

690.74 Battery Interconnections (Revised)

Proposal: Add the following second paragraph to the section:

Flexible, fine-stranded cables shall only be used with terminals, lugs, and connectors that are listed and marked for such use.

Substantiation: UL Standard 486 A and B requires that connectors, lugs, and terminals that are intended for use with flexible, fine-stranded cables be so marked for use with such cables. Very few connectors and terminals have been listed for such use and few are so marked. The vast majority of connectors, lugs, and terminals are unsuitable for use with flexible, fine-stranded cables. However, the limited distribution and wording of the standard has resulted in flexible, fine-stranded cables being used improperly with these nonmarked connectors, lugs, and terminals. Failures in several widely different industries have been reported.

250.134(B) Grounding with Circuit Conductors (Revised)

Proposal: Delete Exception No. 2.

Substantiation: When this exception was added to the code, the drafters correctly realized that pure DC does not have any oscillatory tendencies like AC does that would cause transformer-like heating in metal when the equipment-grounding conductor is separated from the circuit conductors. They likewise realized that there is no frequency-dependent impedance factor associated with DC that might cause higher than desired reactance in the DC circuits that could prevent the operation of overcurrent devices.

A second issue is that DC is not always pure. Any single-phase DC-to-AC power inverter will have a 120 Hz sine wave imposed on the DC that may have an rms value greater than the average DC value. In a similar manner, battery chargers that rectify the AC line to get DC to charge batteries will have 120 Hz ripple currents. Under fault conditions, these DC ripple currents act just like AC currents in that they may cause metal heating if the two (or three) circuit conductors are not routed together. Excess separation leading to increased inductance will also lead to increased impedance in the fault circuit and may not allow overcurrent devices to function properly. The impedance is a function of the frequency, and at 120 Hz, the increased impedance will be higher than at 60 Hz. Also see 690.43.

110.14(A) Terminals (New)

Proposal: Add a third paragraph as follows:

Terminals, lugs, or connectors intended for use with flexible, fine-stranded cables (other than Class B & C stranding) shall be marked and listed for such use.

Substantiation: See 690.74.

250.166 Size of the Direct-Current Grounding Conductor (Revised)

Proposal: Revise 250.166 as follows so that 250.166 (C), (D), and (E) are clearly exceptions to 250.166 (A) and (B) as they were in the 1996 *NEC.*

250.166 Size of the Direct-Current Grounding Conductor. The size of the grounding electrode conductor for a DC system shall be as specified in 250.166 (A) and (B), except as permitted by 250.166 (C) through (E).

Substantiation: As Sections 250.166(C), (D), and (E) are currently written, they are in direct conflict with sections 250.166(A) and (B). Many electricians and inspectors are not able to determine which section takes precedence. For example, many DC systems are not as described in Section 260.166(A), so section 250.166(B) applies. However, a ground rod electrode connection would require Section 250.166(C) to be applied. Sections 250.166 (B) and (C) dictate two different sizes of grounding electrode conductors. This language parallels the language in 250.66 for AC grounding-electrode conductors.

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 to me.

Access

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Inside SB1

California's Solar Program on the Brink

Don Loweburg

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In California, two current incentive programs will expire next year. The Self Generation Incentive Program (SGIP) supports large commercial projects, while the Emerging Renewables Program (ERP) funds residential and smaller commercial projects.

These two programs have made California the third largest market for PV in the world. Germany moved into the top position last year, displacing Japan from first to second place. Though California's ranking is impressive, the state still lags significantly behind both Germany and Japan. To date, California's SGIP and ERP programs have resulted in about 160 megawatts (MW) of PV installed in the state. Last year, Germany installed almost three times this much (400 MW), and Japan installed almost twice this amount (300 MW).

With more sunshine than either of those countries, an 80 percent pro-solar population, and a high demand that has created a logjam of rebate applications at the California Energy Commission and totally exhausted available funding for the SGIP program, California has the potential to be the leading solar market in the world. But to realize that potential, California must continue its support of solar technology. And that support must be long term and predictable, yet flexible enough to adjust to market conditions. SB1 (Senate Bill 1), also referred to as the "Million Solar Roofs Initiative," could provide that support.

Last year, an earlier version of SB1 failed to pass the California State Senate. It contained many provisions of this year's bill; however, a mandated "new homes requirement," which stipulated that 50 percent of all new homes built be outfitted with solar-electric systems, defeated last year's bill. This year, those mandates have been removed and replaced with a requirement that by 2010, housing developers offer the "option" of solar-electric systems to prospective buyers.

The overall goal of SB1 remains to create a strong market for solar electricity, develop the industry in California, and provide valuable peak power to the grid by installing 3,000 MW of distributed PV during the next ten years. Other provisions of this year's SB1 are a ten-year continuation of rebates for small systems and a transition to performance-based incentives (PBI) for larger systems. Rebates are based on a system's size (a one-time payout in dollars per installed KW); PBI rewards a system's performance, offering payouts based on each KWH produced.

SB1 also proposes merging the SGIP and ERP into a single program administered by the California Public Utilities Commission (CPUC). Initially, funding would be split equally between small systems (10 KW and smaller) and large systems (more than 10 KW). Later, actual market needs would determine the future allocation of funding between small and large systems. Finally, SB1 would raise the net metering cap, which limits the total amount of grid-connected PV, from 0.5 percent to 5 percent of utility system total capacity.

With high popular support for solar and a backlog of PV systems to install in California, the success of SB1 would seem to be assured. But things are never that simple. Editorials in several major California newspapers appeared in late June 2005 that signaled behind-the-scenes problems in the California Legislature:

Solar's future is bright, but in the bowels of the Legislature, business remains murky, as usual. There, labor unions are demanding that private contractors pay "prevailing wages" to workers who install solar panels as part of SB1, the governor's legislation to help provide solar energy to 1 million homes.

Sacramento Bee, "Solar Shakedown," June 30, 2005

Homebuilders are skeptical about the prospects for solar: Utilities and manufacturers are objecting to the ratepayer surcharges; labor unions want to be assured a piece of the action.

San Francisco Chronicle, "How to Brighten Solar Power's Future," June 26, 2005

Labor unions also potentially could lead to the bill's defeat in the Assembly. They've already successfully pushed for an amendment to the bill that would allow only contractors with the highest level electrical licenses to install solar systems. Most union electricians work for contractors holding such C-10 licenses, while many existing, nonunion solar installers have C-46 licenses.

Los Angeles Times, "Governor's Solar Plan Is Generating Opposition," June 27, 2005

Other Wrinkles

SB1 began development more than two years ago. At that time, a solar "vision group" composed of stakeholders, including manufacturers and installers in California, started putting together a program to take solar in California to the next level. It was agreed that a key element for success would be that the California solar industry would speak with a single voice. The group envisioned a comprehensive solar program to encourage both solar-electric and solar thermal systems. Unfortunately, the commitment to "speak with a single voice," began to unravel within a few months of the working group's formation.

Some blame last year's initial failure of SB1, in large part, on early tensions and intrigue within the solar vision group. A rift developed between module manufacturers over mandated PV in new home construction. Rather than solve the dispute within the vision group, some manufacturers independently and in concert with a California environmental group, pushed SB1 prematurely, which may have led to SB1's demise in the California Legislature.

During the next year, the vision group continued to disintegrate. Two main issues were evident. First, though the major PV manufacturers agreed to speak with one voice and maintain transparency, it appeared that they were pursuing separate agendas. Secondly, the "comprehensive" solar vision originally agreed upon did not include solar thermal. The collapse of the vision group occurred in January 2005, when PV module manufacturers withdrew their financial support and themselves split into two separate groups.

So now, the union grab for the installation of PV is taking place within the context of a disrupted and fractured solar industry. Clearly, manufacturers need labor, but they are not critically sensitive about who supplies it. If SB1 passes, independent solar contractors and installers who have largely been responsible for bringing PV to the mainstream may be excluded from installing future systems.

A Starting Point

There is so much to like about SB1—long-term financial support for PV; a goal of installing 3,000 MW; flexibility in responding to the market for PV systems; and even provisions for low-income customers. But unless the bill is amended to remove both the prevailing wage and electrical license requirement, SB1 is a lose-lose proposition for independent installers. The primary changes needed in SB1 are:

- Mandates should be avoided
- Legislation cannot disenfranchise existing installers

The California initiative is incredibly important, and could help end the shortage of PV modules in the United States and stabilize the supply. This initiative will create demand for many megawatts of solar. And to meet this new demand, manufacturers will be building new facilities. Combined, they'll be capable of producing more than California's demand. The success of SB1 means a boost—not just for PV in California, but also for the entire United States, by creating jobs and providing a successful program model upon which other states may build.

Access

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Wind vs. Nukes & Fossil Fuels

Michael Welch

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The established energy industry tells us that electrical energy demand is increasing, so new power plants must be built. Further, it claims that coal, gas, and nuclear power technologies are well established, so we should look to them first. To bolster that point, the energy establishment often claims that wind and solar technologies are not ready for utility-scale prime time.

The energy establishment seems to be working together to dismiss renewable energy. But beyond that, the individual energy industries part company. Each is beholden only to its own, and each has influence in our government to help get its way. Each also uses public relations techniques to convince the public that everything is fine in its industry.

Nuclear

The nuclear industry promotes the notion that a resurgence in nuclear power is the only thing that can save the world from climate change brought about by greenhouse gases (mostly carbon dioxide; CO_2) that come from burning fossil fuels. The industry lobbyists and public relations spokespeople state that building new coal- and gas-fired plants is not as good an idea, since it will create still more carbon dioxide.

"Yes, nuclear is the most expensive energy available," claims the nuke industry, "but we are also the cleanest and greenest technology that can meet U.S. electricity demand, which makes it worth the extra cost." The long-term potential for problems from nuclear waste—more than a million years—is something they won't admit. They invariably stick to the industry line that says disposal techniques and other methods for dealing with the waste will keep the environment safe.

What the nuclear proponents don't mention publicly is that even *if* they are right about how clean and safe it is (and they are not), their technology is too expensive to stand on its own two feet. Despite being a mature industry, it still requires tremendous taxpayer subsidies to keep electricity rates low enough so that ratepayers do not revolt. Those subsidies include huge amounts of funding for research and development (R&D) of new reactor technologies and old technology redesigns, funding for siting and other preliminary costs, a legislated guarantee that a nuke plant owner will be responsible for only a tiny portion of potential liabilities from a nuclear disaster (the Price–Anderson Act), and a federal agreement to handle all the high level nuclear waste the privately owned plants generate in their lifetime.

Considering the extensive negatives, it is easy to wonder how the nuclear industry got so powerful in the first place. Simply put, the industry was created as a kind of side-business granted to the nuclear weapons industry, a way to take weapons-based processes and apply them to peaceful means. Like the weapons industry, nuclear power caught hold in some of the largest, most prominent corporations in the United States, and has been hard to pry out of the energy mix ever since.

Coal

The coal industry is nearly as vocal in pushing its technology. They claim that unlike oil, which many believe is already past its peak production, the underground coal in the United States can last for hundreds of years at today's rate of consumption. The coal industry has a deservedly bad reputation because of how destructive mining techniques are, health and safety issues for mine workers, the huge amounts of CO_2 released, the sulfur dioxide released (which is a cause of acid rain), and the amount of particulates released from power plant stacks.

But the industry claims that electricity from its plants costs around one-quarter that of oil and gas, and is even more cost effective when compared to nuclear energy. That very compelling argument gains public acceptance, while environmental concerns take a backseat. The industry has been claiming that coal extraction areas can be restored to their original condition or prepared for other productive uses. They claim that scrubbing smokestack effluents and washing sulfur out of the coal before burning can reduce pollution to acceptable levels. But the industry record on implementing these environmental mitigations is pretty poor. They fight at all levels any efforts to make coal more environmentally compatible.

The coal-burning industry is a mature industry, technology-wise. It has been around long enough that direct subsidies are relatively few. Most coal industry subsidies are hidden—power plant owners are not held responsible for the effects of their pollution. The rest of us pay out of our own pockets for the environmental and health effects of global warming, acid rain, and airborne particulates. Some new coal technologies are receiving direct subsidies. Most notable is gasification, which turns coal into a gas to be burned, a process that leaves more of the sulfur behind before burning, thus decreasing acid rain.

Natural Gas

Natural gas is the newer kid on the block, trying to gain a significant foothold in the electrical production industry. Like the other technologies, the gas industry is working hard on our government and with public relations efforts to get further in the doorway. Yes, natural gas has been distributed to residences and businesses for heating and light use for more than a hundred years, even before electrical distribution. But distribution channels (such as leakproof pipelines) are harder to build to move enough of it over long distances for electricity production—oil and coal have been much easier to move around.

The gas industry has legitimate claims that it has the cleanest burning fuels. Pollutants are few, but greenhouse gases are still a significant problem. The industry does not seem to talk about greenhouse gas issues very much, resting on the fact that other pollutants are minimal.

Subsidies for the electrical production side of this industry are minimal, I think because the technology was considered too difficult to make widespread. Many past gas-fired power plants were of the boiler type, and capable of burning multiple fuels. Fuel oil has been more readily available, easier to distribute, and about the same price per Btu.

Relatively recent advances in gas turbine technologies are making gas power plants some of the most efficient. And with gas' less polluting nature, gas-fired electric plants could take off if the distribution and availability increases. Certainly, the gas industry lobbyists are working hard to have our government legislate and regulate away those issues.

The Alternative: Wind

Wind is the darling of utility-scale renewable energy. But gosh, it could use some more support. It certainly has not had any of the large government support that the powerful fossil fuel and nuclear industries have enjoyed. Yet it has done much with the little it has received. For example, it was U.S. government R&D on blade design that led to large enough machines to make them worthwhile to utilities. Wind's cost per kilowatt-hour produced may be more than hydropower, but it is significantly less than nuclear, and comparable to gas and coal.

Wind energy does not pollute at all. No fuel is burned, so emissions are zero. No global warming, no greenhouse gases, no acid rain, and nothing spewing into the atmosphere. Considering the fact that wind has no hidden subsidies from the external effects of pollution, wind power should look pretty good.

Courtesy Illinois State Geological Survey

© European Wind Energy Assoc./Winter

Yet acceptance of wind power has been very slow, and sometimes appears to be going backwards. It seems these days that every time you hear about wind power, in the same breath you hear about how wind generators harm wildlife and despoil the view. We hear these things not only from the competing industries, but also from environmental and other community activists that you would think would be on the side of renewable energy. We almost never hear about how much coal- and oil-fired plants harm birds and other species from their pollution, and how ugly those monstrous plants are.

Wind & Birds. Bird deaths from utility-scale wind generators are minor. Data to date indicates that in the United States, utility-scale wind turbines kill an average of 2.19 birds per turbine per year. Of course, no bird fatalities would be preferred, but do the numbers seem enough for wind generation to get a bad reputation? We also hear about raptor fatalities, mostly in California. But the number of raptors killed by wind turbines in the United States averages 3.3 birds per hundred turbines per year. For the worst-case scenario—Altamont Pass in California—each turbine averages a single raptor death every 30 years.

Some additional perspective might help. About 2 billion birds die each year from house cats and collisions with plate glass windows, communications towers, vehicles, and other means. The negative aspects of wind, like bird kills, really need to be compared to the negative effects of the other industries, which are far greater, yet receive less attention because they are hard to quantify. A dead bird found a hundred yards from a coal-burning plant would be hard to pin on the emissions from that plant, whereas a dead bird found at the base of a wind generator tower has an easier-to-identify cause.

Viewscapes. In the last year or so, much has been said about the proposed offshore wind farm near Cape Cod, Massachusetts. Wealthy landowners are fighting tooth and nail to keep the wind farm out of view, even though the wind turbines would be miles away. To some degree, the fear of large wind turbines altering views reoccurs any time a wind farm is proposed near a populated area. On San Francisco Bay, environmental green-space activists have so far been successful at keeping wind generators out of view in the East Bay hills.

On the other hand, many folks love the sight of turbines turning in the wind, understanding that even though they may interrupt a pristine view somewhat, no generation method is without some negative effects. While visibility puts wind generators in the forefront in these cases, the overall environmental effects of wind generation are nothing compared to nuclear energy and burning fossil fuels.

Wind Capacity. The point that wind only blows part of the time is an often-used argument against turbines. Wind turbines in the United States generally produce between 25 and 50 percent of their total capacity. Wind is actually quite predictable, and utilities can manage high percentages of wind-generated electricity (up to 40% or more) without a problem. U.S. production is still in the low single digits, so arguments along this line are just blowing hot air.

Fair Comparison

All forms of energy production have some level of environmental impact, but wind energy is relatively innocuous. Once a wind turbine is built, no fuel costs are involved, and no pollution is associated with its generation of electricity.

Wind and other renewable energy sources can and should meet an increasingly large portion of our electrical demand. Wind energy is not increasing at the rate it could because of the lobbying, campaign contributions, and public relations efforts of the established energy industry and their efforts to promote their own industries at the expense of others.

Wind energy needs to be chosen by the public, both in action by demanding it from utilities and by helping to debunk the myths that it doesn't work well, kills wildlife, and doesn't look good. If you compare the available energy sources fairly, utility-scale wind energy will doubtless look the best. This is why it's the fastest growing energy source in the world, and we need to follow that example in our own communities, states, and country.

Access

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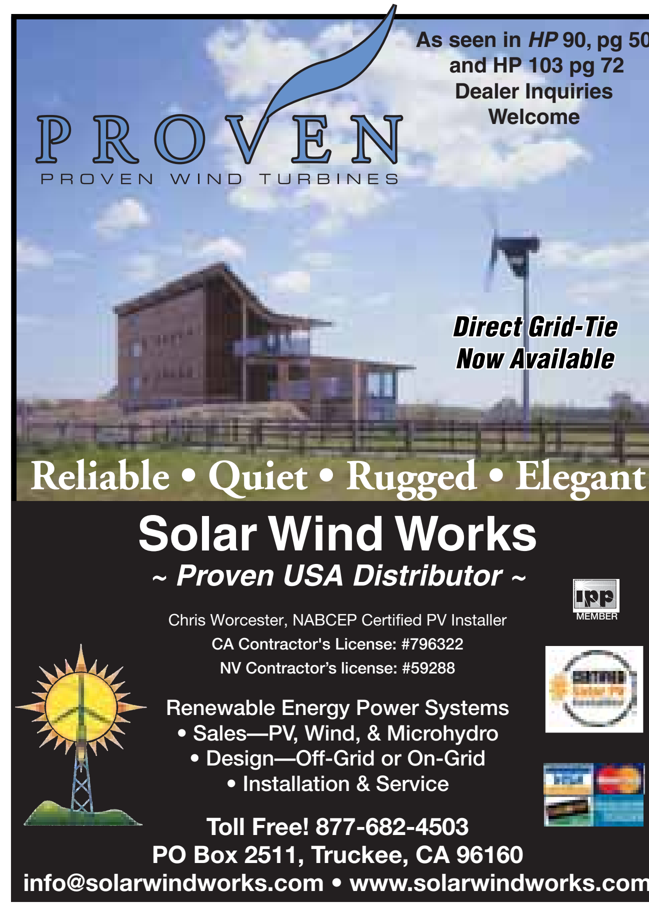
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Cycles Per Second

Ian Woofenden

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Derivation: Named for Heinrich Hertz, a German physicist who verified the existence of electromagnetic waves in 1887.

Alternating current (AC) electricity is cyclical, and ideally takes the form of a sine wave. One "cycle" of AC is a complete waveform—the voltage and amperage start at zero, climb to a maximum (positive peak), drop again to zero, and then dip to a minimum (negative peak) before returning to zero and beginning the next cycle.

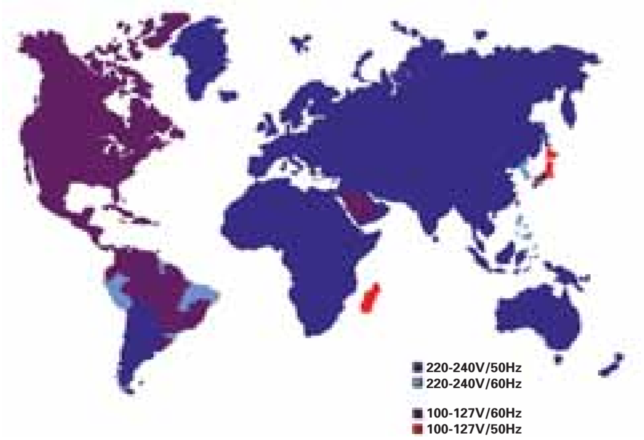
Voltage and amperage change direction many times per second. Frequency is the number of complete cycles per second in any sort of wave motion, such as AC. Until the 1960s, "cycles per second," or cps, was the standard term for AC frequency. Today, frequency is measured in hertz (Hz). So "20 Hz" means "20 cycles per second."

The frequency of household electricity in North America is 60 Hz. This was apparently a compromise between efficiency (early motors were more efficient at low frequencies) and avoiding flicker in lightbulbs (too slow a frequency allows the filament to cool and darken between peaks).

Many parts of the world use 50 Hz (see map). There is some disagreement about why this frequency was settled on. One prevalent view is that it fits into the metric system better than 60 Hz.

One device that generates alternating current is called an alternator. Frequency is determined by the rotational speed of the alternator and number of magnetic poles. Speed is steady in most AC alternator applications, so frequency is relatively constant. Regulators hold the speed (and therefore frequency) constant.

Voltage & Frequency Around the World



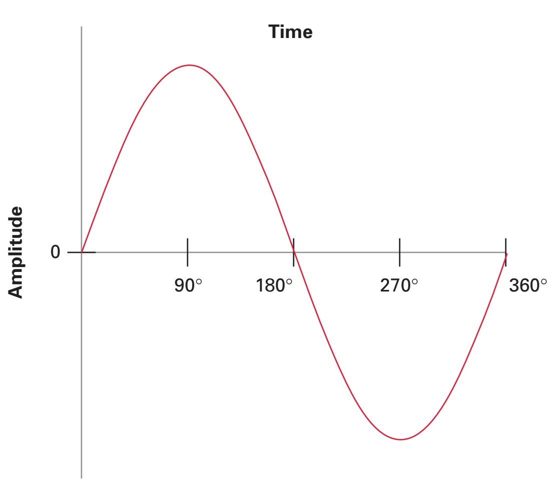
Courtesy of Conrad McGregor http://users.pandora.be/worldstandards/index.htm

In the renewable energy world, there are a few interesting frequency wrinkles. AC hydroelectric systems are regulated so that the frequency and voltage stay within a tight range. If something happens in the system that allows the frequency to wander, an electronic controller can add or subtract loads from the system to alleviate the problem. And as a last-ditch safety feature, a separate controller can drop a deflector in front of the water jet, stopping the turbine until the operator can correct the problem.

Small wind turbines run at variable voltage and frequency, directly dependent on the wind speed. But the variable frequency is not an issue, because rectifiers convert the electricity to direct current to charge batteries or to be inverted to grid-synchronous voltage and frequency.

Electrical frequency isn't something we have to think about in our daily lives, unless we work as electrical engineers. If we buy our appliances in the part of the world where we're going to use them, we're all set. When we travel, we may need transformers and adapters to convert to varying voltages, or appliances that can handle either 50 or 60 Hz.

AC Wave Form



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Enlightened Chick

Kathleen Jarschke-Schultze

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The other day, I found myself in quite a fix, just because we live an energy efficient lifestyle. It all started out down in the Chicken House of Mystery (*HP101*). I had acquired two new hens—Colette, a real show bird, is a Blue Cochin; the other is a white Jersey Giant that I named Jersey Girl.

Well, Colette decided to go broody on me and started sitting on an assorted clutch of eggs. I have strong tendencies towards nurturing, so much that I have a hard time pulling up volunteer plants in the garden. So I could not deny her instincts to set. She had probably never been allowed to hatch eggs before.

Chick Peck & Pack

Colette had six eggs under her in the nest. I braved her pecking beak, and took each egg out to draw a pencil line around the circumference of each egg. Because hens turn the eggs that they set several times a day, a mark on just one side wouldn't work. This way I could quickly identify the original six eggs and remove any others that my other hens might deposit in the nest.

It takes 23 days for chicken eggs to hatch. As the time neared, I started checking Colette and her clutch a couple of times a day. One day, I lifted her up to check the eggs and counted only five. I put her back and checked the floor in front of the nest. There was a dead chick; I was completely bummed. I lifted her again to look at the eggs that were left, when a tiny, fuzzy chick climbed out from below half an eggshell.

Colette started pecking the chick, even while I was holding her in the air. "That's it for you, Missy," I thought. I snatched the chick out of harm's way and tucked it in my shirt. I took the four eggs that were left and came back to the house.

Hot Chick

I needed to get a chick house and incubator together, and fast. First, I would need an incandescent lightbulb for a heat source. I checked the lightbulb drawer. Hmmm, none there—just compact fluorescent (CF) bulbs. I looked in the lamps. Nope, not a one. I checked the winery, the pantry, and the laundry room. Zip. I was getting desperate. As unforeseeable as it seemed, I desperately needed a watt-sucking, inefficient, heat-producing incandescent lightbulb. I was considering the hour's drive to town when I had a vague memory of a box of electronic test equipment in the basement. Bingo! I found a 60-watt bulb.

Chiclet cavorts at the author's desk.

I got a small cardboard box, cut a little doorway in its side, and placed it in a large metal cage. I hung the bulb inside the upside-down cardboard box. A jewelry box drawer, lined with velvet and chicken down, was placed on top of half an egg carton for height. I placed the sensor of an indoor/outdoor thermometer in the drawer/nest.

I put the four unhatched eggs and the chick in the drawer. She immediately fell asleep among the eggs. I covered the floor of the box and cage with paper towels. I found my old chick-watering jar and used half a mint tin for a feed dish. By hanging a cloth dinner napkin like a curtain over the opening of the box (with an inch-and-a-half gap at the bottom) the chick could go inside to be warm or outside to cool off. This was as close an approximation to the mother hen's protective underside as I could manage.

Chiclet

The eggs never hatched. I dutifully turned them several times a day. I kept the humidity up. The temperature was right. After three more days, I gave up. I was so hoping the orphaned chick would have at least one sibling.

I named the orphan Chiclet. I always refer to Chiclet as a she, hoping if I say it enough, it will be true. The egg she hatched from was sage green, laid by one of my Arucanas. She was a very good-looking chick.

I felt sorry for her spending so much time alone in her cage. I put a tiny, stuffed dog toy in her cage. After

One Lightbulb at a Time

According to the Environmental Protection Agency, a total switch to energy-efficient lighting in the United States would keep 202 million tons of carbon dioxide, 1.3 million tons of sulfur dioxide, and 600,000 tons of nitrogen oxides out of the atmosphere. Some experts suggest such a switch would reduce the U.S. yearly energy bill by at least US$30 billion.

If all U.S. households replaced one incandescent bulb with one CF bulb, one nuclear power plant could be shut down. If U.S. homes replaced all of their 500 million incandescent bulbs with CF ones, the United States instantly would have untold energy wealth and surplus—no more shortages or brownouts.

searching, I found a small cloth lizard stuffed with sand. That went into the cage also.

It soon got to the point that when I opened her cage, she would run to me. Several times a day, I would hold her close in my hands and she would fall asleep. She took little chick naps. They would last anywhere from 15 seconds to a full minute. Then she would wake up and peep. I called it the peep-and-sleep mode.

When I gave her a red worm from my worm bed, she ran around the cage with it. Then she started on one end and gobbled it down like a string of spaghetti. Afterwards she stood there and kind of swayed on her little legs, like that was a pretty big dose of protein for such a little bird.

Hip Chick

Chiclet has outgrown her lightbulb and needs no heat at night now. She has the merest vestige of chick fluff left. She talks all the time and warbles like a songbird. During the day, I put her in a chicken tractor (bottomless cage) outside in the front yard. At night she comes back inside to her cage. She still runs to me.

She needs to grow bigger before she can be integrated into my flock. There is a dark underbelly to chicken society that people don't talk about, but consider the probable origins for phrases like "Bantam rooster complex," "hen-pecked," and "pecking order." Chiclet needs to be able to hold her own among the brutish biddies.

Watt-Ever, Chick

So, as it turns out in the end, there is a use for incandescent bulbs—as a heat source, which is what they do best. Just as Chiclet needed to be nurtured and given a chance, so do efficient technologies. Compact fluorescent lighting is the first step for many people.

CF bulbs have improved over the years, and they have become very affordable. The light is a warm color, not like old office fluorescents. If you don't use CFs yet, buy a package. As your incandescent bulbs burn out, replace them with CFs. Better yet, don't wait for your old bulbs to burn out, and replace them all now. The world will be a better place if you do.

Access

Kathleen Jarschke-Schultze is preparing for the grape harvest at her home in northernmost California • c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 • kathleen.jarschke-schultze@homepower.com

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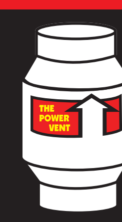
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Credit Where Credit Is Due

After publishing "The People's Power" article in HP108, we learned more about the groups that spearheaded and coordinated the Bayview–Hunter's Point community's solar-electric program. Bayview–Hunters Point Community Advocates, in partnership with the San Francisco Environment, formed Alternative Community Energy (ACE) to make possible the installation of 38 free solar-electric systems in a neighborhood that was suffering the effects of long-term pollution from a PG&E facility.

James Morrison was hired as the coordinator of the project. In conjunction with Solar Energy International, community members were trained in solar-electric system siting, design, and installation, with the goal of bringing new jobs into the community. Occidental Power of San Francisco, California, was also involved in this training, and installed eleven residential and two commercial systems for the Bayview project. Joseph Snell, who took part in both ACE's training and many of the project's installations, now works for Occidental Power. The Bayview–Hunter's Point project is a great example of people coming together and making solar energy happen. The HP *Crew*

Change in *Home Power*

Over the years, I have noticed a subtle change to the content of *Home Power* that I like. The most recent issue (*HP107*) is a prime example. Wow—solar hot water, biodiesel, cordwood construction, harvesting rainwater, RV solar electricity, and solar cookers all in one issue! And that was only some of the topics included. It seems to me that the venerable old title *"Home Power"* may be a bit narrow considering the diversity of the technologies now presented. A new title would have to reflect the focus on self-reliant, independent, efficient, and enviro-friendly application of technology and political influence to improve one's lifestyle. Russ Barlow, Wexford, Pennsylvania • sbarlow@nauticom.net

Energy Efficient Computing

The question from reader Thomas Bluefeather in *HP107* about how to obtain a more energy efficient computer was timely. Since most desktop computer power supplies are only about 60 to 70 percent efficient, about a third of all the energy computers consume is wasted in the AC–DC conversion process. Add to that the low power factor and high total harmonic distortion levels typically found in computer power supplies, and it's no wonder that *Home Power's* readers are looking for a better option for their capacity-constrained PV panels, inverters, and batteries.

To respond to these problems, various electric utilities in the Northwest, California, and Northeast have recently begun funding a program operated by Ecos Consulting called 80 Plus (www.80plus.org), which pays incentives to manufacturers to install highly energy efficient, power factor-corrected power supplies in desktop computers and servers. The incentives are US$5 to $10 per unit—about the same as the incremental cost to manufacturers of better power supplies—yielding lifetime savings of US$25 to $100 per unit on energy bills. Four different power supply manufacturers have now submitted a total of seven different qualifying models, which were to begin appearing in computers available from value-added resellers last summer. One of the manufacturers—Seasonic—recently announced its intent to qualify every power supply model it sells by the end of the year under 80 Plus.

At the same time, Energy Star is in the midst of revising its labeling specification for energy efficient PCs. For the first time, the Environmental Protection Agency (EPA) plans to specify minimum power supply efficiency and maximum allowable power consumption in idle mode. The draft specification and background info are posted at www.energystar.gov/index.cfm?c=revisions.computer_spec.

Manufacturers are beginning to make a number of design changes to achieve lower power levels in desktop PCs. The most important ones are to use mobile processors, and more efficient power supplies and video cards, though many other innovations in cooling technology, memory, storage, and software can play a role. We plan to test a desktop system shortly that claims to idle at only about 30 watts, which would be a huge savings compared to other systems that idle at 100 or even 150 watts. What this means, in brief, is that *Home Power's* readers have choices for efficient computing that go well beyond laptops.

There is also a new Energy Star specification for external power supplies. Rather than relying on comparisons of nameplate values for input power and output power on power supplies, this new labeling program (and a similar mandatory standard in California) requires that manufacturers test their power supplies at 25, 50, 75, and 100 percent of rated current output, and average the measured efficiencies to determine if they comply.

The EPA's new spec for computer monitors takes effect in January 2006, and drops power about 40 to 50 percent from the levels currently used for Energy Star labeling. The most efficient LCD screens now need only 15 to 25 watts for 15- to 19-inch screen sizes and 1280 x 1024 resolution. The myth is that simply choosing an LCD monitor assures high efficiency. But some LCD monitors use twice as much energy as others of similar size and resolution.

As computers become more and more central to household entertainment, work, control, and security, the need for efficient computing grows too. I'd encourage *Home Power* to publish a follow-up story on the subject. Chris Calwell, Ecos Consulting • calwell@ecosconsulting.com

Feel the Waste

In response to Thomas Bluefeather's letter in *HP107*, I suggest a simple way to identify wasteful external power supplies, including "wall cube" transformers used for small appliances and chargers for portable computers: *Feel the heat!* Most wasted energy manifests as heat. Any electrical device that runs cool is demonstrating good efficiency (unless it's an electric heater). I use Apple laptop computers and don't own any desktop machines. Their chargers get very warm when charging a low battery, slightly warm when running the computer with full battery, and very slightly warm when the computer is charged and idle (and cold when unplugged, of course). This is an indication of reasonably good efficiency.

Manufacturers' power rating of computers (and chargers) are of limited value because real power draw varies greatly with different activities, screen brightness, etc. The ratings are always the maximum that you can expect under extreme conditions. Often, the average use is less than half of that. If you want to get real data, use a watt meter, like the Kill A Watt meter reviewed in *HP90* or the Watts Up? Pro meter reviewed in *HP95.* However, if you are shopping around, it's easiest to first use your own sense of touch to narrow down your search.

When feasible, I use a mobile charger that plugs into 12 VDC. This eliminates a step in the power conversion and uses even less energy. DC chargers are available from specialty suppliers that you can find on the Internet. Any time you can avoid a step in conversion, you will save energy. Converting from DC in a remote power system, to AC (in the inverter), and back to DC for your computer will always consume at least twice the energy of using DC directly.

If you use your computer a lot and want your solar-electric system to remain 100 percent independent, it is probably most economical to pay the premium for a laptop machine and reap the benefit in energy savings. However, if you prefer a desktop machine, go to the store and *feel* the heat in the newest computers. Look for the most compact models with LCD screens. They use much of the same technology as laptops. Windy Dankoff • windydankoff@mac.com

Looking for Ideas

I am a new reader and soon-to-be subscriber to your magazine. I am looking for some ideas on saving energy and making some of my own electricity as well. I have already insulated my home and switched to compact fluorescent lights where possible, and I have installed a tankless water heater and efficient furnace.

I live in a suburb of Detroit, Michigan. I have looked at wind maps and we are not rated very well for wind power. We do get a good amount of wind in the winter, but the spring and summer are pretty calm. As far as solar energy goes, the summers are sunny, but a good part of the rest of the year we have heavy overcast.

I live in a neighborhood, so I don't have a lot of room for a tower or large wind generator. The back of my house faces south, so I have a good area for a solar-electric array. I am looking for a small solar array on a tracking mount (possibly roof mounted) and a small windmill that can be roof mounted or mounted on a pole against the house just above the second story with a grid-tie inverter. Please let me know what you can recommend for my situation. And let me know who to talk to about state or federal tax credits or low-cost loans. Thank you, John Lemon • jdlhp@netzero.com

Hi John, If you don't have room for a tall tower, forget about wind energy. It's not worth doing if you can't get up where the wind is strong and smooth. Mounting a wind generator on a roof or building is a big mistake.

If you've done all the efficiency work you can do, the next logical step would be a solar hot water system, and then a solar-electric system. See recent issues for excellent introductory articles on both of these topics. See www.dsireusa.org for information on incentives. Best, Ian Woofenden • ian.woofenden@homepower.com

Rainwater Success

Great article on rainwater harvesting in *HP107!* We installed our rainwater system in 1999 and wouldn't live without it. In normal years, we shut off the city water and live on rainwater all winter long. Thanks, Bob & Sherrill Hawley, Mt. Angel, Oregon • hawleyb@mtangel.net

Solar Cooking Bonuses

I liked the article about using solar ovens, "Cooking Under the Sun," in *HP107* by Rose Woofenden. We live in a grid-tied solar-electric home, use a solar oven daily and many other forms of renewable energy. The only part of the article that bothered me was the general reference of slow cooking only. I cook breads, muffins, and cookies in the same amount of time as with a conventional oven. We do live in Arizona, which has some of the best sunshine available, but many other states and countries also have lots of good sunshine. Many areas have solar cooking get-togethers with homemade ovens. The Kerr-Cole team has made inexpensive ovens and sold them at cost to help developing countries. The amount of heat not transferred into the home is also a big advantage of solar cooking! Jim & Elaine Stack • solarstacks@gmail.com

Diode Dynamics

I enjoyed Mark Byington's article about bypass diodes. Very little has been written about these. I'd like to raise a small warning flag, though. Here in Thailand, bypass diodes have been a *huge* problem for community PV battery charging stations. Here's what happens. A community battery charging station is a place where folks in villages bring in their 12-volt battery and hook up clip leads to the modules (typically three modules in parallel per battery, no controller, no blocking diode). Naturally, from time to time, folks get the polarity of the battery reversed. With a reverse polarity battery, the bypass diodes become forward-biased, attempting to conduct the full short-circuit current of the battery. Usually this just blows up the diode. But when the battery is pretty dead, it sources just enough current to start a fire in the junction box. I estimate that more than a thousand PV modules have been destroyed this way here in Thailand. For an article I wrote on the problems with bypass diodes in Thailand, see: www.palangthai.org/docs/BipassDiodes.pdf

I agree with Mark that for high-voltage series strings like the ones in his system, bypass diodes play an essential role. But for 12-volt systems, bypass diodes won't do you any good, because bypassing an 18-cell string renders the module producing about 9 volts—too little to charge a 12-volt battery. If (a) there's any chance of reversing battery polarity; (b) your controller doesn't protect against reverse polarity; and (c) you don't have a blocking diode, the bypass diode can cause substantial damage to your module. If the bypass diodes are removed, the module would actually be immune to reverse polarity because the PV cells themselves are reverse-biased to a reverse-polarity battery. For some 12-volt systems, removing these may be the best choice. Chris Greacen • chris@palangthai.org

A burned diode in the junction box of a PV module, after the module was incorrectly connected to a battery.

Hi Chris, Thanks for your great letter, and your most excellent work for renewable energy in Thailand. For folks who don't already know it, a blocking *diode (see Chris' option c) is put in series between the solar-electric panels and the system's battery to prevent reverse current while still allowing charging. Think of them as a one-way or "check" valve in a circuit. PV systems without modern charge controllers need them to prevent battery drain through the PVs when the sun goes down. In the case of the battery charging stations, a blocking diode would prevent the reverse current that Chris mentions can blow up bypass diodes. Using blocking diodes does not come without a penalty, though, because they do add some voltage loss when there's current between the source and the battery. Michael Welch • michael.welch@homepower.com*

Load Analysis Education

Hi Ben, I am developing an online course about renewable energy for Wisconsin educators to take for one credit of continuing education. One of the assignments I'm having them do is a load analysis. I'm reading the article you wrote in the *HP58* titled "Doing a Load Analysis: The First Step in System Design," and I have a few questions for you. First of all, the article is wonderful and I'm learning a lot about renewable systems (I have a lot to learn)! I'd like to put the load profile form online for the "students" to download and use, and wondered if that would be OK. I found an Excel spreadsheet on *HP's* Web site called EnergyMaster and was wondering if this is the correct form? Do I just delete the appliances and other information that is already on it? If you don't want me to use that form, I can just give them the Acrobat PDF file and have them print it and write their information in. Either way, I'll probably have them make a copy and send one copy back to me for credit.

In the article, you were talking about refrigeration and said that a Sun Frost fridge may cost US$2,500 but uses only about 540 watt-hours each day, while a typical major, nonefficient brand costs a lot less to purchase but will use 1,500 watt-hours each day. Then you went on to explain the electricity cost for an RE system (US$0.65 KWH). Why is the electricity so much more for an RE system? On my utility bill, I'm only paying US$0.09262 per KWH. The answer to this question will probably explain how you came up with the numbers for how much those systems will cost for 10 years. I can't figure out how you got those numbers.

Anyway, I'll look forward to hearing from you. Thanks so much! Sara K. Windjue • ssaksews@uwsp.edu

Hi Sara, Sounds like a great project. Be sure to use the resources (and great people) at the Midwest Renewable Energy Association. They are some of the best renewable energy educators in the country, and are right in your neighborhood.

The file you want is www.homepower.com/magazine/downloads_past_articles.cfm; click on "Load Calc. Spreadsheet." Also, be aware that Scott Russell has written an updated version of the load analysis article. It is also available at the link above. Scott's article may clear up some of the confusion that you have. At the time that I wrote my article, the mainstream appliance manufacturers were not building efficient fridges. A Sun Frost was the only reasonable solution for off-grid homes. That has mostly changed; now Energy Star fridges from major manufacturers are available that have energy consumptions within the range of reasonable renewable energy systems—and they have all the features of a modern fridge as well.

The difference between the costs of utility grid electricity and renewable energy is a direct result of the cost of the RE components divided by their expected life span. Ben Root • ben.root@homepower.com

Finding Hydro Sites

Do you have any tips on how to find microhydro real estate for sale? Within the next year I'll be buying a home somewhere in the Pocono Region (central eastern) of Pennsylvania. I'd like the property to be a good site for microhydro. I've read your mag and Web site, so I more or less know what the site needs.

I'm having trouble finding properties with good microhydro potential. Real estate advertising doesn't seem geared toward people looking to hydropower their homes. I'm sure the properties are out there—I just can't find them. Do you have any tips for me? Kevin Carpenter • mail4kcc@yahoo.com

Hi Kevin, Real estate descriptions often mention if a stream is on the property, and that would be a way to begin. Real estate professionals will not likely recognize the hydro potential of a stream, but should be able help clients search for properties with streams. That's the first requirement.

Knowing the topography of the area is a big help, and a clue to the prospective buyer as to the possibility of a hydro site at any parcel of land presented by the seller. Very flat lands can offer streams that have hydro potential, but it is not common, and they are difficult to develop, since a low-head site requires handling large amounts of water. So the Poconos are a good place to look.

Those of us who have considered buying property have a long list of items we check on. Besides access and view, sunshine and water, we need to know if we can build and live on the property, what permits are required, as well as the variety of financial questions we must check off. Someone looking for a hydro site merely adds to that list, by making sure they have measured head and flow, researched the variations in flow, and checked into permitting requirements. Any hydroelectric supplier will accept head and flow numbers, and offer equipment cost estimates as well as calculate expected power. Best of luck on the search. Regards, Dan New, Canyon Hydro • citurbine@aol.com

Hello Kevin, I purchased a new piece of off-grid property three years ago, and hydro potential was the first thing on my list. When I was looking for property, I checked if they had creeks on them. Real estate agents almost always point out when they do, since it's a selling point.

Then I picked up a USGS topographic map for the property (www.terraserver.microsoft.com is also an excellent site for both topographic maps and aerial photos). From the topo map, I got a rough estimate for the amount of vertical drop along the creek's course across the property, and an estimate for how long the pipeline would need to be.

Using this approach, I was able to get a feel for a site's hydro potential without visiting it and actually measuring the creek's drop. Next you need to visit the site, and measure the stream flow (something you can't get from maps). Remember that flow will vary season to season.

My creek doesn't flow year-round, but the seven to eight months that it does are when the solar resource is less (fall, winter, and spring). Now I just need to make some time to get the hydro pipeline and transmission wiring installed…Let me know if you have any additional questions. Best, Joe Schwartz • joe.schwartz@homepower.com

Low Pressure Water System

I hope I can help George Blakey with his "Water Pumping Dilemma" in *HP107*—not only for his sake, but for others who want to use a solar pump, but do not have enough elevation gain on their property (about 100 ft.) to get "normal" pressure from gravity.

I lived for twenty years in a location where I had the advantage of a spring for my water supply. All was well, until I built an addition in which the showerhead ended up being higher than the spring. I was fortunate enough to have a second spring, which was about 5 feet higher than the first. I ran a couple of hundred feet of 1-inch PVC pipe to the new spring, and voila—gravity flow to the shower head.

The actual pressure at the showerhead was only 3 psi. Since I knew, when I originally built the house, that the pressure from my gravity-powered water supply was going to be minimal, I used oversized pipes throughout the house—1-inch main and 3/4-inch feeders. I found that you do not necessarily need 40 or 50 psi (which require 92 and 116 feet of elevation, respectively) in a gravity system.

A couple of caveats: If you are using an extremely low-pressure system such as this, it helps a lot to remove the strainers from sink faucets. And it is highly advisable to shop around for a shower control that has the largest orifices possible. Since they are designed for at least 40 psi, most modern shower controls have tiny orifices, which would likely make your showering experience less than perfect, to say the least.

Another idea is to use large supply lines for your toilet and sinks. Here, I'm speaking of the pipes that come from your stop valves to your faucets—those tubes made of copper tubing, or modern flex tubing of plastic or stainless steel. The way to minimize friction losses is to use 1/2-inch flexible copper pipe, or at least the larger of the two standard-sized copper supply pipes. The flexible plastic or stainless steel tubing that I am familiar with has tiny orifices at the fitting ends.

OK, now for some "thinking out of the pressure tank." If George or someone in his situation places a tank, or a series of tanks, up at the peak of his roof, he'll likely have enough water pressure inside the house. It is very common in several areas I have visited in Mexico to see rooftop tanks. The owners there typically wait until the water runs out to go turn a valve to refill them. Usually, there is only one tank, which looks like a concrete wine barrel set on its side at the peak of the roof.

For George, though, he'd want several small tanks interconnected with pipes, and either an overflow or a float valve to shut off the water when the tanks are full. The float valve I'm referring to is readily available at plumbing stores; it looks and functions like an oversized old-fashioned toilet valve, and costs ten or fifteen bucks last time I checked.

I personally have a 2,500-gallon storage tank, located at an elevation 75 feet higher than my house, so I get about 32 psi from the gravity. Do not try putting a 2,500-gallon tank on your roof, George! That much water weighs about ten tons. Most roofs will handle small tanks spread out along the ridge with no problem. Don't take my word for it, though; check with someone who can examine your specific situation.

One more nice thing about this type of system is that pump companies often have old pressure tanks that leak under high pressure, but work fine for storage tanks. If the leak is big enough to even locate, just turn the tank so the leak is on top. I've had some of these old pressure tanks last fifteen or twenty years. In these parts, the companies have to pay to dispose of them at the "sanitary" landfill, so they are happy to give them to you for free.

One final benefit to this is that it requires a heck of a lot less powerful pump, and fewer PV panels to pump your water to a rooftop tank than to a tank a hundred feet higher. In other words, you can save a bundle of money! Malcolm Drake • jumpoffjoe@roguelinkdsl.com

Thanks, Malcolm. Good letter. I sometimes wonder why folks need such high water pressure in a home. I guess they might need to put out a fire, or use a water nozzle to move dirt or leaves out *of a driveway. Or maybe their demand water heater requires more pressure on the input. But for most domestic water usage, such high pressures are not needed and make for a waste of energy and, often, water.*

My storage tank sits in a cradle between two conifer trees above my house. I'm not exactly sure, but I think it must be about 40 feet above my showerhead. I feel like I have more pressure than I need everywhere except *the showerhead; yet I can live with what it puts out, and have for 15 years.*

I stuck with the low-flow showerhead for my low-pressure system, because it gives a spray with acceptable velocity. Using a showerhead with larger holes made the water come outward just a little bit before losing momentum and dropping straight down.

I have gotten used to this, and think that everyone can. It might take a little longer, but rinsing my long, thick locks seems to work just fine. I wonder if we really need the high pressure we've gotten used to in modern America. Michael Welch • michael.welch@homepower.com

I agree, Michael. If you have 40 feet of head, you have about 17 psi at your showerhead. Our solar shower has about 4 feet of head from the showerhead to the bottom of the tank, so only 1.7 psi, and I use it every day for about eight months of the year—works for me, though I don't have much hair... Ian Woofenden • ian.woofenden@homepower.com

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CANADA

Oct. 1–2, '05. Toronto, ON. Green Energy Fair. Workshops, tours, demonstrations, vendors, kids' activities & guest speakers on energy efficiency & sustainable technologies. Info: Kortright Centre • 416-661-6600 • info@trca.on.ca • www.kortright.org

British Columbia. BC Sustainable Energy Assoc. meetings at chapters throughout province • www.bcsea.org/chapters

Calgary, AB. Alberta Sustainable Home/Office. Open last Sat. of every month, 1–4 PM, private tours available. Cold climate, conservation, RE, efficiency, etc. • 403-239-1882 • jdo@ecobuildings.net • www.ecobuildings.net

CHINA

Mar. 16–18, '06. Shanghai. New Energy 2006. International exhibition & conference on providing national impetus for China's RE goals. Coastal International Exhibition Co., Rm. 2106, China Resources Bldg., 26 Harbour Rd., Wanchai, Hong Kong • 852-2827-6766 • general@coastal.com.hk • www.coastal.com.hk

COSTA RICA

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ITALY

Nov. 14–16, '05. Rome. Green Power Mediterranean. Policy & networking. Green Power Conferences • info@greenpowerconferences.com • www.greenpowerconferences.com

Nov. 23–25, '05. Milan. PV Tech Expo 2005. Conf. for PV manufacturing industry. Info: www.pvtech.it

JAMAICA

Dec. 28, '05–Jan. 3, '06. Camp-Us—RE camp for teens. Discover relationships between energy, nature, spirit, technology & social diversity. Hands-on activities, lectures & recreation. Info: hareef99@yahoo.com • www.youthcamp-us.org

MEXICO

Dec. 5–9, '05. Isla Holbox. Understanding PV workshop. Design & installation of PV: stand-alone, grid-tie, water pumping & more. Ecovillage Training Center • 970-527-4680 • ecovillage@thefarm.org • www.thefarm.org

NEPAL

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NICARAGUA

Oct. 17–23, '05. Sabana Grande. RE for the Developing World workshop. Install a PV lighting system & help a women's cooperative build & use solar ovens. Info: see SEI in Colorado listings.

Jan. 2–13, '06. Managua. Solar Cultural Course. Lectures, field experience & ecotourism. Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

UNITED KINGDOM

Dec. 2–4, '05. Winslow, Bucks. Self-build solar domestic hot water course, w/ or w/o all system components. Low-Impact Living Initiative, Redfield Community, Buckingham Rd., Winslow, Bucks, UK MK18 3LZ • 01-296-714-184 • www.lowimpact.org

U.S.A.

Oct. 1, '05. Everywhere, U.S.A. National Tour of Solar Homes. Info: Local chapters of the American Solar Energy Society • www.ases.org/about_ases/chapters.htm

Info about U.S. wind industry, membership, small turbine use & more. American Wind Energy Assoc. • www.awea.org

Info on state & federal incentives for RE. North Carolina Solar Center • 919-515-5666 • www.dsireusa.org

Ask an Energy Expert. Online or phone questions to specialists. Energy Efficiency & RE Info Center • 800-363-3732 • www.eere.energy.gov/informationcenter

Stand-Alone PV Systems Web site. Design practices, PV safety, technical briefs, battery & inverter testing. Sandia Labs • www.sandia.gov/pv

ARIZONA

Scottsdale, AZ. Living with the Sun energy lectures, 3rd Thurs. each month, 7 PM, City of Scottsdale Urban Design Studio • 602-952-8192 • www.azsolarcenter.org

CALIFORNIA

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

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IOWA

Iowa RE Assoc. meets 2nd Sat. every month at 9 AM. Call for schedule changes. I-Renew • 319-341-4372 • irenew@irenew.org • www.irenew.org

MASSACHUSETTS

Mar. 7–9, '06. Boston, MA. Building Energy 2006 & Trade Show. Speakers, workshops & exhibitors. Northeast Sustainable Energy Assoc. • www.nesea.org

MICHIGAN

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

MONTANA

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

NEW MEXICO

Oct.–Nov. & Feb.–Mar. each year. Deming, NM. Intro to Homemade Electricity. Meets 5 Thurs. eves. Mimbres Valley Learning Center • 505-546-6556 ext. 103 • www.mvlc.us/dabccmain.htm

Six NMSEA regional chapters meet monthly & have speakers. NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NEW YORK

Oct. 27–28, '05. New York, NY. Green Power North America, Green Power Conferences • info@greenpowerconferences.com • www.greenpowerconferences.com

NORTH CAROLINA

Pittsboro, NC. RE, biofuels, green building & others. Piedmont Biofuels Coop • 919-542-6495 ext. 223 • www.cccc.edu or www.biofuels.coop

Saxapahaw, NC. How to Get Your Solar-Powered Home. Solar Village Institute • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OREGON

Oct. 23, '05. Portland, OR. Biofuels Car Show & Conf. Speakers, exhibitors, car show & solar-powered music. Info: 503-784-5275 • kathypeper@comcast.net • www.energyelement.com

Nov. 10–12, '05. Eugene, OR. Solar & Radiant Heating Systems workshop. Learn design & installation. Info: see SEI in Colorado listings.

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

PENNSYLVANIA

Oct. 14–15, '05. Spring Grove, PA. Passive Solar Greenhouse Workshop. Design, construction & year-round production. Steve & Carol Moore • 717-225-2489 • sandcmoore@juno.com

Philadelphia, PA. Penn. Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@erols.com

TEXAS

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

Houston, TX. Houston RE Group meetings. HREG • hreg04@txses.org • www.txses.org/hreg

WASHINGTON DC

Oct. 6–9, '05. Solar Power 2005. Business-to-business solar conf. Solar Electric Power Assoc. • 202-857-0898 • htaylor@solarelectripower.org • www.solarpower2005.com

Oct. 7–16, '05. Solar Decathlon. College teams compete, assembling energy-efficient, solar-powered houses. Consumer workshops & educational exhibits. U.S. Dept. of Energy • solar_decathlon@nrel.gov • www.solardecathlon.org

Oct. 13–15, '05. Solar & Radiant Heating Systems workshop. Learn design & installation. Info: see SEI in Colorado listings.

Oct. 17–18, '05. RE in America: Policies for Phase II. Caucuses with U.S. legislators. American Council on RE (ACORE),1825 I St. NW, Ste. 400, Washington, DC 20006 • 202-429-2037 • weirich@acore.org • www.acore.org

WASHINGTON STATE

Oct. 8, '05. Guemes Island, WA. Intro to RE. Solar, wind & microhydro for homeowners. Info: see SEI in Colorado listings • Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Oct. 10–15, '05. Guemes Island, WA. PV Design & Install workshop. System design, components, site analysis, system sizing & hands-on installation. Info: see above.

Oct. 17–21, '05. Guemes Island, WA. Microhydro Power workshop. Design, system sizing, site analysis, safety issues, hardware specs & hands-on installation. Info: see above.

Oct. 24–29, '05. Guemes Island, WA. Wind Power workshop. Design, system sizing, site analysis, safety issues, hardware specs & hands-on installation. Info: see above.

WISCONSIN

Custer, WI. MREA '05 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


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questions & answers

Battery Strings

Our loads are bigger than they were in 1996—would it be advantageous to expand our battery bank, since we are replacing our twelve L16s? We are considering adding four more L16s. The batteries are set up in 24 V strings. Array #1 is twelve SP75 PV panels. Array #2 is two SP75s with expansion room. We have a Trace SW4024 inverter, an Ananda power center, and a Kohler 6.3 KW propane genset. Your thoughts and ideas are appreciated. Thanks, Scott & Geri Vasak, Butte Falls, Oregon • svasak@ccountry.net

Hello Scott and Geri, Sounds like you've been taking good care of your batteries (way to go!) and got pretty good life out of your current battery bank. Twelve L16s is a common-sized battery bank for a system of your size. I can't recommend expanding it without more information. Questions you need to ask yourself are: How deeply am I discharging the bank on a daily basis? And how often is the bank getting fully recharged? The less deeply you routinely discharge your battery bank, the longer it will last. I like to design systems so the average daily depth of discharge is less than 20 percent (80 percent of the capacity remaining). Your amp-hour meter will be able to provide you with this information.

Second, off-grid battery banks should be fully recharged every day, with the exception of cloudy periods. One common mistake is to install a battery bank that is oversized compared to the charging source. In many cases, this leads to regular undercharging, sulfation of the battery plates, and early failure. In your case, it all comes down to how many loads you have on the system each day, and how well your charging sources keep up with these loads. What increasing the size of the battery bank would buy you is less frequent use of the engine generator during cloudy periods—always a plus!

I usually advise people not to install battery banks that have more than three series strings in parallel. Two is even better. Each additional series string means an additional current path, and a higher probability of unequal charge and discharge rates between the strings. This situation will leave some strings chronically overcharged, and others undercharged, and lead to early failure of the bank in many cases. The solution for larger battery banks is to use larger, 2-volt cells, so you end up with fewer series strings. Dyno, for instance, makes 2-volt batteries that have the same physical dimensions as an L16. Another option would be to look at high quality, industrial 2-volt cells. Northwest Energy Storage (www.nwes.com) carries HUPs, which get good reviews from the field. Also, check out Surrette's 2 VDC and other high capacity cells (www.rollsbattery.com). Let me know if you have additional questions. Best, Joe Schwartz • joe.schwartz@homepower.com

PV Arrays in Storms

We would like to install a solar-electric array on our roof in Palm Harbor, Florida, which is about two miles from the Gulf. What about the vulnerability of solar arrays during tropical storms and hurricanes? I would appreciate any information or leads. Thanks, Sally Coupal • sal10go@aol.com

Hi Sally, I do not think we have published an article on this particular subject, but over the years, we have heard of many rooftop PV systems that have survived hurricanes, and a few that have not. One person had a home destroyed in 207 mph winds, but found their twenty solar-electric panels still in usable condition.

After reviewing past letters to the editor and articles touching on the subject, I can suggest these things to consider: Purchase racks that are engineered to withstand at least 125 mph winds (some are rated for 150+ mph winds). If you cannot find those, work with your rack manufacturer and a local engineer to increase the wind load that they will withstand by modifying the design. Of course, if "the big one" hits your home squarely, all bets are off.

It is helpful to install the panels at the angle of the roof. In other words, it may make things worse to use adjustable or longer legs on the upper side of the array, making the panels stick out like a sail. But for cooling while the panels are producing electricity in full sun, space between the panels and the roof is best—6 inches or so. Attaching the panels flat on the roof may increase their survivability, but without air movement behind them to help keep the panels cool, their electrical performance will suffer.

Be sure to tie the rack feet directly into the rafters; do not try to attach them between rafters without adequately secure blocking. A roof-mounted solar energy system is only as strong as the roof it is on. Be sure that your rafters are appropriately tied to the walls that support it.

Your local installer should be able to provide a secure mount for your panels, to meet your local historic wind load needs. It will be up to you or your carpenter to make sure the rafters are well tied to your house. Michael Welch • michael.welch@homepower.com

PVs on Curved Roof

I have a question regarding a PV system that is supposed to be mounted on a curved roof of a residential duplex building. The curved roof means that the PV modules will be mounted at different angles, so that the individual modules generate maximum power at different times of the day. Is that a problem for the inverter? Can you recommend any particular inverter manufacturers for this application? Thanks, Philip Engelhardt • pengelhardt@ctg-net.com

Hi Philip, There's a common misconception that mounting PV modules in different orientations—so some of them are always facing the sun—will net more energy at the end of the day than if all the panels were facing south. Not true! Local weather patterns aside, the greatest amount of solar energy hits the earth's surface at solar noon, and an array facing south (in the northern hemisphere) will capture the most energy. Mounting the array you mention along the roof's curved surface will generate less energy than if the array was oriented directly south.

That said, it's hard to get any more specific without knowing the size of the array, or the actual curve of the roof. If it's a slight curve, the impact on system performance may be negligible, and *following the roofline usually results in a better-looking array installation. Keep in mind that installing an array on a curved surface will increase the complexity of laying out and mounting the panels, and likely increase the cost too.*

Grid-tie inverter manufacturers suggest that system performance will be maximized if module series strings feeding a given inverter are mounted in the same orientation. In addition, an individual series string should never be installed in more than one orientation. These statements typically refer to orientations that are 90 or 180 degrees from one another. In your case, if the curve of the building is slight, you might not have much of an issue. I'd suggest that you contact the inverter manufacturers, and have building and array specifics handy for them. If there is a significant curve in the roofline, both Magnetek and Sharp manufacture inverters that are capable of independently tracking more than one series string, so multiple array orientations are less of an issue. Joe Schwartz • joe.schwartz@homepower.com

Parallel PVs

I have a couple of technical questions about solar-electric panels that I would really like your advice on. I currently use four old, brown, Arco quad-lams in series to run a 12 V system (charge controller, T105s, etc). However, I recently acquired several lightly used Siemens SM55 panels, and I would like to replace the elderly Quads with these un-sunburned panels.

I've never operated PV panels in other than series wiring; I've always assumed that they can operate in parallel, but I haven't ever done that. Is there anything special I should know before wiring up the SM55s in parallel? Also, the panels have a bypass diode in their junction box—is that something that I should use, or is it for series connections instead of parallel? I'm planning to upgrade the wiring to the panels to accept the higher current. Thanks, Kevin Gray • graykevi@mattel.com

Hello Kevin, PV modules (or groups of modules such as the quad-lams) will happily operate in parallel. Here on Agate Flat, our 12-volt system is composed of many different types of PV modules all wired in parallel (that's positive to positive and negative to negative). Some of these are quad-lams.

Don't worry about the bypass diode(s) wired into the M55s' junction boxes. These are strictly for shading issues when the modules are wired (in series) into a high-voltage array (over 50 VDC). In a 12-volt system, these diodes don't do anything at all and are best left undisturbed.

Make sure to upgrade that home run wiring between the arrays and the charge controller. Voltage drop can be a real killer on 12-volt systems. Also double-check the charge controller and make sure it can handle the extra current. Richard Perez • richard.perez@homepower.com

Small Grid-Tie Inverters

Are any grid-tie inverters available for those of us with 500 W or less of modules? It seems that you must have at least a KW invested before you can go the grid-tie route. I have a stand-alone 320-watt system and would like to lose the 20 percent battery charging inefficiency by going grid-tied. And on many days, the batteries are floating with the panel output just idling away. I looked pretty hard on the Internet, but haven't turned up much. I'm hoping that you can turn me on to some low-wattage interties. Jack Powell • turdmail2go@yahoo.com

Hi Jack, The smallest grid-tie inverter I know of that's available in the United States is the Sunny Boy SB700. It has three programmable voltage ranges. At the lowest range, the minimum voltage is 73 V, and at that range it will put out up to 460 W. This might be exactly what you are looking for, and would allow you to add modules if you want to grow the system, to a maximum of 700 W (but at a higher voltage range). But please run your array specs by your dealer to verify suitability before purchasing. There may be other smaller inverters out there in the near future, so keep your eyes peeled. Michael Welch • michael.welch@homepower.com

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Know Your System

Richard Perez

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I've grown accustomed to using this column to discuss the growth of our off-grid renewable energy systems. The only problem with doing this is that our systems have been very boring lately—we've had no new additions this year. These large PV systems just smile at the sun and do their work, making more than 20 KWH of electricity per day.

Even though I'm not out there with a wrench making additions and troubleshooting problems, I still have daily involvement with the systems, beyond using the energy that they make—I read meters.

Reading Meters

Our systems, one 24 volt and the other 12 volt, are equipped with five different battery amp-hour meters. While only one meter per system would suffice, I enjoy comparing them and testing various models. Most of these meters are of older vintage—Cruising Equipment E-Meters, and older TriMetric meters. All are of the standard variety—reading battery voltage, net battery current, and battery amp-hours. They are all very accurate and read within 0.5 percent of each other.

The Bogart TriMetric battery system monitor.

By reading these meters, I have learned the behavior and effective use of our systems. I read them regularly and compulsively. The information from these meters allows me to see if the systems are performing at their full potential—this is the fast way to find minor problems before they become major problems. The information from these meters enables me to effectively operate our systems—many day-to-day energy decisions in an off-grid home depend on the systems' state of charge.

Battery Voltage

In the old days, we used battery voltage as a rough indicator of a system's state of charge. Happily, those days are gone. Now we use the amp-hour reading on the meter to determine the battery's state of charge.

But battery voltage still delivers essential information. During the day and while under charge, the battery voltage should remain at the PV regulator's set point. Any higher voltage indicates a regulator failure, or that the system's users forgot to switch the regulator to equalization mode. During the night, unduly low battery voltage can indicate that the batteries are nearing the end of their life, or that they haven't been sufficiently charged during the day.

I know what the voltage readings mean from experience, by constantly reading the meter and learning each system's voltage parameters. Your experience will be different—your battery is different and so is your usage. What *is* important is reading the meter and becoming familiar with the "normal" readings for your off-grid RE system.

Battery Current

Perhaps the most important thing to remember about the battery current (amperage) function in amp-hour meters is that it reads "net" battery current. Net battery current means the rate of charge either moving into or out of the battery at that instant. While this is an important function, it's good to remember that it does not indicate PV amperage being drawn by specific appliances or the source amperage. It is just the net amperage either going into or out of the battery.

The battery current reading is constantly changing. Appliances are turned on, some automatically, such as refrigerators, freezers, and pumps. When an appliance is started, either automatically or manually, the energy it consumes must come from somewhere—either the battery or the RE source, such as a PV array. This consumption is reflected, but not separately quantified, by the battery current reading in the amp-hour meter.

If the PV array is producing, an appliance's energy comes directly from the array. This means lower current available to recharge the battery, so the battery current reading of the meter decreases. At night (or when an energy source is not producing), an appliance's energy consumption is included in the negative battery current reading in the amp-hour meter.

Battery Amp-Hours

The amp-hour function of the meter is really just a bean counter, only it counts electrons. Every electron moving either into or out of the battery must pass through the shunt located at the battery. The amp-hour meter counts passing electrons and notes whether they are moving into or out of the battery.

When a battery is fully charged, the amp-hour meter reads zero. As the battery is discharged, each amp-hour removed from the battery is displayed as a negative number. For example, if a battery has been discharged 100 amp-hours, the meter will read -100. As the battery is charged, each amp-hour is added, as a positive number, to the total.

So if a battery that has been discharged 100 amp-hours is recharged with a current of 50 amps for one hour, the meter will add this amount to the total, which will then read -50. When the battery is once again fully recharged, the display will return to zero.

If the battery is overcharged (a modest daily overcharge is normal in RE systems), the number on the display will read positive. For example, if a battery is overcharged by 50 amp-hours during the day, the display will read 50. When the sun goes down and charging ceases, the display will once again return to zero as the battery goes into discharge mode.

The amp-hour function of the meter requires correct programming by the user. The user must input the voltage and charge amperage at which the battery is considered fully recharged, and the battery's capacity in amp-hours.

The full-charge voltage is set at slightly less than the controller's bulk voltage setting. If the full voltage setting of the meter is set higher than the system's PV controller, the meter will never recognize the battery as fully recharged. I program my meters to recognize the battery as fully recharged at 0.1 VDC less than the setting on the PV regulators.

The full-charge setting for current (amperage) is a bit more difficult. This setting is the current level *below* which the battery is considered fully recharged. As the battery is recharged, the system's regulators hold the voltage constant, and as a result, the amperage into the battery decreases. The number is programmed into the meter as a percentage of battery capacity. The number usually used is between 2 and 4 percent.

For example, my 24-volt battery has a capacity of 1,640 amp-hours. I set the meter for 3 percent. Multiplying 1,640 amp-hours times 3 percent equals 49.2 amps. So when the system reaches full voltage (29.2 VDC for our system) and the current to the battery reaches 49 amps, the meter considers the battery full.

The battery amp-hour meter is smart. It knows that no battery is 100 percent efficient, so it scales, with an efficiency factor, the incoming amp-hours on the charge side. And the meter determines battery efficiency based on the last three charge–discharge cycles, so the efficiency factor changes with battery use and age. The meter considers a charge–discharge cycle to be at least 10 percent of the battery's programmed capacity. Cycles that empty the battery less than 10 percent are not counted in this process.

The new Xantrex XBM battery monitor.

Modern battery amp-hour meters will also read the battery's state of charge as a percentage of battery capacity, for example, 92 percent. If you are not comfortable with the concept of amp-hours, set the meter to read percentage of battery capacity.

Knowledge Is Power

Your battery amp-hour meter should be mounted where you can look at it many times per day. Don't hide it in the power room! Put it on the wall in the kitchen or the living room—someplace where it's always in your face. Distance to the battery is not a problem. I mounted our meters in my office, more than 120 feet (37 m) from the batteries. It's possible to go 500 feet (150 m) or more with some meters.

Check the meter often. Only by becoming familiar with the readings will you learn how your system performs and how best to use the energy it produces. I start my day, within minutes of getting up, by reading the meters. I want to see how many amp-hours were withdrawn from the systems overnight.

Normal consumption from our 24-volt system is between 150 and 210 amp-hours, while the 12-volt system uses about 130 amp-hours. Overnight consumption depends on how much time we stay up watching television and running the lights. Hotter weather means more overnight consumption because our two refrigerators run more to compensate for the heat.

Overnight consumption that is far higher than normal deserves investigation. One time, I located a faulty solar hot water controller that was running the pump all night instead of shutting it off. I noticed the higher consumption and went around at night to see what was using energy when it should have been off.

During the day, I watch the amp-hours count back to zero, indicating that the batteries are refilling. I also check the amperage in each system to make sure that the PV charge rate is what I'd expect. I know from experience the consumption of the usual appliances that are on during the day, and there are many—three solar hot water pumps, three computers, a StarBand satellite communication system, a laser printer, and refrigerators, to name a few.

I also try to notice when our systems become fully recharged. When this happens, it's time to use energy for a number of chores—pumping water (an 800-watt load that takes one or two hours), washing clothes in the washer (a load that takes 90 minutes and consumes about 150 watt-hours), vacuuming the house (a big load at 1,350 watts for an hour or two), and other energy intensive jobs that can be done when we decide to do them.

We wait to do these jobs until the system is fully recharged, using the energy directly from the arrays. This means better efficiency, since we don't have to retrieve the energy from the battery, which also extends the battery's useful life.

At the end of the day, I check the meters to see how many overcharge amp-hours we have accumulated. Ideally, I'd like to see 2 to 4 percent overcharge, but that doesn't happen many days. Having the batteries fully recharged at the end of every day makes them last far longer, and they run more efficiently.

Once every week or so, I delve into the historical data contained within the amp-hour meters. Different meter models track and display different historical data. On my meters, I check things like charge efficiency, deepest depth of discharge, and average depth of discharge. This information helps me keep the systems in peak condition.

Meter watching is only effective if it's done all the time. Only checking the meters when the system fails is less than informative since you don't have the background to determine what is normal and what is not. So if you have a battery-based system, install and read a battery amp-hour meter regularly. The familiarity with its information will enable you to more effectively use your system, and to find problems before they become critical.

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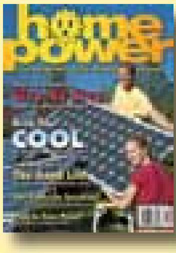

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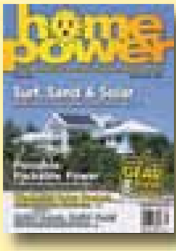

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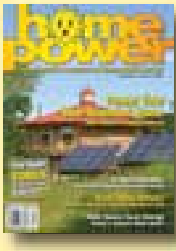

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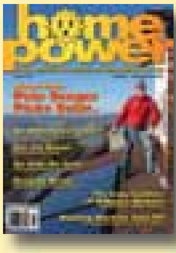

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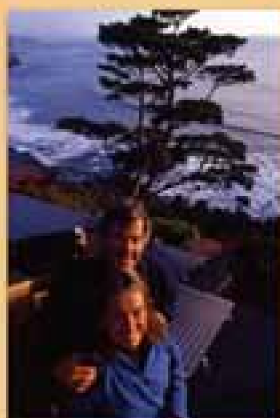

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