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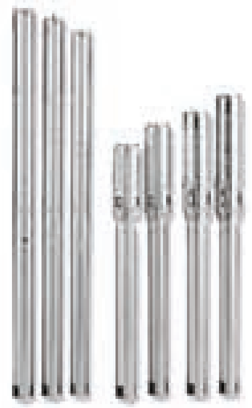

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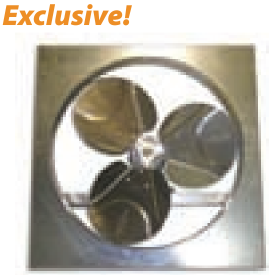

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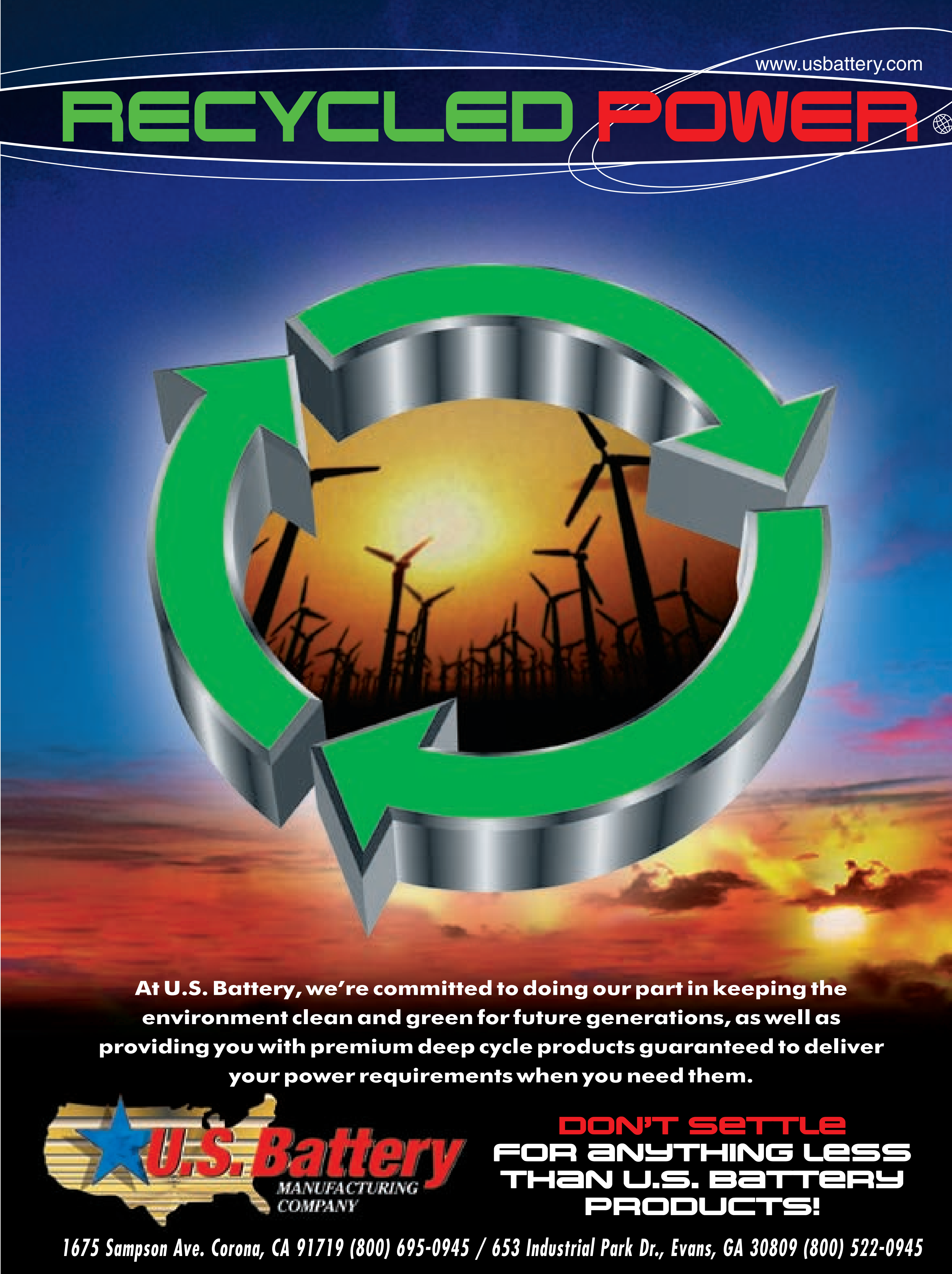
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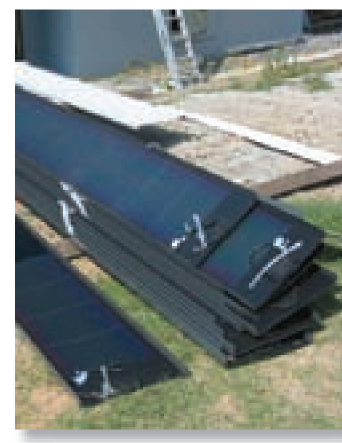
HP105 contents



On the Cover

Alan Stankevitz's hand-built, cordwood home is powered by his self-installed 4.2 kilowatt solar-electric array.

Regulars

Big Business... The Kind We Like

Home Power attends about a dozen end-user focused energy fairs each year. These fairs have workshops, vendor display areas, and entertainment, all aimed at increasing the public's exposure to renewable energy (RE). We also participate in conferences geared toward RE industry professionals. These business-to-business conferences are vital networking events for the companies that manufacture and distribute the equipment we use (or plan to use) for our homes and businesses.

This past October, the Solar Energy Industries Association (SEIA) and the Solar Electric Power Association (SEPA) organized one of the premier industry events to be held in recent years—Solar Power 2004. The host city was San Francisco, and 1,120 exhibitors and participants attended the event. Eighty booths displayed state-of-the-art RE technologies.

Many multinational corporations are diversifying their focus to include RE. I walked away from Solar Power 2004 with the strong feeling that renewable energy has solidly entered the realm of big business. While some long-time RE enthusiasts may cringe at the thought of solar and wind energy becoming "corporate," this is exactly what needs to happen if RE is going to be adopted by the U.S. and the global mainstream.

If you're an industry professional, don't miss the Solar Power 2005 conference, which will be held October 6–9, 2005 in Washington, DC (www.solarpowerconference.com). And if you're an end-user of RE technologies, rest assured that many of the world's brightest minds are working on developing innovative, clean-energy technologies, and making them available the world over.

–Joe Schwartz, for the *Home Power* crew

Think About It...

"It is not the strongest of the species that survive, nor the most intelligent, but the most responsive to change."

–Charles Darwin

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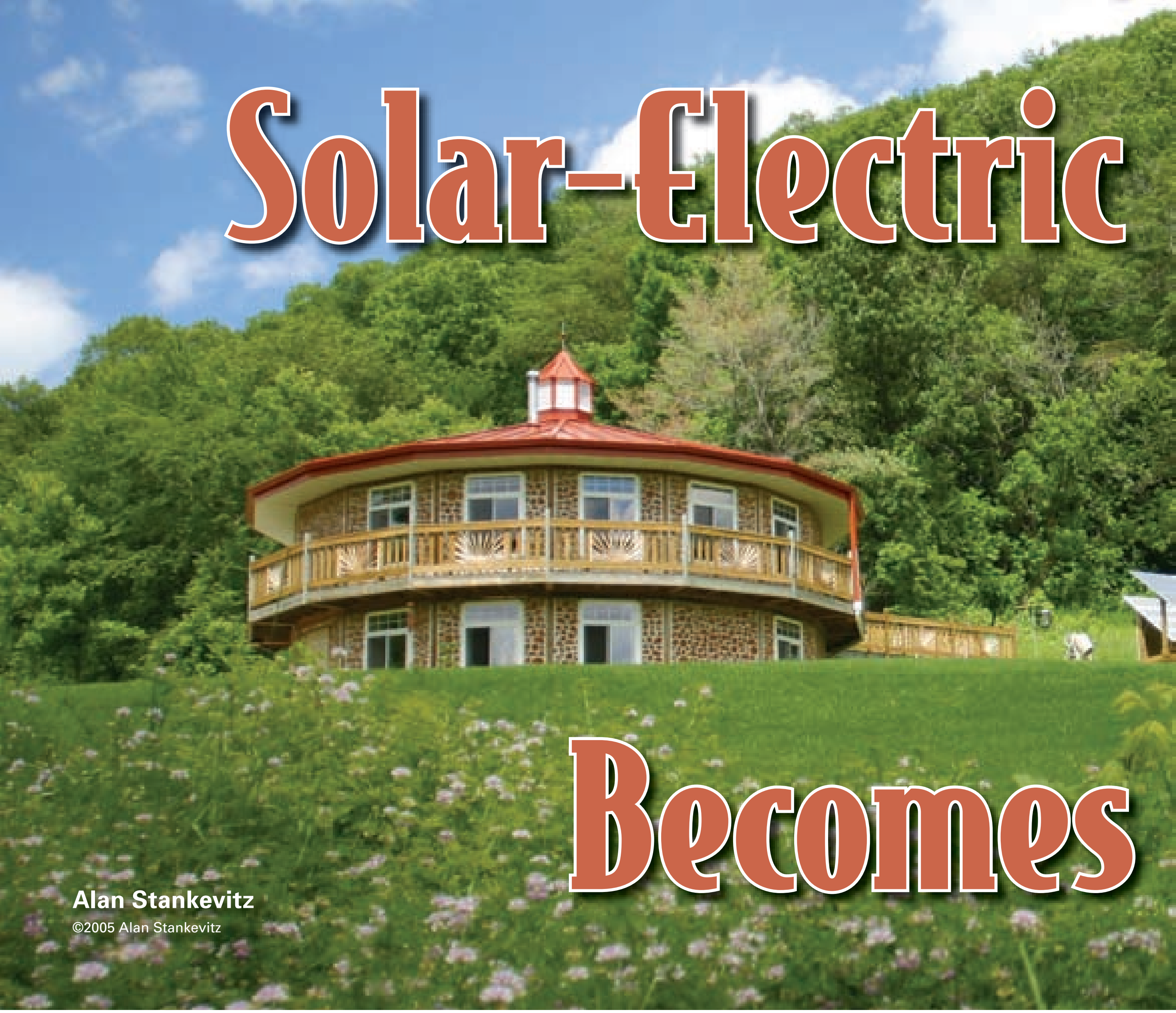
Solar-Electric Becomes



Alan Stankevitz

The Stankevitz residence is a sixteen-sided, cordwood house using passive solar design, solar hot water, and solar electricity.

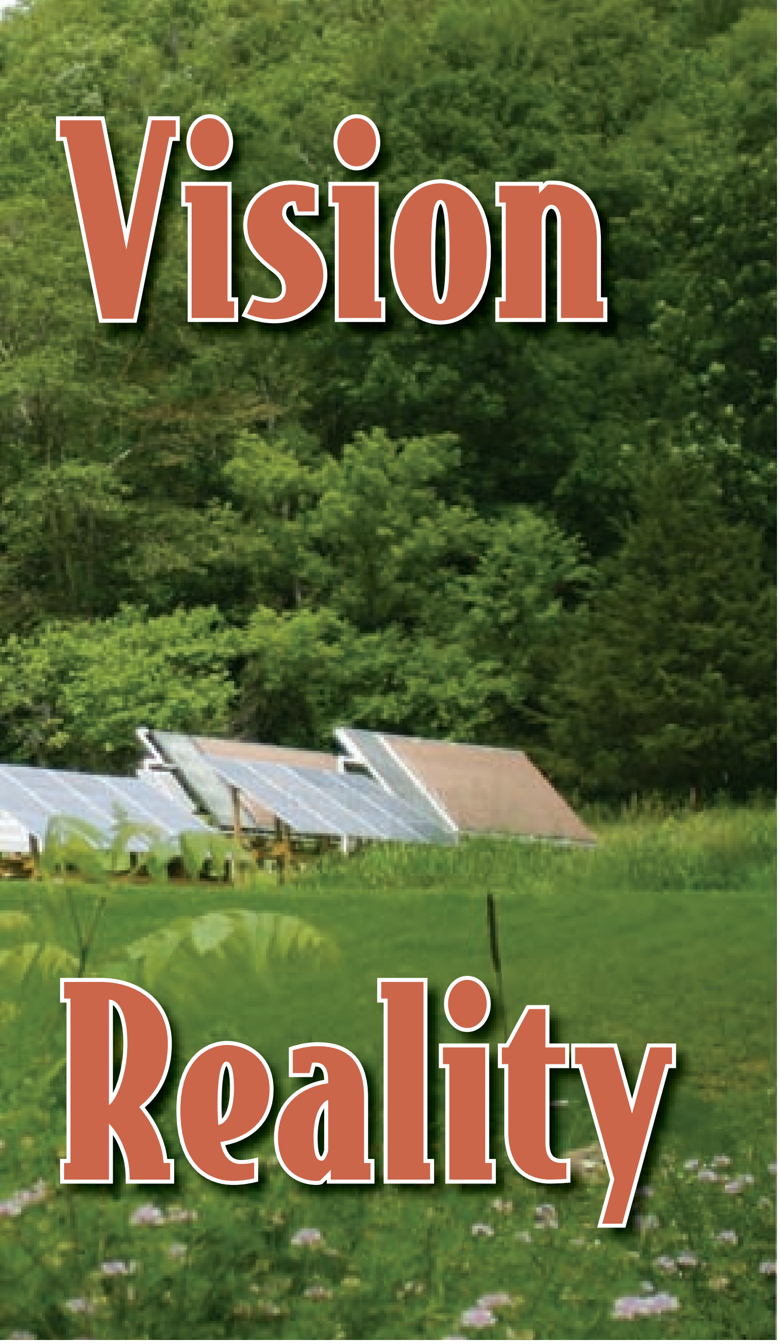
It's now been eight years since we took the plunge and bought our piece of heaven in southeast Minnesota. Shortly afterwards, we decided that I would take a sabbatical from work and build our cordwood dream house. This was a big step for us, and thanks to my loving and understanding wife Jo, I started an adventure of a lifetime—designing and building an energy-efficient house from the ground up. This house has been designed to be our final resting place, and with that in mind, our motto is "invest with today's dollars to offset tomorrow's costs."

I liken us to Oliver and Lisa Douglas from the 1960s sitcom classic *Green Acres*. Living in the Chicago area and disillusioned by the corporate world, I suggested to my wife that we should think about living a more intentional, self-sufficient lifestyle. Although Jo thought it was just a phase I was going through (or temporary insanity), it's now become our passion.

We could have attempted country living in the city, but it would have been tough. On our small city lot, putting up solar panels might have been acceptable, but a wind generator was out of the question. Putting in a cistern, expanding our vegetable garden, and digging a root cellar wasn't permitted or our lot was too small. It became apparent that there were too many obstacles, and we decided to look elsewhere and build our house from scratch.

The house is a double-wall cordwood house with an insulation value of approximately R-35 in the walls (nearly twice that of a conventionally insulated 2-by-6-inch wood frame wall), plus plenty of thermal mass. Add an R-60 ceiling, along with a sand-bed storage solar heating system, and the house is quite energy efficient. We planned to incorporate a solar-electric system at some point, but it was low on our priority list. That was until the Minnesota solar rebate program became available to us.

Vision Reality



house log-by-log to installing a solar heating system, why stop there? Time for another project!

Utility Wrangling

Like every other aspect of our house, I did lots of research before committing to the project, and plenty of hurdles had to be overcome. Our local utility cooperative had only a few other "cogenerative" customers selling electricity back to the grid—our solar-electric system would be a first for them. I asked that they send me their packet of rules and regulations regarding cogeneration systems.

After reviewing their documents, it became quite apparent that their rules were written for large 30 to 40 KW wind systems. Requirements included such things as a US$300,000 liability insurance policy (with their name included on my policy), site survey (at my cost), meter installation, US$200 processing fee, and approval by their board of directors. I was also told that I would no longer be eligible for the discounted rate for using off-peak electricity. It was either that or trench in another line and pay an additional monthly connection fee.

Our local utility and I spent way too much time debating various rules and regulations. I do not want to estimate how many hours were spent by their CEO, their lawyer, and me ironing out the issues. It required the state's utility commission as a mediator to finally reach an amicable agreement. After the dust settled, I was able to keep the discounted, off-peak rate and sell my surplus electricity at the average retail rate. They also accepted a certificate of liability insurance—something that most residential insurance policies will produce upon request.

With financial support from the State of Minnesota, Alan Stankevitz installed the PV system himself. His goal for the system is to provide 100 percent of the home's annual electricity needs.

Solar Incentive

Minnesota has had a grid-intertie solar rebate program since 2002, but it wasn't until this year that we were able to take advantage of the rebate. The rebate is funded by Xcel Energy, and originally it was only available to this utility's own customers. The state mandated that any remaining funds after the second year would become available statewide, regardless of the local utility.

The rebate provides US$2,000 to US$8,000 for installing a qualifying solar-electric system on your home or business, at US$2,000 per rated kilowatt. The rebate application states that this should reduce system costs by 20 to 30 percent, but I thought I could do better. My plan was to take full advantage of the rebate by installing a 4.2 KW system using my own labor. Since I had used my own sweat equity for everything from building a cordwood

Alan built the PV array mounts himself using pressure-treated lumber and Unistrut rack. They are not adjustable, but set at an angle that maximizes annual production.

But the utility didn't have to bend as far as they did. After reflecting on the months of negotiation, I am very pleased with the cooperation we received from our local electric cooperative. There is no doubt that much work is needed in the state of Minnesota on the rules that govern net metering. They are rather ambiguous, which leads to plenty of misinterpretation of the original intent.

The two Xantrex SunTie inverters in their custom cabinet send the output from the PV panels to the house and utility grid.

System Design

While the grid-intertie discussions with our local utility were underway, I was also designing our system. My goal was to build the system as frugally as I could within the design parameters of the rebate. The rebate required specific UL listings for both the panels and inverters, and a 25-year warranty on the panels.

I called multiple distributors of PVs and inverters, attempting to ascertain via phone calls how reputable they might be. If they failed to call me back after two attempts, they were removed from my list. Prices were all over the board. It was a real eye-opener shopping via phone and the Internet.

Tech Specs

System type: Batteryless, grid-tied PV system

System location: La Crescent, Minnesota

Solar resource: 4.5 average daily peak sun hours

Production: 400 AC KWH per month average

Utility electricity offset: 100 percent estimated

Photovoltaics

Modules: 24 Kyocera KC158G, 158 W STC, 23.2 V_{mp}, and four Shell SR100, 100 W STC, 17.7 V_{mp}

Array: Eight, three-module series strings (K158Gs), and one, four-module series string (SR100s); 4,200 W STC total, 69.6 V_{mp}

Array combiner box: Built-in Xantrex SunTie with 20 A fuses

Array disconnect: Built-in Xantrex SunTie, 100 A breaker and 1 A GFI

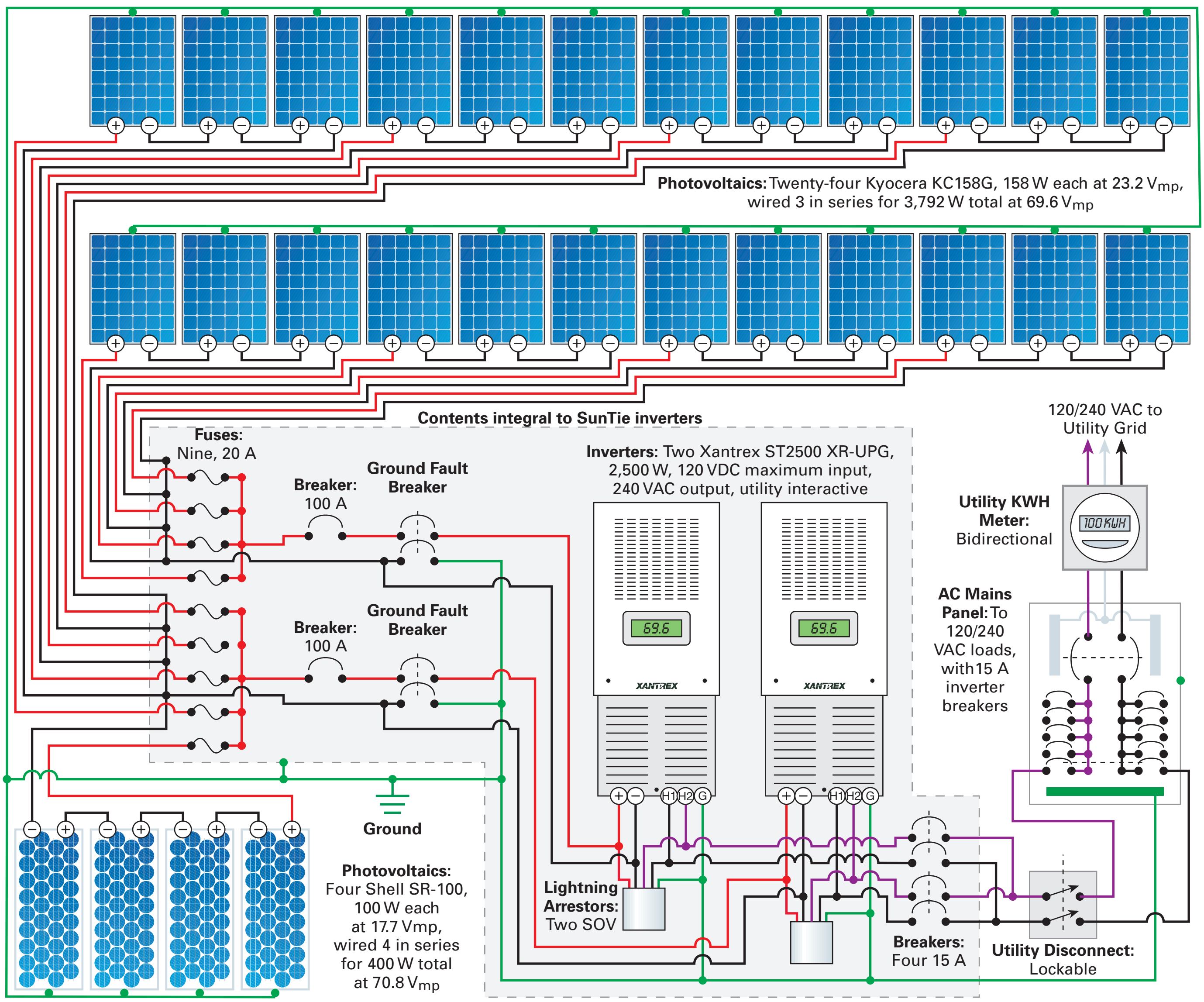
Array installation: Custom ground mounts, 40-degree tilt angle

Balance of System

Inverters: Two Xantrex ST2500 XR-UPG, 120 VDC maximum input voltage, 44–85 VDC MPPT window, 240 VAC output

System performance metering: Two-channel utility KWH meter, Solar Guppy PC software to monitor inverter performance

The Stankevitz PV System



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

While I was checking out prices, I was also investigating grid-intertie inverters. A fair number of new players are on the market, but I didn't want to be on the bleeding edge of technology, so I stuck to the ones that have been out for at least a couple of years.

Of course, Sunny Boy has become the de facto standard for grid-intertie inverters, but I was also curious about the SunTie. The SunTie inverter did not have a good reputation among dealers—and rightfully so. It was quite apparent in Henry Cutler's side-by-side comparison between the Sunny Boy and SunTie (*HP91*) that Xantrex had to redesign the SunTie.

Doing a Google search on Henry Cutler linked me with his Solar Guppy Web site, and I was encouraged by what I saw. Henry, working for Xantrex, had redesigned the SunTie, and his white paper convinced me that the death of the SunTie inverter was greatly exaggerated. My interest was piqued, and after numerous e-mail messages to and from Henry, I was convinced that the SunTie was a viable product. From a connection point of view, I also liked the fact that the SunTie has a built-in combiner box and DC disconnect.

I was weighing the pros and cons of both the Sunny Boy and SunTie inverters when a local dealer offered to match my best price on Kyocera 158 panels and also offered to sell me two brand new, upgraded SunTies that he wanted to unload for US$1,000 each. It was an offer I couldn't refuse.

So now that I knew what PV panels and inverters I was going to use, it was time to design a rack for the panels. I considered building the racks completely out of Unistrut (*HP97*), but I was a little leery of wind loads in our area. Allowing a seasonal tilt would definitely produce a few more KWH every year, but I decided to go with a home-built, fixed mount instead. At some point, I may modify the

Computerized Data Tracking

We put an older Dell Inspiron laptop into service to collect data for both our solar-electric and solar heating systems. Three serial ports continuously feed information to the computer. Through a series of software programs, the information is then fed via FTP to our Web site on an hourly basis.

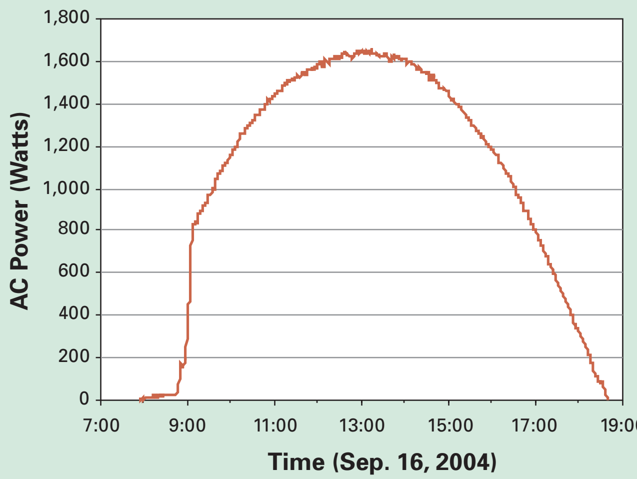
Xantrex does not offer any software for their SunTie inverter, but Henry Cutler does, and it's free. I wrote a Visual BASIC program that reads Henry's data file and extracts the information that is then uploaded to our Web site. I also use another Visual BASIC application to read temperature sensors located on various parts of the solar heating system. This information also gets sent via FTP to the server on the hour and is then read using a Macromedia Flash application. You can monitor our solar statistics online by going to: www.daycreek.com/dc/html/pvstats.htm

Additional hardware is required to interface between the SunTie inverters and the PC. The ground used on the SunTie's serial port is the negative lead from the solar-electric panels, and it's not something you want being fed to the computer. An opto-isolator is required to protect the PC's circuitry and eliminate noise from the inverters.

I highly recommend the use of opto-isolators wherever a data connection is tied into any high voltage equipment or subjected to the outdoor environment. An opto-isolator uses a series of LEDs and light receptors to electronically isolate data signals.

System Data at a Glance

Solar-Electric Output: West Array



rack to be tilted for the winter sun's angle, but for now the array will stay fixed at a 40 degree angle. This produces the most energy year-round for our location, based on nearby La Crosse, Wisconsin, climatic data.

Since I had previous experience building a wood, ground-mount rack for our ten solar heating collectors, I decided to use a frame with 4-by-4 posts to build the rack. The panels themselves are mounted to 10-foot (3 m) sections of Unistrut using stainless steel hardware, while the Unistrut is mounted to the wood racks using carriage bolts. It would be rather easy at some point to hinge mount them to the rack if I decide I want to.

Digging up the Back 40

With the rebate approved, and equipment on the way, it was time to start digging up the back 40. Our house is located on the side of a south-facing hill and it added a bit of a thrill for this hill-challenged flatlander from Illinois. There were plenty of rocks to contend with, and although I own a Bobcat, it was still quite an adventure using a rented auger to dig twenty-four holes for the racks.

My Bobcat is rather old and I don't normally use the hydraulic connections. Because of this, it took me about half a day just trying to get the auger connected. All the holes were finally dug—partially by machine and partially by hand. I had no major injuries to speak of other than the head gash I received while prying out a rock the size of a Buick.

Next came the construction of the 4-by-4 post frame. The frames were plumbed and braced, and the top plates were put in place before the concrete pour. I decided to mix it myself with an electric cement mixer. After a dump truck load of gravel and a few trips to town for twenty-four bags of Portland cement, I was ready to pour. It was slow going, but not too bad. Within two weeks, the panels were ready to be mounted.

Mounting the panels went quite well. Three racks support all of the panels. Each of the two big racks hold twelve Kyocera 158s, while a much smaller rack holds four

Shell SR-100 panels. The SR-100s were additional panels that I traded for some Web design work. This boosted the total system output from 3.8 to 4.2 KW, and allowed me to "max out" the rebate.

The small rack that supports the four SR-100s sits between the house and the other two larger racks, and makes a great shelter for the SunTie inverters. Installing the inverters midway between the house and large PV arrays allowed me to keep my transmission wire size small (#10; 5 mm^2). The inverters are weatherproof and designed for outdoor installation, but I decided to build a cabinet to further protect them from the elements, and from the hoards of Asian beetles that manage to get into every nook and cranny around here every autumn.

After the racks were completed, it was on to digging trenches for the wiring. Code mandates 18-inch (46 cm) trenches, and at first this seemed easy enough. I thought about renting a trenching machine, but I figured that hand digging the trench would keep my costs low, plus I knew that plenty of rocks were under that hill and would give a trenching machine fits. Well, hand digging the trench gave me fits. I already had dug up a rock the size of a Buick while digging the holes for the racks, and in the trench I found a rock the size of a Plymouth.

Finally, the trench was dug and 1-inch conduit was laid into it. With help from my friend Tom (also an avid reader of *Home Power*), we were able to run all the wires in one afternoon. The rest of the job was rather painless, and a few days later the wiring was complete.

System Costs

System Components	Cost (US$)
24 Kyocera 158 PV modules & shipping	$12,010
2 Xantrex STXR-2500-UPG inverters	2,000
Rack, hardware, & concrete	767
Misc. electrical	313
240 Struts, A1200 HS-10-PG	290
Wire, #10	103
8 MC cable extensions, 10 ft.	64
Auger rental	53
Stainless hardware	37
Total System	$15,637

Remote Monitoring Equipment	
Opto-isolators, cables & power supply	$231
Cable adapters, USB to RS-232	30
Connectors, DB9	13
Software	0.00
Total Monitoring	$274
Less Minnesota Rebate	-$8,000
Grand Total	$7,911

Alan Stankevitz in front of his solar-electric panels—another phase of his solar vision becomes reality.

Throwing the Switch

I cannot tell you how euphoric a feeling you get turning on the inverters for the first time. With the throw of a few switches, the inverters powered up and began their test countdown before going online. Finally the seconds counted down to zero and we were producing our own electricity. I was ecstatic!

But then I started to hear a noise coming out of the inverter similar to the sound of the single-cylinder engine from the movie *African Queen*. I wasn't sure if it was normal or not, but after hearing both of them making the noise, I deduced that it was. Sure enough, the fans inside the inverters make this noise when production is low at the beginning and end of each day.

Electrical Inspection & Approval

After the system had been tested, it was time to call our local electrical inspector. I have been working with our inspector over the past few years while wiring the house. So

The Stankevitz home is a model of efficiency, beauty, and craft—showing just what can be accomplished if you follow your vision.

I knew he was comfortable with my work, although I didn't know what to expect since PV was new territory for him.

He came out to inspect the work and found that I needed to correct the bonding of a ground rod. I had connected multiple wires to the ground rod clamp, which is a no-no. The proper way is to run one wire off of the ground rod and then connect the multiple wires (pigtailed) to a split bolt. All three racks have their own ground rods, and a #6 (13 mm^2) ground wire bonds the ground rods from the racks to the electrical service ground rod.

I explained that I would fix the problem, and scheduled an appointment for the following week. He also said that he wanted to familiarize himself with Chapter 690 of the *NEC*. On his return visit, I showed him that I had fixed the grounding issue and he was pleased with the connection.

He had a copy of an electrical inspectors' magazine that had an article written by John Wiles, which he thought I should read. I said "Oh, John Wiles? I have all of his *Code Corner* articles from *Home Power* magazine and I have written to him with a few code questions that I had while wiring the system." I showed him the stack of John's articles that I had collected over the past few years. At this point, I think he was pretty convinced that I had done a thorough job.

We went through the wiring of the entire system, and he seemed to still be a bit reluctant to give me the final inspector's approval. He said that he wanted to double-check with his boss, before he gave me the green light. But the following day he gave the approval that I needed to show to our utility company.

Within a week after the inspector's approval, the electric utility installed their digital meter to record both incoming and outgoing KWH, and we were producing electricity. Our hopes are that we will be able to produce enough to cover our annual consumption—in other words, netting zero electricity usage from the utility.

Living the Dream

A special thanks goes out to the Midwest Renewable Energy Association (MREA) for their many workshops that gave me the skills to install this system. And thanks for the many years of ideas obtained through *Home Power* magazine. A little bit of common sense and knowledge can go a long way towards installing your own system and saving money by using your own labor instead of someone else's.

Over the years, we've had many friends and relatives visit our house-in-the-making and leave us with their "words of wisdom." It has become a tradition that visitors at least sign and date a log to be mortared into our cordwood walls. We've gotten quite a few comments and artistic renderings that we will enjoy for years to come. My favorite words of wisdom were written by Jo's parents: "A Dream Worth Living...The Vision Becomes Reality." I couldn't have said it better.

Access

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Next Step Energy Systems, Zeus Stark, 1319 Altoona Ave., Eau Claire, WI 54701 • 888-926-1603 or Phone/Fax: 715-830-9337 • zeus@nextstepenergy.com • www.nextstepenergy.com • PVs and solar heating components

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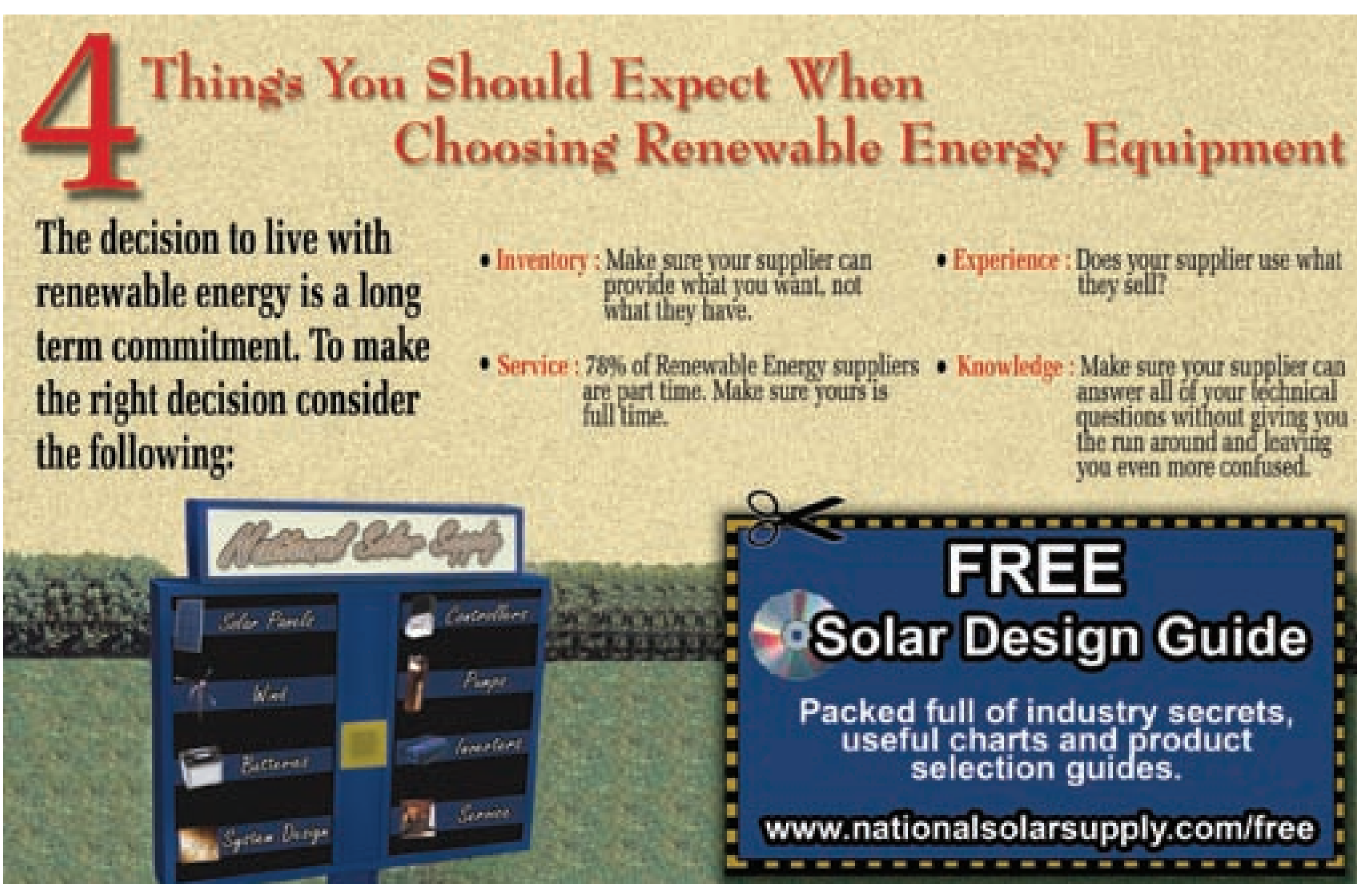

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Tools of the Solar-Electric Trade

Joe Schwartz

Thinking about installing a solar-electric system? Having the right tools will allow you to get the job done quickly, done right, or done at all. If you have some electrical wiring experience or you're the type of person who undertakes household building projects, you likely have a pretty well-equipped shop or tool shed. In addition to standard hand tools like insulated screwdrivers, a socket set, and box and open-end wrenches, you'll need some specialized tools to install a solar-electric system.

Many of the tools that the pros use are described below. Once you have them, and learn to use them properly, a safe and professional installation becomes a possibility. Quality tools, like quality anything, aren't cheap, so plan to spend some money gearing up for your installation.

Many of these tools are useful for other projects around the house and definitely worth the investment. But before you buy a bunch of expensive tools that you may only use once, make sure to realistically gauge your ability to design and install an efficient, code-compliant, and safe system; consider hiring a pro to do the job for you. So either tool up, or take it easy and remain an armchair solar-electric installer. Here's my list of the tools of the trade—and brief descriptions of their use.

Angle Finder

Allows you to set your solar-electric modules to a precise tilt angle, or quickly determine the pitch of the roof you're planning to mount them on. US$10–15

Solar Pathfinder

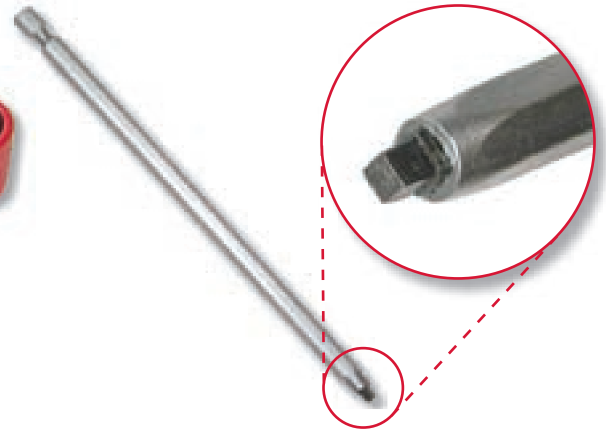
Helps you find the best location for your solar-electric array, by determining shading from trees or buildings for every hour of the day, every day of the year. US$175–255

Cordless Drill

Fitted with a variety of bits, from square drive to Phillips to hex head, it can be used for lots of tasks, including quickly securing solar-electric module mounting hardware. US$25–200

Right Angle Drill

High power, heavy-duty AC drill used for drilling or cutting holes for conduit or wire runs. Right angle design allows it to be used in tight spaces. US$250–300



Square-Drive Bits

Used with square-drive screws when mounting wiring enclosures or securing conduit straps. Long, square-drive bits make things easy since screws stay on the bits during positioning. US$2–5

Hole Saw

Circular bit used with cordless and AC drills with a $\frac{1}{2}$-inch chuck for cutting holes for conduit runs or in metallic or plastic wiring enclosures. US$5–150 (set)

Cordless Reciprocating Saw

One of my favorite tools—perfect for quick and accurate cutting of Unistrut, and metallic and PVC conduit, without the hassle of extension cords or hacksaws. US$100–180

Hole Punch

For multiple holes in metallic wiring enclosures, hole punches, also known as slug busters or chassis punches, quickly make clean, burr-free holes for conduit fittings. US$150–700 (set)

Torque Wrench

Adjustable torque settings allow precise tightening of mounting rack hardware and wire terminations, according to equipment torque specifications. US$40–180

Fish Tape

A reel of stiff wire that is fed through installed conduit runs, and used to pull system wiring through the conduit. Lengths of 50 to 250 feet are common. US$25–120

Conduit Bender

EMT metallic conduit is one thing that makes a job look professional. Benders are used to create smooth curves, and accurate bends. US$40–100

Torpedo Level

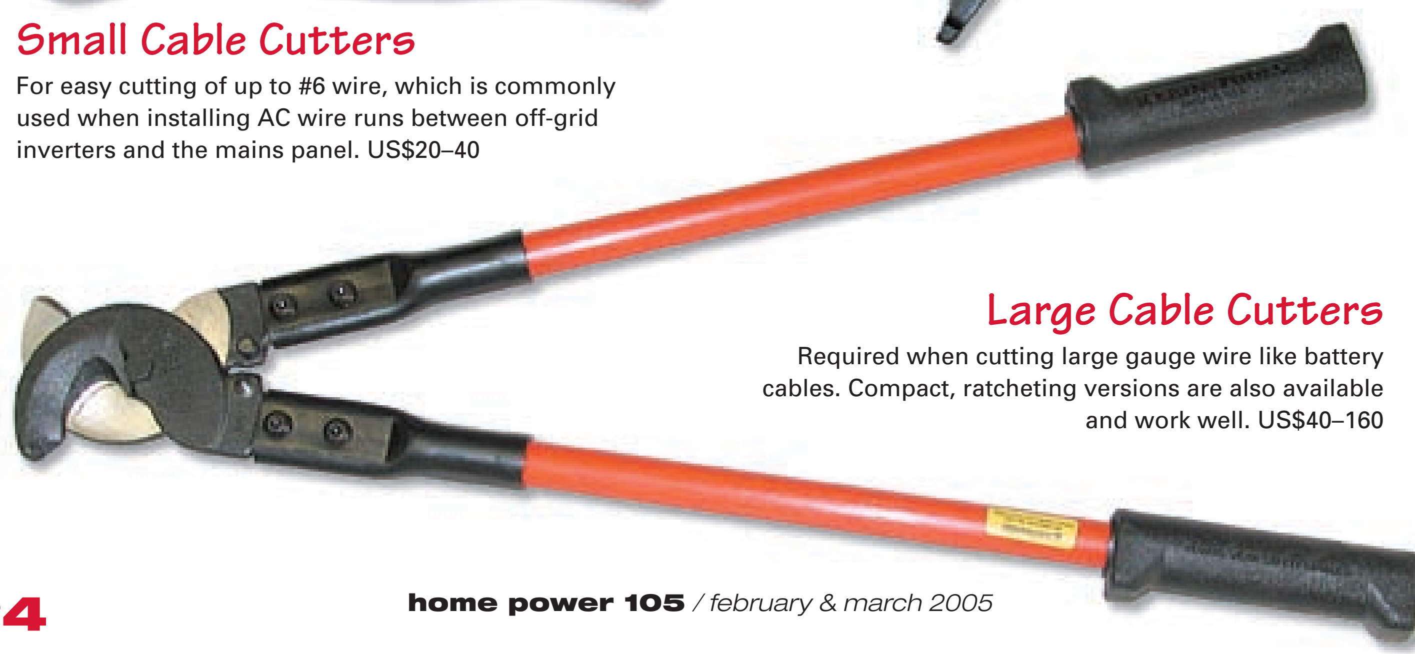
Short level used for accurate and straight mounting of wiring enclosures, conduit, and equipment. Level components look good, and will impress your neighbors. US$5–30

Wire Stripper

Common electrical tool used for cutting and stripping small gauge wire. You probably already have one of these if you've done any wiring around the house. US$10–50

Small Cable Cutters

For easy cutting of up to #6 wire, which is commonly used when installing AC wire runs between off-grid inverters and the mains panel. US$20–40



Large Cable Cutters

Required when cutting large gauge wire like battery cables. Compact, ratcheting versions are also available and work well. US$40–160

Small Crimper

Many pieces of solar equipment are fitted with stud posts that require ring terminals/lugs. Small crimpers are used to attach these connectors on #8 wire and smaller. US$20–40

Courtesy of quickcable.com

Large Crimper

Enables secure installation of ring lugs on large (typically #2/0 and #4/0) wire. Commonly used to make battery and inverter cables in off-grid systems. US$180–220

Needle Nose Pliers

The perfect tool for feeding/pulling small wires through fittings, and aligning wires in terminals for tightening. Most have wire-cutting blades as well. US$10–40

Lineman's Pliers

Excellent multipurpose pliers. Used for wire cutting, pulling, and twisting multiple wires together. US$25–50

Slip-Joint Pliers

Adjustable pliers used for holding and tightening conduit fittings. Deluxe models have a quick and secure, ratcheting adjustment mechanism. US$20–50

Nut Drivers

For hex head nuts and bolts. Hollow shaft allows clearance for long bolts. Used to remove wire enclosure covers and to fasten equipment ground screws. US$5–50

Digital Multimeter (DMM)

A must-have tool for anyone doing solar-electric work. Most models measure AC and DC voltage and amperage, along with resistance and frequency. Shown with an optional clamp-on current probe for measuring higher amperage. US$20–300

Access

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Quick Cable Corporation, 3700 Quick Drive, Franksville, WI 53126-0509 • 800-558-8667 • Fax: 800-733-8611 • sales@quickcable.com • www.quickcable.com • Large crimper

Thanks to our friends at Consolidated Electrical Distributors (CED) in Medford, Oregon, and Ashland Hardware in Ashland, Oregon, for letting *HP* Art Director Ben Root photograph some of the shiny new tools off their shelves, instead of the well worn and weathered tools on my truck.

What the Heck? 17

Wire Nut

Used In: Electrical systems of all types

AKA: Wing nut connectors, yellows, reds, blues, and greens

What It Is: An insulated, twist-on connector for electrical wire

What It Ain't: Somebody who can't stay off a high wire; someone with a copper fetish

Need to join a few electrical wires? In many instances, you'll need a wire nut—a tough plastic connector that houses a plated steel spring or threaded copper insert, which helps twist wires together. In days gone by, electricians twisted wire by hand and used friction tape to insulate the connection. Then came plastic electrical tape—a more effective insulator that stuck to the wire better. Today, the *National Electrical Code* requires wire-to-wire connections be made with a mechanical device, such as a wire nut. The wire nut twists down on two or more wires to join them mechanically. The plastic shell insulates the connection.

Wire nuts are used in almost all wire-to-wire electrical connections for smaller gauge wire. (Larger wires like #4 typically call for different coupling hardware, such as split bolts.) Wire nuts are rated for the maximum and minimum wire size they can accommodate, and the number of wires they can effectively connect and insulate. These guidelines are typically printed on the packaging and should be followed to ensure a safe installation. Most wire nuts are recommended for use only in dry locations. If the connection may be subject to moisture, wire nuts rated for wet conditions must be used. Wire nuts suitable for direct burial also are available. (For more information on wire nuts and other electrical connectors, check out "Making Connections" in *HP 100*, page 100.)

Wire nuts come in a variety of colors, which represent different sizes. Each size accommodates certain gauges and numbers of wires.

To connect wires, strip back the wire insulation the length specified for the wire nut you're using (usually 1/2 to 3/4 inches). In one hand, hold the wires parallel, with the ends together. With the other hand, twist the wire nut over the bare wire ends until the wire nut is tight. Gently pull on each wire encased in the wire nut to ensure a tight connection. Failure to check that the wires are secure is one of the biggest causes of electrical malfunctions, since a loosely connected wire is likely to break the circuit eventually, if not immediately.

Chuck Marken • chuck.marken@homepower.com

Intro to Hydropower

Part 3: Power, Efficiency, Transmission & Equipment Selection

Dan New

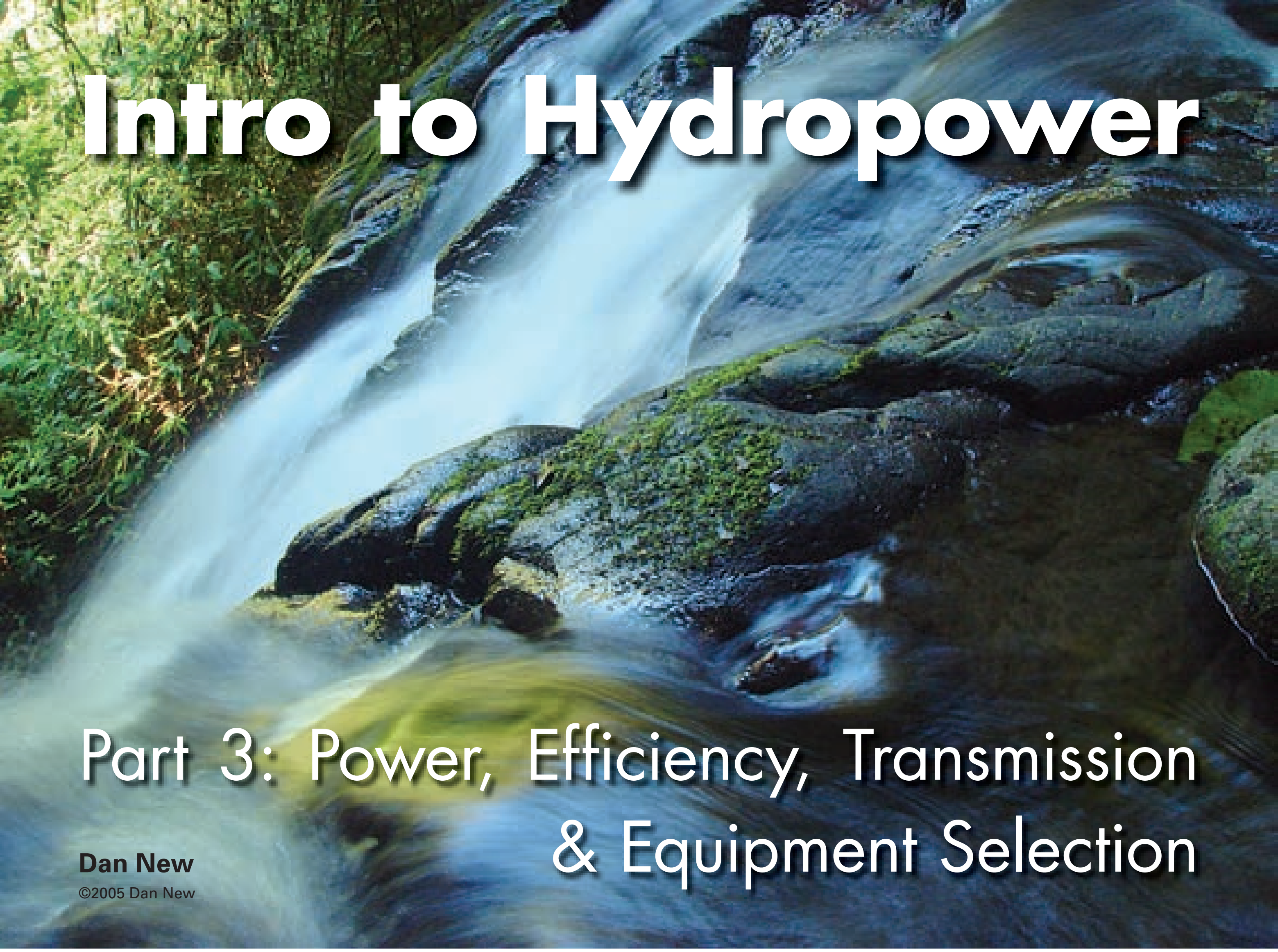

Photo courtesy of Eugenio Garcia Lopez

Compared to solar- or wind-powered systems, small-scale hydroelectric systems are almost always the least expensive way to make your own electricity. Most people don't have a stream with adequate flow and vertical drop, but if you do, pat yourself on the back. You're the envy of your renewable energy neighborhood!

In the first two articles in this series, I covered system components and design, and ways of measuring head (vertical drop) and water flow at your site. This time, I'll discuss calculating the power available from a given stream, system efficiency, options for transmitting electricity from your hydro turbine to your home, and several other factors that make a good hydro system.

Computing Water Power

Net head is the vertical drop from your pipeline intake to your turbine, adjusted for pipe friction (losses caused by water moving through a pipeline). Design flow is the amount of water you have to work with. See "Intro to Hydropower, Part 2" in *HP104* to learn how to measure these two important site variables. Once you've determined net head and design flow, you can begin to estimate the potential output of a hydro system. These computations are only rough estimates, and you should consult with your turbine manufacturer or equipment supplier for more accurate projections.

Both head and flow have a linear effect on power. Double the head and power doubles. Double the flow and power doubles. Keep in mind that total head will remain constant once your system is installed—you can count on it year-round. Increasing head is the least expensive way to increase power generation because it has minimal effect on turbine size. You can increase head by going higher up the creek to place the intake, or lower down for the turbine. Don't overlook the head that you have on your property.

In contrast, flow will likely change significantly over the course of a year, and it's rarely cost effective to size your hydro system for maximum, flood-level flow. *Always maximize head*, and work with your turbine supplier to determine the most practical design flow.

Accuracy is important! The design of your system revolves around your measurements of head and flow, and errors will directly affect the efficiency of your system. Take the time to measure head and flow carefully before you begin to evaluate hydro system components.

Efficiency & Losses

In addition to pipeline losses, small amounts of energy will be lost through friction within the turbine, drive system, generator, and transmission lines. Although some efficiency losses are inevitable, don't underestimate the importance of good design. Efficient systems produce greater output, often at a lower cost per watt. A system that is carefully matched to your site's head and flow usually won't cost any more than a less suitable design. But it will be much more efficient, producing more electricity from your available resource. Other improvements, such as larger pipeline diameter or a better drive system may yield enough added power to justify their higher cost.

Because of the many variables in system design, it is impossible to estimate efficiency without first knowing your head and flow. As a general guideline, however, you can expect a home-sized system generating direct AC power to operate at about 60 to 70 percent "water-to-wire" efficiency (measured between turbine input and generator output). Smaller DC systems generally have lower efficiencies of 40 to 60 percent, though recent testing by *Home Power* shows that some small turbines can achieve efficiencies in the low 70 percent range, depending on the system and electronics. If you have accurate measurements for your head and flow, your turbine supplier will be able to provide some preliminary estimates of efficiency, as well as ideas for optimization.

A Rough Formula

You can get pretty nerdy with power calculations for hydro systems. For larger systems, this is certainly justified, and any supplier worth dealing with can crunch the numbers. But when you're just getting an idea of the potential of your site, what's needed is a simple formula.

Net Head x Design Flow ÷ Adjustment Factor = Power in Watts

If you multiply the net head in feet by the flow in gallons per minute and divide by an adjustment factor, you'll get the continuous potential power output of the turbine in watts. Use a factor of 9 for AC systems, and a factor of 10 to 13 for DC systems.

So if you have 100 feet (30 m) of head and 200 gallons (757 l) per minute, using 10 as the factor, you'll get roughly 2,000 watts, or 2 KW. Multiply that by 24 hours in a day and you have 48 KWH per day (which is a lot).

Transmission

The last important measurement is the distance between your generator and either your battery bank (for DC systems) or where you'll be using the electricity (for AC systems). As with your pipeline, all you need to do is measure the distance along the route you plan to run your wiring.

Transmission lines are a lot like pipelines. Instead of moving water, they move electrical energy, but the same fundamentals of friction losses apply. Longer transmission lines, higher current, lower system voltage, and smaller wires all contribute to energy losses. You can minimize these losses, but the electricity you can actually use will always be somewhat less than what your system is generating.

There are three ways to reduce or compensate for transmission line losses:

- Use a shorter transmission line
- Use larger wires
- Increase the voltage on the transmission line

Shorter lines and larger wires will reduce line losses for any system, but voltage considerations are significantly different between DC and AC systems. Transformers may be used to reduce wire size in long transmission lines, and step-down, MPPT controllers can allow your turbine to run at high voltage while charging your battery at a lower voltage. Your turbine supplier can help you determine the best solution for your site.

Example DC system

Gross head: 135 feet (41 meters)

Measured flow: 25 to 100 gpm, (1.6 to 6.3 l/s)

Pipeline length: 900 feet (274 m)

Gross power: 350 to 1,200 watts

A DC, battery-based system with an inverter is the best choice for a hydro site with the above parameters. If an AC turbine were used, peak usage would be limited to about 1,200 watts at peak flow. This peak power figure would not be sufficient to run the combined electrical loads of most households. Installation of a turbine with DC output would allow energy storage in a battery bank, and an inverter or inverters would be able to provide as much instantaneous power as was required by the residence.

With a design flow of 100 gpm, using 3-inch diameter PVC pipe would result in a head loss of 2.33 feet per 100 feet of pipe, for a net head of 114 feet (35 m), and a maximum power output of about 1,200 watts at maximum flow. Over a 24-hour period, this system would produce 28.8 KWH. As summer approached and the flow rate dropped off to the site's minimum of 25 gpm, the same 3-inch pipe would result in a net head of 133 feet (41 m), and a power output of about 350 W, or 8.4 KWH per day. This would typically be enough energy to power all the electric appliances in an efficient home, excluding cooking, space heating, and water heating.

Example AC System

Gross head: 230 feet (70 meters)

Measured flow: 220 gpm to 900 gpm (14–56 l/s)

Pipeline length: 1,700 feet (518 m)

Gross power: 5 to 20 KW

Clearly, a direct-generating AC system could be built at this site. The flow range could support development of a 5, 10, or 20 KW system, depending on the selection of pipe diameter. As an example, by choosing 6-inch diameter PVC pipe and planning on a design flow of 450 gpm (28 l/s), head loss would be about 1.3 feet per 100 feet of pipe, for a calculated net head of 208 feet (63 m), and an expected system output of 10.5 KW. This would be a very nice system to supply all the energy needs of a home/shop/greenhouse complex.

What Makes a Quality Hydro System?

Think of a hydroelectric system in terms of efficiency and reliability. In a perfect world, efficiency would be 100 percent. All the energy within the water would be transformed to the rotating shaft. There would be no air or water turbulence, no mechanical resistance from the turbine's bearings or drive system, and the runner would be perfectly balanced. The signs of energy loss—heat, vibration, and noise—would be absent. Of course, the perfect turbine would also never break down or require maintenance.

Obviously, no turbine system will ever achieve this degree of perfection. But it's good to keep these goals in mind, because better efficiency and reliability translate into more power and a lower cost per watt. Quality components and careful machining make a big difference in turbine efficiency and reliability. Here are just a few of the things to consider when selecting a turbine.

A 3.75-inch pitch diameter Pelton runner from Harris Hydro for high head, low flow sites.

Turbine Runner

The runner is the heart of the turbine. This is where water power is transformed into the rotational force that drives the generator. Regardless of the runner type, its buckets or blades are responsible for capturing the most possible energy from the water. The curvature of each surface, front and rear, determines how the water will push its way around until it falls away. Also keep in mind that any given runner will perform most efficiently at a specific head and flow. The type and size of your runner should be closely matched to your site characteristics.

Look for all-metal runners with smooth, polished surfaces to eliminate water and air turbulence. One-piece, carefully machined runners typically run more efficiently and reliably than those that are bolted together. Bronze manganese runners work well for small systems with clean water and heads up to about 500 feet (152 m). High-tensile stainless steel runners are excellent for larger systems or abrasive water conditions. All runners should be carefully balanced to minimize vibration, a problem that not only affects efficiency, but can also cause unnecessary wear on the turbine over time.

Turbine Housing

The turbine housing must be well built and sturdy, since it manages forces of the incoming water as well as the outgoing shaft power. In addition, its shape and dimensions have a significant effect on efficiency. For example, consider

The author inspects a 990-pound, 22-inch pitch diameter Turgo-style runner for an 880 KW turbine.

a Pelton-type turbine. As an impulse turbine, it is driven by one or more jets of water, but spins in air. This means that both hydrodynamic and aerodynamic forces must be considered in the design of the housing. It must minimize the resistance from splash and spray, and smoothly exhaust tail waters, yet also be sized and shaped properly to minimize losses due to air turbulence. Similarly, housings for high-flow designs like crossflow and Francis turbines must be precisely engineered to smoothly channel large volumes of water through the turbine without causing pockets of turbulence.

Look for a smoothly welded housing that is carefully matched to the proper runner for your site. Keep in mind that both the water forces and the runner will be producing considerable torque, so the housing material and all fittings should be heavy duty. Mating surfaces, such as pipe flanges and access covers, should be machined flat and leak free. Since water promotes rust and corrosion, make sure all vulnerable surfaces are protected with high-quality powder coating or epoxy paint. All bolts should be stainless steel.

Like this Energy Systems & Design alternator from a Stream Engine turbine, many small, DC, hydroelectric units now use more efficient, brushless, permanent magnet alternators.

Other Turbine Considerations

All surfaces that carry water can impact efficiency, from the intake to your pipeline to the raceway that carries the tail waters away from your turbine. Look for smooth surfaces with no sharp bends. Jets and flow control vanes should be finely machined with no discernable ripples or pits.

Efficiency is important, but so are durability and dependability. Your hydroelectric project should deliver clean electricity without interruption. The quality of components and their installation can make a big difference on the quality of your life in the years to come. Look for quality workmanship in the design and construction of seal systems, shaft material and machining, and all related components. Pay particular attention to the selection and mounting of bearings; they should spin smoothly, without grating or binding.

Alternator

In the past, most small, battery-charging, hydroelectric turbines relied on off-the-shelf alternators with brushes. These alternators work well, especially when a specific stator is chosen, based on the parameters of a given hydro site. Swapping out the stator optimizes the alternator's rpm, and increases the turbine's output. While these types of alternators are still used due to their low cost, they are not ideal. The major drawback is that the alternator's brushes need regular replacement. These days, brushless permanent magnet (PM) alternators are available, and are a better choice, since they eliminate the need for brush replacement. In addition, brushless permanent magnet alternators perform at higher efficiencies, increasing your hydro system's output.

Regardless of type, an alternator's output is always AC. The frequency of the AC will vary depending on the rotational speed of the alternator, which is a direct function of the pressure available at the turbine. This AC output is not usable as is, because AC appliances are designed to run at a specific frequency. Larger AC-direct turbines are designed to run at a specific speed (and therefore a fixed frequency), with governors to regulate the speed. The AC output of smaller, battery charging units is always rectified to DC, so the energy generated by the turbine can be stored in batteries. The system's inverter converts this DC to AC at a fixed frequency.

Alternative Power and Machine, Energy Systems and Design, and Harris Hydroelectric all manufacture turbines with brushless PM alternators. These alternators are very flexible in terms of their output voltage. The AC output of the turbine can be rectified to DC at the turbine for short transmission runs. High-voltage units operating at 120 VAC or higher can transmit the AC output of the turbine over longer distances. This AC output is then stepped down at the batteries to match the nominal battery voltage, and rectified to DC. In addition, transformers can be used to further step up the output voltage for transmission. Finally, the specific wiring configuration (delta, wye, etc.) of the alternator is flexible, allowing the output to be optimized for a specific hydro site.

For larger, AC-direct turbines, good quality alternators are available from a number of sources, and the reputation of the generator manufacturer is an excellent place to begin your selection process. Marathon Electric, Kato Engineering, and Stamford Newage, are all well known and respected small generator builders serving an international market.

For a household- or ranch-sized AC-direct turbine under 50 KW, you would normally choose a single-phase output, two bearing alternator. Quality alternators are available in a variety of voltages, phases, and output frequencies to match your local utility electricity. Three-phase units are selected for larger projects, for large motor loads, or complex distribution schemes.

If you are able to match your turbine speed to a common generator synchronous speed, then use a direct-drive coupling between the turbine shaft and generator shaft if

The balance of system components for a DC hydro system are very much like a photovoltaic system, except the charge controller shunts to a diversion load.

possible. It may be worth the investment in a slower speed generator to make this possible. If it is necessary to use a belt drive between the major components, then avoid two-pole generators, and pay the extra money to install a four-pole generator. Four-pole units have a 60-Hertz synchronous speed of 1,800 rpm, half the speed of the two-pole units, four times the weight, and six times the life. A standard feature in most industrial-quality generators will be an automatic voltage regulator (AVR). The AVR will maintain steady voltage over a broad range of generator loads.

In an AC hydro system, an electronic load governor automatically adjusts the load on the generator to maintain constant voltage.

Turbine Supplier

When it comes to suppliers, there is no substitute for experience. While the principles of hydropower can be mastered indoors, it is real world experience that teaches both the highlights and pitfalls of diverting water from a stream, pressurizing it, and forcing it through a turbine. A turbine supplier with many years of field experience will be invaluable as you design and build your hydro system.

Look for an experienced supplier that specializes in the size and type of hydro system you intend to build. A good supplier will work with you, beginning with your measurements of head and flow, to help you determine the right pipeline size, net head, design flow, turbine specifications, drive system, generator, and load management system. You should be able to count on your supplier to make suggestions for optimizing efficiency and dependability, including their effects on cost and performance. A good turbine supplier is your partner, and should take a personal interest in your success. After all, a satisfied customer is very good for business.

Next Steps

Armed with four essential measurements—head, flow, pipeline length, and transmission line length—you're ready to begin evaluating your site for a hydroelectric system. As we discussed in Part 1 of this series, there are many choices to make about DC vs. AC, intake designs, turbine types, etc. Many of these decisions will become obvious once your four measurements are complete.

Advice from turbine suppliers can be invaluable during your design process. If you provide them with your measurements, most suppliers will propose a system that is tailored to your site characteristics. You may find that a given supplier will specialize in certain types of systems (like DC or AC), but most are happy to refer you to someone else when appropriate.

Emphasize efficiency. Your head and flow determine how much raw water power is available, but efficiency determines how much of it you'll be able to transform into usable electricity. There are cost trade-offs, of course, but in many cases, a more efficient system will result in a lower cost per watt. This is especially important if you're thinking of connecting to the grid, where higher efficiency means more dollars in your pocket.

I hope you have found this series of articles on hydropower helpful. I've only scratched the surface of this substantial topic, but I hope I've whetted your appetite. As you've seen, the concepts behind hydropower are simple. Water turns a turbine, the turbine spins a generator, and electricity comes out the other side. Even a novice with little or no experience could produce some hydroelectricity—given enough water power.

Do you have a stream? Of the three most popular renewable energy technologies, hydropower delivers the most watts for the investment, and can be most accurately assessed. A few quick measurements will tell you if you have hydro potential. In any event, you'll have a great time playing in the water.

Access

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Harris Hydroelectric, 632 Swanton Rd., Davenport, CA 95017 • 831-425-7652 • www.harrishydro.com

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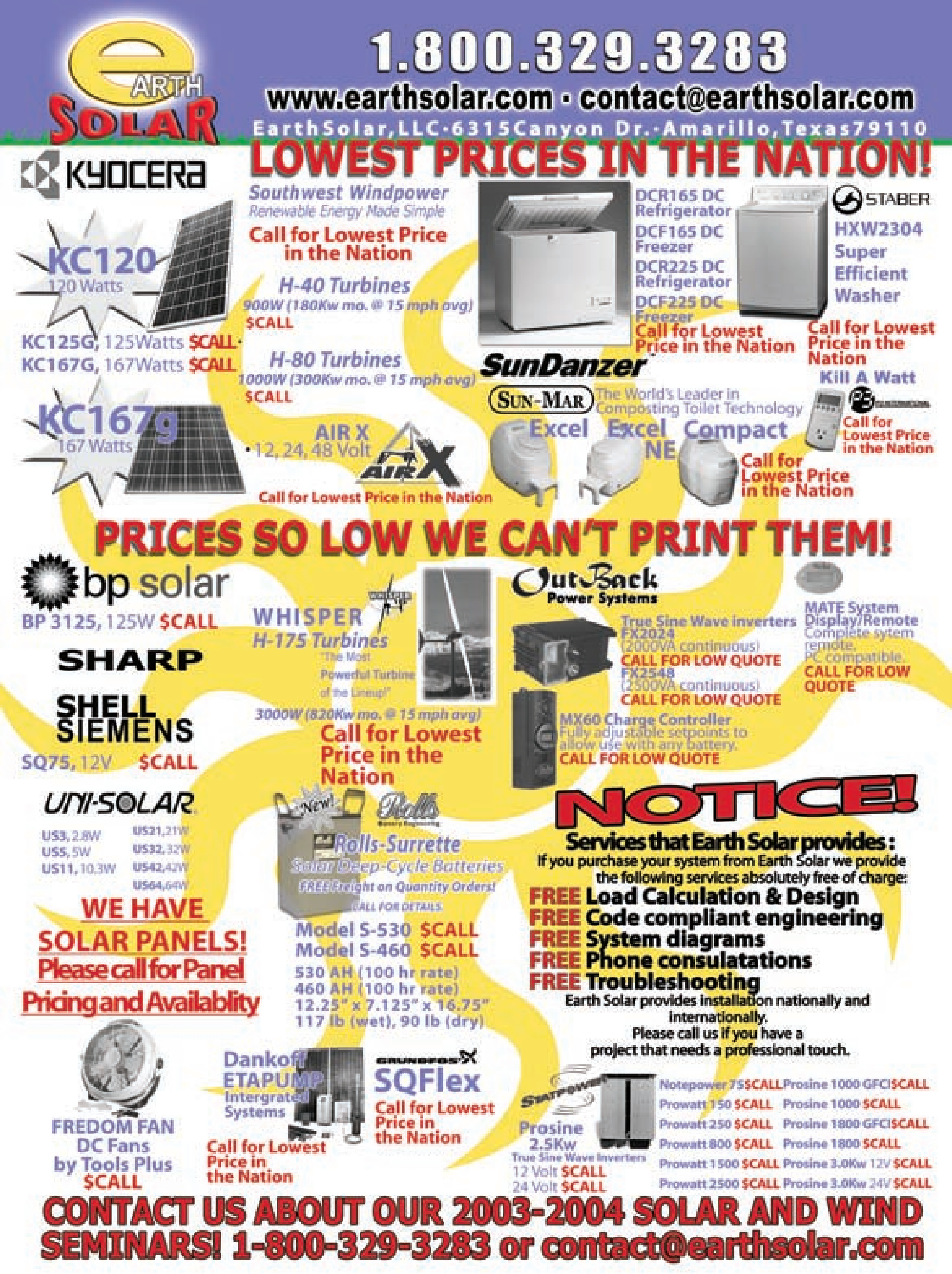
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Sun-Wise Design:

Avoiding Passive Solar Design Blunders

Dan Chiras, (Adapted from *The Solar House: Passive Heating and Cooling*)

Building or buying a home is a long-term financial commitment. Good passive solar design offers big payoffs in thermal comfort, energy efficiency, and conservation, with miniscule monetary commitment. Poor design has the opposite effect—it can obligate a homeowner to unnecessarily high energy bills and living in an uncomfortable house. The same holds for environmental performance. Over a structure's lifetime, well-designed buildings have less impact on the environment, while poor design results in a lifetime of high energy use and resource consumption.

Although solar designs have improved, an awareness of the lessons learned from the past is vital to the future of passive solar heating and cooling. By understanding the common problems, builders, architects, and designers can work diligently to avoid them—either in building new homes or when retrofitting existing ones.

Lessons Learned—The Hard Way

In the late 1970s, I purchased my first home, an attractive bungalow built in 1925. It wasn't a passive solar structure, but it had good southern exposure. Soon after moving in, I started to work on the house. I purchased solar collectors to heat domestic hot water. I removed some rather large, leaky north-facing windows, beefed up the attic insulation, and sealed air leaks. Next, I attached a small sunspace on the home's south side, my first attempt at passive solar heating. I based the design not on science and solar engineering, but on pure speculation.

Not surprisingly, the sunspace failed miserably. The reason? It was far too modest to meet my home's heating requirements. It did provide some warm air, but not enough to noticeably affect the home's temperature. Had I known more, I would have constructed a space commensurate to the home's square footage and installed a system to move air out of the sunspace that was more sophisticated than a portable fan.

Many other people experimented with passive solar heating in the 1970s and 1980s. Venturing boldly into the field, many of us designed intuitively. What could be so difficult about passive solar design? You concentrate windows on the south side of a house, provide overhangs for summer shade, insulate well, and then sit back and bask in the benefits of your labor. Trouble is, good passive solar heating design requires more than intuition—it requires understanding the concepts of orienting a home properly, balancing glazing and thermal mass, and allowing for good insulation and ventilation.

Blunder #1, Improper Orientation

A few years ago, a friend of mine called to ask if I'd assess a passive solar home she was considering buying. As we drove up to the house under question, my first impression was quite favorable. The house was on a nice, clear lot—no trees or hills obstructed the low-angled winter sun—and was built with a large thermal storage wall (also known as a Trombe wall). However, on the morning of that sunny September day, the owner revealed that he had started a fire in the woodstove to raise room temperature from a chilly 60°F (16°C). I was baffled. My own passive solar home was performing quite well, despite the frosty nights. Standing alongside the house, my puzzlement cleared when I realized that the thermal storage wall was on the *west* side of the house. The south side was an ordinary wood-frame wall without a single window for solar gain! Had the architect's compass been off?

The first and most important element in passive solar design is proper orientation. Ideally, a passive solar home should be oriented toward true south, exposing the greatest surface area and window space to the low-angled winter sun. The long axis of the home should run east and west. (Note that true south is not the same as magnetic south. In many regions of the country, magnetic north and south deviate significantly from true north and south.)

Bob was sure glad that he had a fireplace, because his fancy solar home never seemed to perform quite as he had hoped.

Blunder #2, Excess Shading

Ensuring that a home's south face can access sunlight is as critical as correct orientation. One of the most common problems is that people build their homes, and then plant trees on the south side. Some even plant evergreens. When they're small, the trees don't contribute much shade, but as they mature, they begin to reduce solar gain significantly.

Deciduous trees along a home's south side are less problematic than evergreens, because most lose their leaves in the fall and remain leafless throughout the wintertime. Some trees, like oaks, are not so cooperative—they tend to retain their leaves, shading throughout the fall and winter. But even leafless trees can block solar access. Limbs, branches, and tree trunks can produce wintertime shading levels between 25 and 50 percent. For maximum solar gain, keep the southern exposure tree-free.

South-facing windows collect no heat if the sunlight can't get to them.

Blunder #3, Overglazing

A local contractor who had grand ideas of helping reduce home energy use built my second home. I was especially excited about this house because it employed three different passive solar design features: direct gain, where south-facing glass admits the low-angled winter sun into a home's interior; an attached sunspace; and a thermal storage wall. The builder had oriented it properly, insulated well, and provided adequate mass, or so we thought. Additionally, the house had great solar exposure. The south-facing windows were exposed to the sun from 10 AM to 3 PM each day.

As well-thought-out as this home was, though, we soon discovered that the house had some fatal flaws. The builder had installed five large skylights, four of which were on the south-facing roof, and two large sliding glass doors in the west wall. In the summer, the skylights and west-facing sliders admitted an enormous amount of sunlight and heat, baking the house almost all day long.

In the winter, excess sunlight entering the house through skylights and south-facing glass and inadequate, poorly situated mass caused temperatures to rise into the mid-80s (29°C). I often walked around in shorts and a T-shirt during the dead of winter, and still felt as if I was about to spontaneously combust. The air inside the house was unbearably hot and dry.

The builder's overglazing zeal had more impacts on the house—the sliding glass doors were inexpensive models that leaked excessively during the winter, so at night they produced a bone-chilling draft. My wife and I installed a layer of Plexiglas magnetically attached to the door trim and a Warm Window insulated curtain to reduce this problem—at a cost of about US$400 for each slider. The skylights also permitted a lot of heat to escape at night. A layer of Plexiglas, mounted similarly on the interior, cut heat loss by about half.

As a general rule, the area of south-facing glass in passive solar homes should fall within 7 to 12 percent of the home's square footage. The more heat you need, the more south-facing glass. For optimal, year-round performance, designers and builders should also pay close attention to windows on the north, east, and west sides of homes. East- and north-facing glass should not exceed 4 percent of the total square footage. West-facing glass should not exceed 2 percent of the total square footage.

In a solar home in which solar glazing falls under the 7 percent mark, sunlight can satisfy 10 to 25 percent of a home's annual heat requirement. In solar homes with solar glazing greater than 7 percent, solar gain falls within the range of 25 to 90 percent. That is, homeowners can satisfy 25 to 90 percent of their annual heat requirement from the sun. Although 100 percent solar heating is possible, it is difficult to achieve. In all but the most favorable climates, some form of backup heat is required.

To prevent overheating in the winter, passive solar homes require thermal mass inside the structure. Mass absorbs and releases heat into rooms at night, helping to minimize temperature swings. In passive solar homes in which south-facing glass is less than 7 percent of the total square footage, no additional thermal mass is required. Incidental mass—mass in the structure, such as drywall, framing, and furniture—is usually sufficient. If solar glazing exceeds 7 percent, additional thermal mass is required.

A proper glass-to-mass ratio, for example, protects against unbearably hot room temperatures. High performance windows that have a high solar heat gain coefficient (greater than 0.5) reduce unwanted heat gain, heat loss, and leakage. For most climates, double- or triple-pane, argon-gas-filled window assemblies with warm edges (thermal spacers that reduce heat conduction through the frame) are advised.

Too much glass can cause huge temperature swings. Homes tend to overheat during the day, even in the winter, and get too cold at night, because windows lose considerable amounts of heat.

Blunder #4, Inadequate Overhangs

Many early passive solar homes and some more recent structures feature huge, two-story glass walls. I've visited three breathtaking examples lately. But after extolling the virtues of their homes, the owners all confided that they wouldn't build a home this way again. Why? One of the problems is that two-story, south-facing glass walls can lead to overheating in the winter.

Overheating also occurs in these homes during the swing seasons—the late spring and early fall—because of a lack of sufficient exterior overhangs. In the designs I've studied, the upper levels of glass are frequently protected by an overhang, but the lower levels are not. The result is that too much sunlight enters from the intermediate-angled sun.

In a single-story home with sufficient overhangs, sunlight penetration is controlled quite naturally. In the fall, as the sun angle decreases, sunlight begins to penetrate south-facing glass, but just deep enough to provide the small amount of heat generally required for comfort. In a two-story glass wall, the unshaded lower-tier glazing lets in more sunlight than is needed. Unless the lower story has been protected with an overhang or sufficient mass has been provided to absorb the excess heat, overheating is practically guaranteed. In a two-story glass wall, sunlight can even enter the lower windows during the summer months, greatly increasing the cooling load.

Nighttime heat loss can also be significant with this design. And huge expanses of glass are rather difficult to cover with window shades. Even if you can install shades, the second-story ones are often difficult to access and operate. As a result, many homeowners leave their glass walls unprotected in the winter, and suffer the consequences—discomfort and high heating bills.

The overhangs in this house provide adequate shading for the upstairs, but the ground floor bakes in the summer sun.

Blunder #5, Angled Glass

The rationale for sloped glass is that it permits maximum sunlight penetration during the winter months. With the glass set perpendicular to incident sunlight on the shortest day of the year, the house achieves maximum solar gain. Reflection of light rays, which occurs in vertical glass, is minimized.

Angled glass is one of those design ideas proffered by those seeking 100 percent or near 100 percent passive solar heating—and it is also valuable when trying to grow year-round in planters located along the south side of a house. If you don't provide angled glass for plants, you'll need skylights. Plants don't grow well behind vertical glass, especially in the summer when the sun cuts a steep arc in the sky.

Although angled glass has its benefits, the problems it creates are significant. Any time a window assembly is off-vertical, it is likely to eventually leak, especially if it is exposed to extreme temperature swings. Unshaded, tilted glass permits unwanted solar gain during the swing seasons and the summer, increasing cooling loads. Angled glass is not easy to shade—it is not conducive to overhangs and it is difficult to fit with internal shades. One of the only options you'll have is external shades, which are inconvenient and unappealing aesthetically.

Sloped glazing is hard to shade, often allowing too much heat gain in some seasons.

To beat the stratification of heat in his great room, Don...well, poor Don.

Blunder #6, Underinsulation

Insulation and reducing air leakage are the other keystones of successful passive solar design and passive cooling. Modern solar architects and builders pay close attention to them, and achieve levels that greatly reduce the heating and cooling loads of homes and other buildings.

Although windows perform admirably as solar collectors, the best-built, airtight, energy-efficient windows still permit massive amounts of heat to escape at night or on cold, cloudy days. In the winter, the period of solar gain is far shorter than the period of heat loss. In all homes, especially passive solar structures, insulated shades, and internal shutters are all well worth the investment. They insulate cold window surfaces that suck heat from a house, and may even diminish air infiltration around windows.

Insulate the ceilings, walls, floors, and foundation well, paying special attention to foundations and concrete floors that collect and store thermal mass—you won't want to lose this heat to the earth. Although many municipalities and counties have upgraded their insulation standards, most are still woefully inadequate. I recommend insulation levels 30 percent greater than the International Code Council's Model Energy Code.

Blunder #7, Inadequate Thermal Mass

In my second home, the thermal storage wall seemed to be the only feature the builder got right. But, as I soon found out, it too had some problems. Like many early Trombe wall designs, this one had been built with vents to move hot air from the space between the glass and the mass wall to the living space. In a vented thermal storage wall, hot air moves upward by convection, creating a thermosiphon effect, and ensures some daytime heating from a structure that otherwise provides mostly nighttime heat.

Unfortunately, we found that the Trombe wall had the opposite effect. After the sun stopped heating the thermal storage wall, a reverse thermosiphon was established, pulling warm air from the room. We solved this problem by permanently inserting foam blocks into the openings to block the flow of air. (Operable louvres were another possible solution, but daytime heating was not something this house needed.) My thermal storage wall worked perfectly from that day on.

Thermal mass is vital to the success of a passive solar home. It prevents overheating and reduces temperature swings at night by radiating stored heat into the room when the interior air temperature falls below the surface temperature of the mass. Any material that has the capacity to store heat can serve as thermal mass.

In most passive solar homes, thermal mass consists of masonry building materials such as poured concrete and concrete block walls, or earthen materials such as adobe floors and walls or rammed earth walls. Even plaster over a straw bale wall can serve as thermal mass. For effective thermal storage, the mass needs to be about 3 inches (7.6 cm) thick. Besides providing enough thermal mass, successful passive solar design means situating the mass properly to absorb and collect solar radiation.

Blunder #8, Poor Ventilation

A couple of years after we moved into our second house, during the house's fifth year of existence, the shingles on the roof began to buckle. When I examined the problem, I found that the roof decking and insulation were soaking wet. The builder had failed to install a vapor barrier and a roof venting system. As a result, water vapor from the home's interior had been migrating through the ceiling and insulation, condensing on the decking, and then dripping onto the insulation, dramatically reducing its effectiveness.

To solve the problem, I installed soffit vents and a ridge vent, and replaced all of the wet insulation. Vents allow air to circulate over the insulation, drawing off moisture that migrates through the ceiling. The retrofit cost several thousand dollars.

The lesson here is that controlling indoor moisture levels is crucial. Exhausting moist air at the sources with dryer vents, and kitchen and bathroom exhaust fans, and ventilating roof cavities can stop moisture problems at their source. Installing vapor barriers on the warm side of the insulation (interior side in heating-dominated climates) in walls and ceilings also will help reduce moisture problems. Applying latex paint to drywall also helps to reduce its permeability to vapor. The combination of the two can be quite effective.

What About Attached Sunspaces?

Attached sunspaces, while aesthetically pleasing, often prove to be a waste of space, and generally add little, if any, usable living space to a home. In the winter during the day, they're often drenched with sunlight and unusable, unless shaded. At night, sunspaces tend to be very cold and uncomfortable.

If they're designed with a considerable amount of roof glass, they'll end up baking in the sun and will require shading. It's also often difficult to transfer heat from a sunspace into a home during the winter. In my experience, direct gain systems and thermal storage walls work better for heating interior space. They also provide much more useful floor space than an attached sunspace.

Blunder #9, High Ceilings

Aesthetically speaking, I have to admit that part of my second home's appeal was its dramatic 20-foot (6 m) vaulted ceilings. But from a passive solar design performance standpoint, they were a nightmare. The vaulted ceilings permitted hot air to rise and dissipate through the skylights and the roof. At night, the lovely passive solar house that cooked us during the day, chilled us.

Although the builder had anticipated the problem of rising hot air and had installed two fans in wall plenums (metal ducts leading from the ceiling to the lower level) to distribute heat to the house's lower level, the fans were undersized and ineffective. I replaced them with larger models, but they barely made a dent in the problem. A ceiling fan we installed didn't help much either.

When designing a passive solar home, never lose track of the fact that hot air rises, and that moving hot air downward is extremely difficult. In most climates, high-ceilinged, passive solar homes are a poor design. You can install large, powerful fans, but they can be noisy and are often unable to move the volume of air that is needed to ensure comfort. They'll also require additional energy to operate, negating the chief goal of passive solar design—to use as little energy as possible.

High ceilings also mean there's a greater volume of air to heat in the house, and the more volume, the greater the heating load. The greater the temperature differences between the air at ceiling level and the outside air, the greater the heat loss through the ceiling. In this house, ironically, the high ceilings probably made the structure a bit more livable during winter days. Without them, the living room and dining room would have surely been much hotter. But there are other ways of ensuring comfortable temperature that don't spawn secondary problems.

Blunder #10, Sun Drenching

In many early passive solar homes, living spaces were often drenched in sunlight during much of the heating season. Although these designs provided plenty of heat, rooms were so brightly illuminated that they often became unusable during the daylight hours. Excess sunlight can produce glare that can make TV or computer monitor viewing difficult, uncomfortable, or even impossible. Sunlight can bleach carpets and furniture, too. Many a disappointed homeowner has turned to heavy window shades to block the sun, a measure that dramatically cuts down on solar gain.

Fortunately, some simple design strategies can ensure solar gain while producing sun-sheltered spaces. Planters, hallways, partition walls, entryways, and other design features may all be used to create sun-free zones. Sunlight can also be directed into interior stairs where a brightly lit interior meets little, if any, objection. Trombe walls are extremely effective in reducing sun drenching. Clerestory windows can be used to deliver sunlight to back walls of a room.

Future Passive Solar Design

Despite past problems, passive solar heating is moving forward on much more solid footing. Although there is more to be learned, the new generation of informational resources delivers considerably more science and engineering to the task. New resources are available to assist you in the design of energy-efficient, passively conditioned homes. Publications such as *Home Power* and *Solar Today*, and computer software like Energy-10 are just a few of the dozens of resources aimed at helping architects and builders develop cost-effective, energy-efficient, low-impact passive solar buildings.

Access

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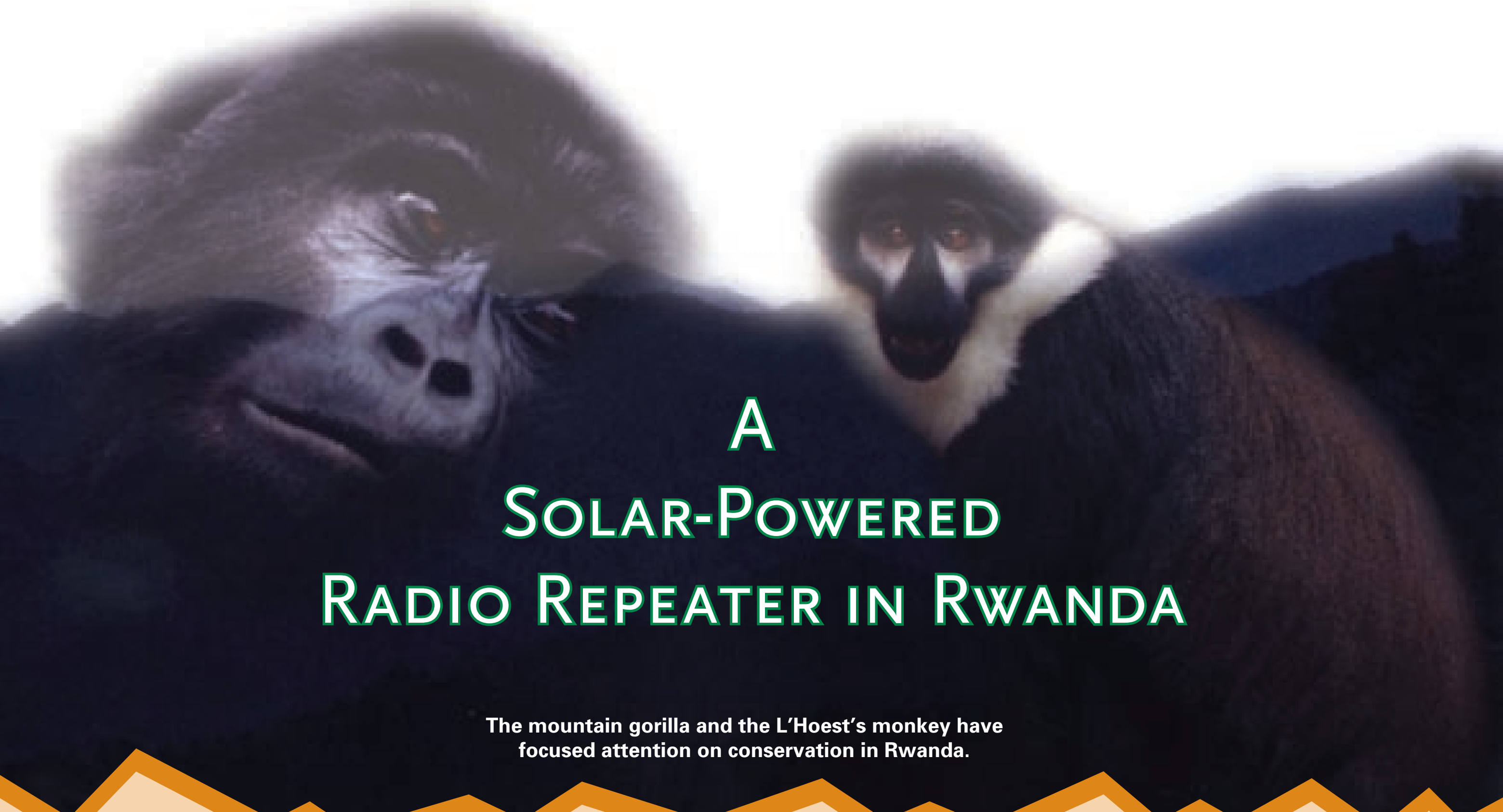
The Solar House Daniel Chiras, 2002, Paperback, 288 pages, ISBN 1-931498-16-4, US$29.95 from Chelsea Green Publishing, PO Box 428, White River Junction, VT 05001 • 800-639-4099 or 802-295-6300 • Fax: 802-295-6444 • info@chelseagreen.com • www.chelseagreen.com

Sustainable Buildings Industries Council, 1331 H St. NW, Suite 1000, Washington, DC 20005 • 202-628-7400 • Fax: 202-393-5043 • sbic@sbicouncil.org • www.sbicouncil.org • Energy-10 software

On Top of Mt. Bigugu

Simon Camp



A Solar-Powered Radio Repeater in Rwanda

The mountain gorilla and the L'Hoest's monkey have focused attention on conservation in Rwanda.

On top of Rwanda's Mount Bigugu, a solar-powered radio repeater allows Nyungwe National Park staff to communicate with each other in the remote forest region. This is not a story of a high-tech, state-of-the-art installation with many bells and whistles. It's the story of a simple renewable energy system that works in a remote, harsh environment.

Rwanda is a country still recovering from one of the most violent and unimaginable wars that this world has known. In just 100 days in 1994, more than 800,000 people were slaughtered. Practically no one was left unscarred, either physically or psychologically. Today Rwandans are striving to make their lives and country better. A handful of individuals are pushing renewable energy in an attempt to bring development and sustainability to Rwanda.

In August 2002, I first arrived in Rwanda, where my wife was conducting her graduate research on chimpanzees as seed dispersers. We lived in the Nyungwe National Park located in the southwest of the country, close to the Democratic Republic of Congo. The Nyungwe National Park is one of the largest (more than 1,000 km^2; 385 square miles) and most important montane rainforests remaining in central Africa, with a wealth of wildlife and breathtaking views.

I was aware that the conservation organization we would be working with, Conservation Project of the Nyungwe Forest (PCFN), had some solar-electric equipment that was not being used. I hoped to help them design and install a photovoltaic (PV) system using the equipment they already had.

I had installed a number of remote PV systems before, while working with the Drill Rehabilitation and Breeding Center (DRBC) in Nigeria. The DRBC is a conservation project dedicated to the survival of the highly endangered drill monkey, *Mandrillus leucophaeus*. With my experience, I felt I was in a good position to help PCFN.

The beginning of the trail—only three hours to go!

Location, Location, Location

When I arrived at the research and tourist camp in the Rwandan forest, I noticed four Siemens M55 panels perched on top of a rather precarious pole mount. Since the war, all the other equipment had either been stolen or broken, but the four panels remained functional, though they were doing nothing. Mr. Ian Munanura, Director of PCFN, and I decided that the best use of the panels would be to power the radio repeater located on top of Bigugu, the tallest mountain in Nyungwe National Park.

PCFN has a network of Motorola hand-held and base-station radios throughout the park. Due to the terrain and the size of the park (Rwanda is known as "Milles Collines" or "thousand hills"), a repeater is needed for reliable communication. The repeater was originally installed on Bigugu three years earlier, and was powered by three truck-starting batteries. They were charged with a generator and then carried for three hours up the mountain!

Imagine carrying a 50-pound (23 kg) battery on your head for three hours to an altitude of 2,950 meters (9,680 feet)! Needless to say, this was not done very often, so the batteries were completely discharged by the time they were bought back down again. This is a sure way to quickly kill a lead-acid battery. The first time I checked the system, the batteries' voltage read 3.2 volts! Not surprisingly, the repeater had not been working for a long time.

System Design

In tropical developing countries, many of the design factors for a PV system differ considerably from more temperate areas. In Nigeria, I learned very quickly that when you are close to the equator, the sun actually moves through both the northern and southern sky, depending on the time

Martin Nsengumuremyi helps the author check that the array fits on the frame before everything is hauled up the mountain.

of year. Unless completely horizontal, a fixed array can literally have the sun behind it for four months of the year! As a result, I made a wooden array mount that is adjustable for both tilt and rotation. In my experience, it is well worth making fully adjustable mounts when working with PV in areas near the equator.

Then there is the issue of the seasons. The difference between the solar resource during rainy and dry seasons can be as much as eight sun hours a day. Sizing a system to work in the middle of the rainy season means that in the dry season, you can probably add a fridge, a stereo, and maybe even a clothes dryer if you really feel the need!

The summit of Bigugu is an exposed mountaintop from which, on a clear day, you can see almost all of Lake Kivu to the west and the Virunga Volcanoes to the north. The altitude has advantages and disadvantages. All of the tree species are dwarfed, so shading is nonexistent, but during the rainy season, the summit can be shrouded in clouds for several days at a time.

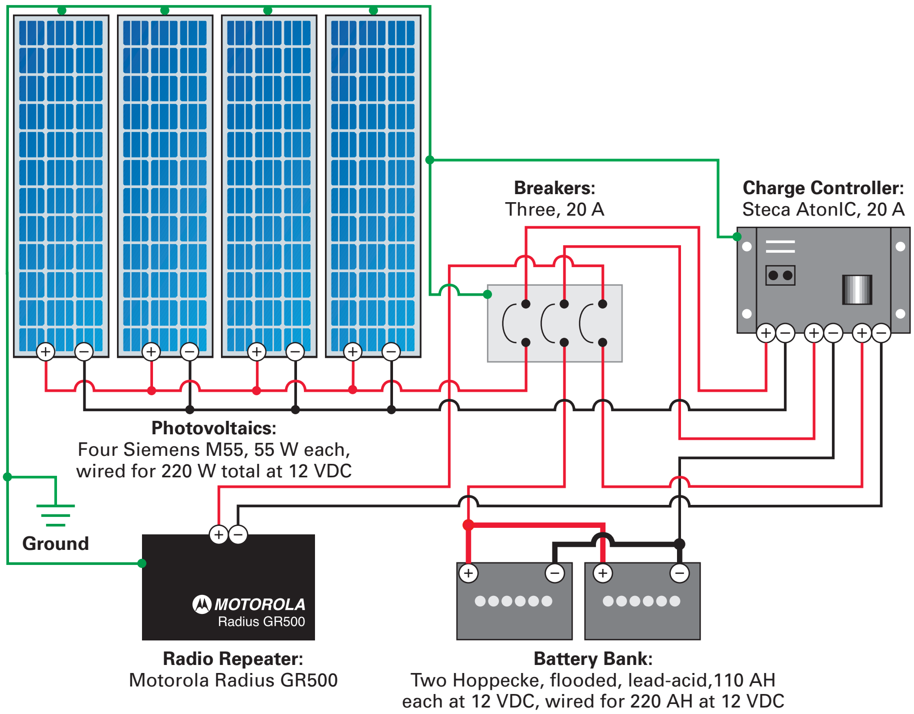
With no data on insolation, I needed to find out how much sun we could expect. I made up a simple sheet with three columns depicting full sun, sun and clouds, and full clouds. Two guards live permanently at the summit of Bigugu to protect the radio equipment and the surrounding forest, since this area is frequented by poachers. After a little explaining to the guards who live at the summit, I had them agree to record weather data for me, checking the sky every 30 minutes and marking the corresponding column on the sheet.

At the summit on a sunny day—one of the guards stands behind their rather humble dwelling.

With some simple calculations, I found the approximate number of sun hours each day. I compared a few weeks of data collection to a heliograph at the research center, and they were consistently within half an hour of each other. The bad news was that between October and December, the summit of Bigugu averaged only 1.2 sun hours.

The repeater was to be the only load, and at 12 volts, it draws 1.2 amps at rest and 6 amps when people are using the radios. It is switched on from 8 AM until 6 PM every day. An estimate of three hours was made for the total time each day that the radios were actually in use. This gave us an average draw of 26.4 AH over the course of the day. The Siemens M55 is rated at maximum output of 3.14 amps, so with four panels in parallel and the rainy season average of two hours of sun a day, we were actually just under the required power.

The PCFN Radio Repeater System



We discussed the possibilities and decided that buying another panel was not an option due to restricted funds and local costs. Because the radio is not an "essential load," we opted instead to install a Steca AtonIC 20-amp controller with a low voltage disconnect (LVD) so that in prolonged periods of poor sun, the controller would regulate the use of the repeater. The meter also included three state-of-charge indicator lights. We bought two new Hoppecke, 110 AH, deep-cycle batteries. Connected in parallel, they would give us enough storage for two or three days without sun.

Putting It All Together

In many ways, determining our needs was the easy part. While renewable energy is still a very young technology in Rwanda, there are two large and well-equipped solar energy stores with knowledgeable staff. Unfortunately, costs remain very high, making renewables cost prohibitive for the majority of the population. Kigali is the bustling capital city of Rwanda, and here we found SECAM, one of the two stores that deal in renewable energy. From SECAM we purchased the batteries, controller, and the necessary cables.

Everything was ready, and all that remained was getting all the gear to the summit. We were in the middle of the rainy season, and as the installation day approached, I nervously watched Bigugu, hoping the big gray clouds would break for at least one day.

The day arrived with a beautiful blue sky and some wispy clouds passing in the breeze, but we knew that could change very quickly! Our crew of porters showed up eager for work—even one day of work is a precious commodity in such a poor country—and we drove out to the trailhead. A

The very simple setup inside the radio repeater room.

Despite being very cold and wet, everyone was happy when we had finished the installation.

small sign warns of the impending hardship: "Mt. Bigugu, Pointe Culminant de Nyungwe 2,950 m." The trail starts with 30 minutes of hard climbing, difficult with just a backpack and some tools. I couldn't even imagine attempting the journey with a 50-pound battery on my head. Thankfully, the main portion of the path follows an old road and climbs gradually most of the way to the summit.

Monkeys and birds are often seen, and occasionally chimps, but this day we were not there to look for wildlife. The final hour is another steep ascent. As we climbed higher, we began to notice wispy clouds blowing through the trees and the temperature dropping. By the time we arrived at the summit, we were totally immersed in cloud, and a light rain had started to fall. Very soon, there was a strong wind, heavy rain, and most definitely no sun! Not exactly the most uplifting conditions for installing a PV system.

Most people huddled around a small fire trying to stay warm, while PCFN employees Martin, Jean-Baptiste, and Anastase helped me put everything together. Other than the cold and the rain, the installation was relatively simple. Within an hour, we were ready to switch the repeater on again. We had hoped to have a small ceremony, but for fear of frostbite, we skipped the formalities. The conservator of the park, Benjamin, tried the radio, and for the first time in months, communication over long distances was again possible.

The last and most important issue was training the guards to operate and maintain the system. With PCFN director Ian acting as translator, I described how to adjust the panels to follow the sun's path. We discussed system safety and when and how they should switch different components on and off. Then we quickly departed and made our way down the mountain while we still had feeling in our legs.

Over the next few months, I returned regularly to the summit to check the system, becoming more fit every time!

PCFN System Costs

Item	Cost (US$)
4 Siemens M55 modules	$2,000
2 Hoppecke batteries, 110 AH	470
Steca AtonIC controller, 20 A	133
Circuit breakers	50
Cables, connectors, & misc.	30
Mount materials	10
System Total	$2,693

Tech Specs

System type: Off-grid PV

Location: Mt. Bigugu, Rwanda

Solar resource: 8 average daily peak sun hours (dry season), 2 average daily peak sun hours (wet season)

Production: 30 DC KWH per month average

Photovoltaics

Modules: Four Siemens M55, 55 W STC, 12 VDC

Array: 220 W STC, 12 VDC nominal

Array installation: Ground mount, adjustable tilt and rotation

Balance of System

Charge controller: Steca AtonIC 20 A with a low voltage disconnect and battery voltage monitor

Overcurrent protection: 20 A array breakers, 20 A load breaker

Energy Storage

Batteries: Two Hoppecke, flooded, lead-acid, 12 VDC, 110 AH at 20-hour rate

Battery pack: 12 VDC nominal, 220 AH total

I was pleasantly surprised to find that even after a few days of heavy cloud cover, the batteries were still maintaining an average 12.5 V under load. With practice, the guards became efficient at positioning and tilting the panels for maximum exposure to the sun.

The Future

I left Rwanda at the end of January 2003 with many good memories and plans for the future. I hope to return to the Nyungwe National Park to install PV systems at each of the remote ranger stations, completing the network of reliable communication throughout the park. At that time, I will assess the PV requirements for improving facilities for tourists, staff, and researchers at Uwinka, the main research and tourist base camp. This work will be in collaboration with the Wildlife Conservation Society (WCS), a leading international conservation organization, based at the Bronx Zoo in New York City. PCFN was founded by and continues to run under the direction of WCS.

As Rwanda continues to heal the wounds of the past, it is truly amazing to see its people remain so positive, so warm and inviting, and so dedicated to improving their lives and conserving their country's natural resources. It is my wish that education and involvement with renewable energy will be one way for Rwanda to move towards a more prosperous and sustainable future.

Many dedicated individuals are working hard to ensure that this happens. Rwanda and the Nyungwe National Park will always hold a place in my heart. I want to be lucky enough to spend much more time there in the future. If you ever have the chance to visit, it is truly a jewel in Africa too often missed.

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ROOF-INTEGRATED PV

From Sunbeam to Standing Seam

William Ball

Building Arkansas' first super-efficient home was challenging on many fronts, as was outlined in "Our Long & Winding Road to a Solar Home" in *HP104.* I knew the home was sure to receive a lot of attention, and most Arkansans have had very little exposure to solar-electric (PV) applications. Because of this, I felt it was important to not only have a system that would perform well—it also had to look good.

The average person considering PV may confuse thermal collectors with solar-electric modules. Even those who know what PVs are may still envision solar-electric systems as a collection of clunky PV panels stuck on a rooftop at some awkward angle. Fortunately, improved low-profile mounting hardware, larger modules, and other features can combine to present a clean, attractive look to a crystalline, roof-mounted array. Because of the demonstration nature of this home, however, I wanted to take things up another notch by using a roof-integrated, rather than roof-applied approach.

The south-facing roof provides optimal sunshine for 5.4 KW of Uni-Solar PVL-128 laminates. The trees in the foreground are off to the east side of the house, and don't shade the array.

Making the roof panels on site.

What's That Up on the Roof?

Back in 1998, I incorporated 1 KW of Uni-Solar SHR17 PV shingles onto the building that now houses our showroom and warehouse. While the shingles held up well, the numerous connections required with the 17-watt, 6-volt format was a lot of work. The next year, during the Y2K scare, my company designed and installed more PV backup power systems in one year than in the entire history of the company. Almost every one consisted of either crystalline or amorphous modules rack-mounted on the roof.

While the crystalline efficiencies required less space and had better warranties, in my experience the amorphous produced 5 to 10 percent more energy per rated watt over the year in Arkansas' sometimes cloudy climate. The amorphous efficiency in low light would be important when trying to "net out" in December and January. I decided that the amorphous Uni-Solar PVL-128 laminate, integrated onto an architectural standing seam metal roof was just what I needed. A combination of available space on the roof and energy requirements for the home led to a design incorporating 42 of the PVL-128 laminates for an array rated at 5.4 KW.

The laminates arrived coiled and well packaged in boxes containing about ten laminates per box. While they are durable and flexible, they should be handled with a degree of care to avoid creasing. The application of the laminates is fairly simple, but it's important to be prepared to do the job.

We built a temporary workbench that would accommodate the full length of the standing seam roof panels. Each roofing panel was placed on the bench and wiped down with alcohol to ensure that it was free of any oils or dirt. Next, we laid a PVL in position with the backing paper intact. Once this is done, the ridge end of the laminate is lifted about 16 inches (40 cm) and the backing paper is peeled back to expose the adhesive. The laminate end is then laid down and the adhesive back is adhered to the first 16 inches of the roof panel. The PVL is then rolled up from the opposite end to the point where the 16 inches is adhered. The end of the backing paper is peeled back as the laminate is carefully rolled into position.

Care should be taken to keep the laminate straight as it is unrolled. Once it contacts the roof panel, it is there to stay, and cannot be pulled up and realigned. The laminate is then pressure-rolled to assure full contact with the roof panel. The roller is constructed of hard rubber and is typically used to install plastic laminate countertop material. We were all a bit nervous with the first few laminates, but once we got the hang of it, the job proceeded with no problems.

Next, the roof panels were installed with the help of a professional roofing crew. The wire leads from the laminates hang neatly under the ridge cap, ready for connection. The leads can also come out at the eaves, which may be an option if the eaves are not too far from the ground and a suitable removable access trim can be designed into the eave construction. This option may also be attractive in the case of a vaulted ceiling that has limited or no attic space. In our application, a walkway above the blown insulation in an attic with plenty of headroom made the ridge the logical location.

The PV laminate requires 16 inches (40 cm) of flat pan between the roofing seams. The laminate is available with prewired plug-and-play (MC) connections or with a field-

Peeling the backing from the end of a Uni-Solar laminate before adhering it to the metal roofing.

applied J-box that encloses screw terminals. The prewired leads require less space, and the J-box requires a standing seam of 1 5/8 inch (4 cm).

Dollar per watt, the laminates were comparable to conventional modules, and there was no mounting hardware. If there is a drawback to the system, it is the added cost of the metal roof. Our next decision was which grid-tie inverter to use.

Batteryless or Backup? Both!

With any solar-electric installation, proper sizing of the array and components is key to a successful project. Energy efficiency is vital in the design of a home to keep the KWH requirements low. Squeezing the most out of the PV system is important as well, considering that it will be producing energy for twenty years or more.

I knew that SMA's Sunny Boy string inverters were developing a strong record of reliability, and operated at a peak efficiency of 94 percent. If the only goal was to net meter, the Sunny Boy was the one. Three strings of fourteen series-connected laminates would deliver the desired voltage range with only three source circuits coming down from the roof.

In most locations, utility outages are uncommon, and a backup electricity source is unnecessary, provided that a home's electrical loads aren't critical ones. But Arkansas is subject to severe ice storms, which mean utility outages, sometimes for days and even weeks. The Sunny Boys are not designed to provide backup during utility outages, and shut down when the grid goes down. Xantrex's SW inverters can provide reliable backup, but aren't nearly as efficient as Sunny Boys for grid-tie applications. Sunny Boys require 250 to 600 VDC; SWs need 24 or 48 VDC.

I needed to design a system that incorporated the best of both worlds. I wanted the ability to send 330 VDC nominal to the Sunny Boy inverters or, with the throw of a switch, divert the PV output at battery voltage to serve backup loads via the SW inverter. OutBack Power System's segmented breaker was the answer. The breaker terminals on the six segments can be wired 48 volts in series for a nominal 300 V output, or in parallel at 48 volts to combine separate inputs to a charge controller.

Rolling the PV laminates to ensure complete adhesion.

Ball System Calculations

System Computations

Max AC amps (everything on)	64.9 A
Max AC load watts	7,788 W
Battery voltage	24 V
Daily KWH load	17.74 KWH
Daily amp-hour load	739.2 AH
Days of no sun (autonomy)	1
Max battery depth of discharge (DOD)	50%
Available battery capacity at 50% DOD	12 KWH

PV Sizing

	Winter	Summer
Peak sun hours per day	3.4 hrs.	5.5 hrs.
Module watts	128 W	128 W
Module volts (nominal)	24 V	24 V
Array voltage (nominal)	48 V	48 V
Array watts (recommended)	5,218 W	3,225 W
Modules needed	41	25

Battery Sizing

Cell voltage (nominal)	2.0 V
Cell amp-hours	1,000 AH
Cells needed for system voltage	12
Cells needed for required battery capacity	12

Wiring Details

This meant dividing the 42 PVL-128 modules, rated at a nominal 24 volts, into twenty-one series strings of two, coming in at a nominal 48 volts. This also meant some extra costs for a spool of #10 (5 mm^2) USE-rated wire for the source circuits. Each PVL-128 module has a short circuit

Ball Load Calculations

AC Loads	Volts x	Amps =	Watts x	Factor* x	Hours =	KWH/ day
Refrigerator	120	4.0	480	1.35	5.0	3.24
Freezer	120	1.5	180	1.35	3.0	0.73
Fan	120	0.6	72	1.35	8.0	0.78
CF lights	120	0.2	24	1.35	30.0	0.97
Incandescent light	120	0.5	60	1.35	25.0	2.03
Furnace blower	120	3.0	360	1.35	6.0	2.92
Washing machine	120	4.0	480	1.35	2.0	1.30
Gas clothes dryer	120	4.0	480	1.35	2.0	1.30
Microwave	120	9.0	1,080	1.35	0.5	0.73
Blender	120	3.4	408	1.35	0.1	0.06
Hair dryer	120	8.0	960	1.35	0.1	0.09
Toaster	120	9.0	1,080	1.35	0.1	0.15
Vacuum cleaner	120	5.0	600	1.35	0.1	0.10
Iron	120	9.0	1,080	1.35	0.3	0.44
Sewing machine	120	0.7	84	1.35	0.2	0.02
Computer	120	2.0	240	1.35	6.0	1.94
Stereo/TV	120	1.0	120	1.35	6.0	0.97
		Total	7,788		Total	17.74

*Battery-based system efficiency factor

current (I_{sc}) of 4.8 amps and a maximum power voltage (V_{mp}) of 33 volts. When two are connected in series, the current remains the same and the voltage doubles.

The design required a combiner box to accommodate twenty-one separate positive leads, each connected to a fuse block with an 8-amp Littelfuse KLKD008. To reduce the number of circuits, the output from two side-by-side fuses was linked in parallel with a short jumper. This configuration allowed for two separate taps, one to the segmented breaker to be connected in parallel and one to the segmented breaker connected in series. Each of the negative leads coming in were first isolated, then combined and tapped in the same manner using a terminal strip mounted on DIN rail.

The nominal 330 VDC output from the segmented breakers connected in series could then be connected to the DC input terminals on the Sunny Boy inverters. The segmented breakers serve as the DC disconnect, and the Sunny Boy inverter contains the PV ground fault interrupt (PVGFI) within the unit, which is required when PVs are mounted on the roof of a dwelling.

The output from the segmented breakers connected in parallel was routed first to a Xantrex PVGFI before continuing on to two maximum power point tracking (MPPT) charge controllers. This was necessary because neither the charge controller nor the backup power inverter has an integrated ground fault interrupter.

By using Blue Sky Energy's (formerly RV Power Products) SB6024HDL MPPT charge controller, we are able to charge a 24-volt battery bank from the nominal 48 volts coming in from the paralleled segmented breaker. A Xantrex PPSW4024 inverter connects to the battery for the backup power circuits. For the 364 days a year that the grid is up, the PV can operate at maximum efficiency via the Sunny Boy inverters. For the times when we have an extended grid outage, the PV can be switched over to the Xantrex inverter for off-grid use.

Because the power rating of the two charge controllers is limited to 1,500 watts each, we diverted only about 3 KW of the 5.4 KW array to the battery. A 24 KWH (1,000 AH x 24 V) forklift battery was chosen for storage. It easily provides 10 KWH of backup to cover nuisance outages without switching the PV array, and is more than adequate for longer outages with the PV switched to charge the battery.

Moving into the Mainstream

For a period of about a month, the home was substantially completed except for the installation of the utility meter. During this time, the house operated in

Assembled PV-laminated roof panels ready to go on the roof.

the off-grid mode. It was rewarding to see the expressions of the various groups that came through when they saw no utility meter and realized that the PV array was providing all of the electricity being used in the house.

The 2,800 square foot (260 m^2) home has now been occupied for just over a year, and the PV array is providing 60 to 70 percent of the electricity. Including the monthly customer service charge and taxes, the electricity bill was between US$10 and US$20 per month from December through May. With the arrival of the air conditioning season, two months were around US$50. This is not too bad compared to the US$206 paid by the neighbor for about the same size home and usage.

When you do the math, the home's electric energy usage isn't costing the homeowners much. Unfortunately, with no state incentives and as of now, no federal tax breaks, when you continue the math, the traditional return on the US$40,000 investment is somewhere around 3 percent. But local RE enthusiasts are putting true value ahead of purely financial return. Two more super-efficient homes are now under construction in the Little Rock area, and local builders, architects, and home buyers are starting to take notice.

The service entrance showing utility service, array combiner/ disconnect, and Sunny Boy inverters.

The backup power system includes a 4,000 W Xantrex inverter and two Blue Sky charge controllers.

The dual-inverter system we used in this home is complicated, and not the most efficient or cost-effective way to go today. New inverter models are capable of operating at approximately 90 percent efficiency in the grid-tie mode and yet provide for battery backup. This greatly simplifies the system design and reduces costs considerably.

The roof-integrated, solar-electric system offers seamless beauty, ease of installation, and efficiency in low-light conditions. As technology moves forward and we begin

Ball System Costs

Item	Cost (US$)
42 Uni-Solar PVL-128 modules	$26,250
2 SMA 2500U inverters	4,550
Xantrex PPSW4024 inverter panel	4,120
Exide 12-125-17 battery, 1,000 AH at 24 V	2,490
2 Blue Sky SB6024H controllers with displays	950
Combiner with fuses & disconnects	800
Trace PVGFP2 with lightning protection & encl.	650
Misc. wire, conduit, & hardware	650
System Total	$40,460

Tech Specs

System type: Battery-based, grid-intertied PV system

System location: Little Rock, Arkansas

Solar resource: 5 average daily peak sun hours

Production: 612 AC KWH per month average

Utility electricity offset: 63%

Photovoltaics

PV: Forty-two Uni-Solar PVL-128 laminates, 128 W STC, 24 VDC nominal

Array: Twenty-one, two-laminate series strings, 5,376 W STC total, 48 VDC nominal

Array combiner box: Stellar Sun with 8-amp Littelfuse KLKD008 fuses

Array disconnect: OutBack, OBSB-15 with six 6-pole, 15-amp breakers (4 used; 2 for disconnect at 48 VDC, and 2 for disconnect at 600 VDC) 100 VDC per pole; 600 VDC total)

Array installation: Building-integrated PV laminates on south-facing roof

Balance of System

Charge controller: Two Blue Sky Energy SB6024H, 60 A, configured for 48 VDC input, 24 VDC output, MPPT, PWM

Inverters: Two SMA Sunny Boy 2500U (grid tie), 2,500 W, 600 VDC maximum input, 234-550 VDC MPPT voltage window, 240 VAC output. One Xantrex PPSW4024 (backup), 4,000 watt, 24 VDC input, 120 VAC output

System performance metering: Computer datalogging from both Sunny Boy inverters, battery voltage, PV current, output charge current, charge mode, and SOC utility meter with display of energy flow, consumption, production, and net difference

Energy Storage

Battery: Exide 12-125-17, flooded, lead-acid, forklift battery, 24 VDC, 1,000 AH

Battery/inverter disconnect: Trace DC250 mounted in power panel

to recognize value and acknowledge hidden costs of fossil fuel and nuclear-based electricity production, the PV integrated home will be the norm. Methinks, "We ain't seen nothing yet."

Installing the roof panels.

Access

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Wind Generator Tower Basics

Ian Woofenden

You've decided you want to make electricity with the wind. You have your eye on a high-quality wind generator, and you've chosen the balance of systems (BOS) components. What's left is the biggest and most important job—choosing and installing the tower.

The mounting structure for a photovoltaic (PV) array puts the solar energy collectors up in the fuel—sunshine. Towers for wind generators do the same thing. Wind is the fuel for a wind generator, and to collect it, you have to get your machine above obstructions. Buildings, trees, and hills block the wind, slowing it down and causing turbulence. The standard guideline is to site a wind generator *at least* 30 feet (9 m) above anything within 500 feet (150 m). The entire rotor needs to be well above obstructions, so start your measurement from the tip of the lowest blade. Doing less is shortchanging your investment in wind energy—it's like putting solar-electric panels in the shade.

Your tower needs to support the weight of your wind turbine and handle the thrust loads put on it by the wind. It's easy to underestimate the severity of the environment that wind generators work in. If you ever see a catastrophic failure of a wind-electric system, you won't forget it. And if you make the tower too short, you won't get much energy. Purchase and install a tall, sturdy, permanent tower, so your wind energy experience will be long lasting and as productive as your wind site allows.

Tower Perspectives

It's easy to get focused on the wind generator as the primary component in a wind-electric system. After all, it's the collector—the machine that converts the energy in the wind to electricity. It moves, which is exciting and attracts attention. But it is quite often not the most expensive component in the system. The BOS components can easily cost more than the turbine, and the tower can cost two to ten times as much as the turbine, depending on the site and situation. Take a realistic view of your plans to tap wind energy by looking at the total system cost, not just the turbine cost. Costs for a typical off-grid installation are shown in the table on page 66.

A freestanding tower can be the most visually pleasing and adaptable to varied terrain, but is the most expensive.

A similar situation occurs when it comes to installation. Students attending wind system installation workshops often expect that they will spend a lot of time dealing with the wind generator. In fact, most of the installation time of a six-day wind workshop is spent with the tower. Assembling the wind generator and attaching it to the tower takes only a few hours, while assembling and installing the tower can take two to four days.

As the gin pole goes down, the tower goes up—tilt-up towers need wide open and level spaces, but make installation and maintenance easy.

Tower Types

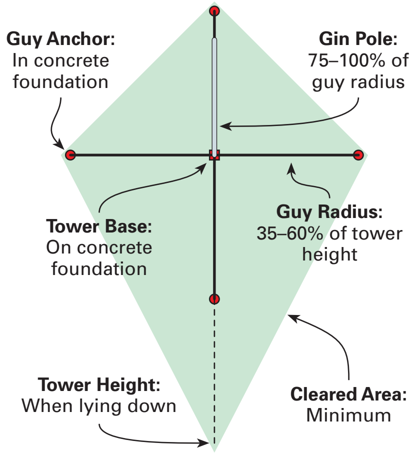
Three basic tower types are used for almost all home-scale wind generator installations. Tilt-up towers make maintenance easy, with no climbing. Fixed, guyed towers are very common, climbable towers. Freestanding towers, with no guy wires, are costly, but attractive, and also climbable.

Tilt-up towers. My advice: If you have space for a tilt-up tower, use one! You will never have to climb your tower (in fact, you won't be able to). All maintenance will be done with your feet on terra firma. If there's any trouble with the machine, you can have it down in less than an hour, and back up in the same time once you've done the repair.

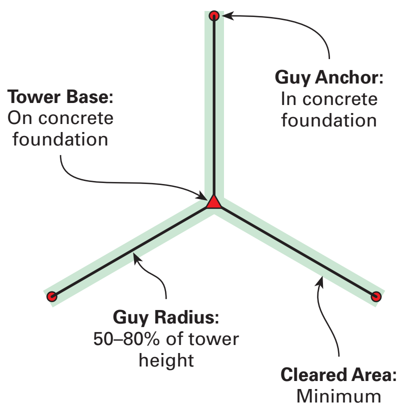
Tilt-up towers come in heights up to around 130 feet (40 m) for small-scale machines, with various sizes for different machine weights and thrusts. The most common tilt-ups are tubular steel, with sections of pipe coupled together, and guy wires attached at each joint. All the guy wires on one side of the pole (from each of the pipe joints) make up a set of guy wires. For tilt-up towers, four sets of guy wires are required, with three sets attached to one of the concrete anchors placed at four separate points in a radius around a concrete base at the center. The fourth set is attached to the gin pole, which in turn gets attached to the fourth concrete anchor when the tower is raised.

The major drawback of tilt-ups is the footprint needed. You need a clear, open area for the tower, a diamond-shaped space (see diagram) that is as long as the tower height plus the guy wire radius, and as wide as the guy radiuses extending from the sides of the tower base. For a 100-foot (30 m) tilt-up tower, the guy radius will be about 50 feet (15 m); so a diamond-shaped area 150 by 100 feet will be required. This area needs to be clear of trees and structures so the guy wires can lie down cleanly. You'll also need a clear lane to drive a lifting vehicle, if you use one. Other drawbacks: for minor repairs or service by people who are comfortable climbing, a tilt-up can be less convenient than a climbable tower. And you won't enjoy the views from the top of your tower!

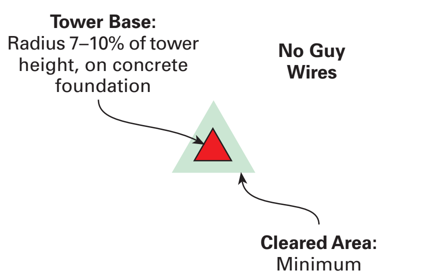
Tilt-Up Tower Footprint



Fixed, Guyed Tower Footprint



Freestanding Tower Footprint



Fixed, guyed towers share characteristics of both tilt-ups and freestanding towers.

Tilt-up towers consist of the tower pole and a "gin pole" that is attached to it at 90 degrees. When the tower is down, the gin pole sticks straight up in the air. When the tower is up, the gin pole rests horizontally near the ground. The gin pole is a big lever that allows you to easily lift the tower, which pivots at its concrete base.

You can raise and lower the tower with a truck, tractor, winch, come-along, or grip-hoist. The latter options allow you to install towers in remote locations not accessible to vehicles. The gin pole is generally 75 to 100 percent of the guy radius in length. I prefer tower systems that use the full guy radius for the gin pole length and permanently attach the rear guys directly to the end of the gin pole.

Example Off-Grid Wind System Costs*

Item	Cost (US$)	% of Total
Tilt-up tower kit, 127 ft.	$5,100	31%
Inverter & power panel	3,439	21%
Wind turbine, 12 ft. dia. rotor; controller; & dump load	2,500	15%
8 Batteries, 6 V, 415 AH	1,500	9%
Misc. wire, conduit, etc.	1,200	7%
Tower engineering (may not be required)	1,200	7%
Concrete & rebar for footings	800	5%
Trenching & footings	700	4%
Watt-hour meter	220	1%
Total	$16,659	

* Your cost may vary widely. Labor, shipping, and tax not included.

Like all towers, tilt-ups have their hazards. Things can go wrong. They can get dropped. Tow vehicles can slip. There are real dangers if the anchors are not correctly positioned and the guys get too tight while lowering or raising the tower. You should do your homework before attempting to install one, and always put the tower up without the turbine on it the first time.

Fixed, guyed towers. Another type of guyed tower, a fixed tower is lifted up once, and does not tilt down. Guy wires hold it up, and any maintenance on the tower or turbine is done by climbing the tower. These towers come in various configurations, the most common being triangular lattice sections, 10 or 20 feet (3 or 6 m) long, that bolt together. You've probably seen this type of tower used for commercial radio antennas and the like.

These towers must have a minimum of three sets of guy wires, with an underground concrete anchor for each set, and a concrete base under the tower itself. It's possible to install them one section at a time, using a different type of gin pole, a vertical temporary crane that mounts on the tower. The gin pole is moved up the tower one section at a time, and is used to lift each succeeding section. This is a slow, laborious process, and many people opt instead to lift these towers with a crane.

While fixed, guyed towers don't require the open area that a tilt-up tower needs, you still must have open lanes for the guy wires. The guy radius will be 50 to 80 percent of the tower height, and the guy wires will be visible. Costs for fixed, guyed towers are in the same general range as tilt-ups, but these towers can be installed on many sites that will not accommodate a tilt-up tower, mostly because fixed towers don't need as much cleared space, or as level ground.

Freestanding towers. If your budget isn't tight, a freestanding tower might be your first choice. No guy wires, no tilting, and it only needs a modest clear space for the tower base. The drawback, of course, is cost. Freestanding towers rely on steel and concrete to hold them up instead

Tower Comparison

Tower Type	Advantages	Disadvantages
Tilt-up	No climbing	Large footprint
	Maintenance on ground	Four sets of guy wires
	Medium cost	Need relatively level site
	Pipe locally available	Cannot climb for minor work
		Takes longer to assemble
Fixed, guyed	Modest footprint	Three sets of guy wires
	Lowest cost	Must climb
	Uneven sites OK	Crane cost
Freestanding	Small footprint	High cost
	No guy wires	Must climb
	Uneven sites OK	Cost of crane installation
	Safest installation (crane)	

of guy wires—lots of steel and concrete. This means higher cost for these materials, as well as for excavation, concrete forms, rebar, and labor.

Freestanding towers take two basic forms. Most common is the three-legged Eiffel Tower style, with tubular legs connected by angle iron braces. The other option is a monopole tower—a large, single tube, similar to what is used for utility-scale wind turbines. These are often quite expensive, and out of the financial reach of most small-scale renewable energy (RE) users. Both types are usually assembled on the ground and lifted with a crane.

A freestanding tower will cost at least a third to half more than a tilt-up or fixed, guyed tower. But the end result may be worth it. Aesthetically speaking, most people prefer not to look at guy wires. Less land clearing is necessary, and the tower is less vulnerable to damage than a guyed tower.

Homebrew towers. Many RE enthusiasts like to do things for themselves. While I have a great deal of respect for homebrewers, I urge you to be careful when it comes to towers. This is no place for lightweight construction or engineering guesswork. If you're going to try to build your own tower, do careful research. Look at engineered towers and get a sense of the designs, as well as the size and quality of hardware used.

When in doubt, overbuild. Better yet, stick with engineered towers that are professionally designed for the job. To obtain permits, you may need an engineer's stamp on your plans, anyway. Most tower manufacturers have engineers on staff who can provide you with specifications and calculations that will make your local engineer's job easier, and less expensive for you.

Choosing Your Tower

So how do you choose your tower? First of all, look at the function. Each turbine manufacturer will tell you what tower size (pipe diameter or lattice tower size) is necessary to hold your wind generator. Using the 30-foot/500-foot rule, determine how tall your tower needs to be. Consider mature tree height, and remember that trees grow, while towers don't. Then look at what tower options you have.

Look at your site. Is there space for a tilt-up tower? Do you have the available footprint for guy wires? Then ask yourself whether you or someone you hire is going to be willing to climb the tower to do the regular, twice-a-year maintenance. And ask yourself, your family, and neighbors about the aesthetics. Take the time to go and look at installed wind-electric systems to get a sense of what you're getting into. Look at your budget. Many people would love to have a freestanding tower, but the cost is prohibitive.

Whatever your tower choice, avoid the most common mistake in wind system design—don't make your tower too short! Taller towers will always give you more energy for your investment, and you will not regret going higher. Take the time to research your tower choices, and make the best investment for the long-term. If you don't

Check the Regulations

When considering potential sites for your wind generator, make sure to check local land use laws, zoning laws, and with building officials, for any regulations that will affect installing a wind turbine. Some local codes may restrict tower height or require a "fall zone" around your tower. Other issues about noise and aesthetics may come up, as well.

However, if you live in a rural location, and aren't within a mile of an airport, the height of your wind turbine's tower probably won't be an issue. And fall zones should be a concern only when you are installing or raising and lowering towers. Common sense should suffice about how close an installation should be to a residence or other structures. Fall zones are not required for utility poles, trees, or buildings. Properly engineered and installed wind generator towers are safe to install within range of people and buildings. If you're worried about a tower falling, perhaps you should buy a sturdier tower, or not install a wind generator.

Nonetheless, local restrictions may apply, whether they're practical or not. You may need to start your project by educating and lobbying local government. See *HP86*, "The Hard Part about Wind Turbines" by Douglas Stockman.

have experience installing wind generators and towers, seek qualified help. Tower installation is not something to be taken lightly, but if you do it right, you'll have a solid base for making some or all of your electricity with the wind!

Access

Ian Woofenden, PO Box 1001, Anacortes, WA 98221 • ian.woofenden@homepower.com

What the Heck? "Gin Pole," by Ian Woofenden, *HP99*

Major U.S. distributors of wind generator towers:

Abundant Renewable Energy, 22700 NE Mountain Top Rd., Newberg, OR 97132 • 503-538-8298 • Fax: 503-538-8782 • info@abundantre.com • www.abundantre.com

Lake Michigan Wind & Sun Ltd., 1015 County Rd. U, Sturgeon Bay, WI 54235 • 920-743-0456 • Fax: 920-743-0466 • info@windandsun.com • www.windandsun.com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Solar-Powered Circus

Henrik Bothe

It's always a balance figuring out how many panels are enough.

A group of performance artists has pooled their resources and learned to juggle the needs of their growing community—by implementing solar-electricity and other self-sufficiency strategies.

Out of the Jungle & into the Sun

Bellyacres—a troupe of jugglers and performance artists who live together—was first formed nearly two decades ago. Original members of the community first met at the Third Hawaiian Juggling Festival held in Puna, Hawaii, in 1987. Many, including me, loved the Big Island of Hawaii so much that we started coming back year after year, staying for longer periods as our busy performance schedules could accommodate.

The love of this land prompted an island-wide hunt for property, and when one of our members spotted a secluded 12-acre site, we pounced. Ten of us pooled our funds and bought the property, and at the same time, committed to lifetime partnerships in one of the first communities of jugglers. No individual member can buy or sell the land or his or her membership. We are members for life—the entire group approves all members, and the members present make all major decisions at yearly meetings.

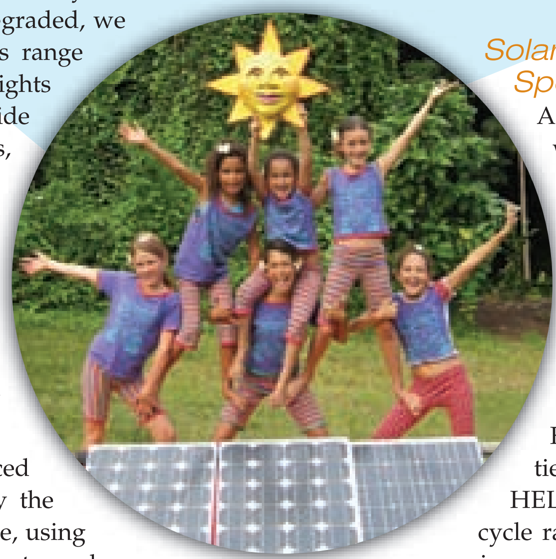
The early days of living on the land found us battling mosquitoes and bushwhacking our way through the overgrown thickets of vines to establish trails and survey the site. Eventually, we brought in a bulldozer to clear a driveway, establish homesites, and make space for orchards. We built a communal kitchen, sauna, and workshop, and planted fruit trees.

As word spread about our efforts, our community grew. Today, 35 members belong to our land trust—the Village Green Society—and participate in our nonprofit organization, Hawaii's Volcano Circus. Our land has been host to 19 festivals and serves as the home base for the HICCUP (Hawaii Island Community Circus Unity Project) Circus, a children's program that teaches circus classes, and puts on shows and community events.

Juggling Self-Sufficiency

While necessity was the primary impetus for installing our solar-electric systems—the land was remote and utility lines hadn't marched our way yet—we considered renewable energy important enough to include in our original manifesto of community values. We wanted to learn what it takes to be part of the solution to the world's energy problems. Being solar-energy activists is one way we are able to contribute positively to making change in the world. We also wanted to remain committed to serving as an example and motivation for our many visitors who otherwise would never experience solar energy in action.

Six small houses, ten "jungalows" (small, primitive cabins without toilet or kitchen facilities), a communal kitchen, sauna, hot tub, and chopstick factory have been built on the land. The six houses each have individual photovoltaic (PV) systems with backup generators. Although as the years have gone by and as the systems have been upgraded, we hardly use the generators. The house systems range from a couple of panels that power a few lights and a water pump, to larger arrays that provide electricity to run refrigerators, washing machines, wireless Internet connections, and computers.



My household's needs for electricity have slowly increased and so has our PV system. Although it's a hodgepodge of three different types of panels, it works well. (We benefited when the electric utility finally moved into our neighborhood and many of our neighbors got connected to the grid. They sold their used PV panels to us—cheaply.)

Power-hungry appliances have been replaced with more efficient ones—I've learned to buy the most efficient rather than the cheapest appliance, using the Energy Star rating system. Energy Star products use less energy and must meet strict energy efficiency criteria set by the U.S. Environmental Protection Agency or the U.S. Department of Energy (see www.energystar.gov).

In a few of the more luxurious jungalows, a spare 10-watt PV panel and old 12-volt battery provide enough energy for two 12-volt lights. For cooking facilities, jungalow users take advantage of the communal kitchen, which relies on two 75-watt panels and four 90-watt "quadlam" panels to run a couple of water pumps, six compact fluorescent lights, and the occasional laptop computer.

Although grid power through the Hawaii Electric Light Company (HELCO) is now an option in our neck of the jungle, we remain committed to our energy independence and also rely on other aspects of self-sufficiency to support our community. For many years, our only utility connection was a phone line.

Each structure at Bellyacres has its own catchment system to collect and store water. Rainwater gutters run from almost every building's roof to ten different water tanks, which have a combined capacity of 46,000 gallons (174,340 l). We use the water for everything—drinking water, kitchens, showers, sauna, hot tub, laundry, car wash, and garden and fruit tree irrigation. In seventeen years, we've only had to truck in water five times. We grow much of our own food, mostly tropical fruit crops, and raise chickens for eggs and meat. Two diesel vehicles we use for transportation run on vegetable oil.

To sustain our financial independence, our major income sources are from work with the HICCUP Circus or from performing, although we have diversified our cash-making strategies by establishing a market-quality crop of noni fruit (*Morinda citrifola*) and a flourishing coconut orchard on our farm. Our chopstick factory, where local tropical hardwoods are turned into exotic inlaid chopsticks, provides partial employment for two community members. Although we now run the factory with a petrodiesel-powered generator, we intend to switch to biodiesel fuel in the near future.

Solar Energy in the Spotlight

After many years of fussing with backup generators and babysitting batteries, we are investigating grid-tie systems with the local electric utility. Ironically, in this land of ample sunshine, Hawaii offers few incentives for renewable energy. Further complicating grid-tie matters is the fact that HELCO follows the lunar cycle rather than the solar cycle, zeroing out their customers' electric bills monthly.

The ramification for grid-tied users is this: say you produce 300 KWH in both the months of January and February, but *use* 150 KWH in January and 450 KWH in February. With HELCO's net-metering policy, you'll pay nothing in January, but end up paying for 150 KWH of use for February—even though over the two months you produced as much electricity as you used.

Another hurdle HELCO poses to implementing residential solar-electric systems is that they won't pay for surplus electricity you send back to the grid. If you want to be paid for energy produced, you can sign up as an "independent power producer" (IP), which pays you 8 cents per KWH produced. The catch? You pay a premium—21 cents per KWH—for the power you *use*. As an IP, your meter is not allowed to run both ways, so HELCO requires a second meter for your system. Further limiting the spread of solar-electric systems on the island, the largest grid-tied system HELCO will buy electricity from is 10 kilowatts.

Despite the grid-tied challenges posed by our local utility, our future plans remain bright, and include a utility-tied, solar-powered performance and educational center we call SPACE (Seaview Performance Arts Center for Education), where we plan to host our annual juggling festival, our circus classes, and other workshops. At a proposed 9,700 square feet (901 m^2), not only will SPACE let us showcase our circus talents under its big top, but with its state-of-the-art solar-electric system and solar water heating system, it'll also put solar energy in the spotlight.

Access

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Bellyacres, c/o Graham Ellis, RR 2 Box 4524, Pahoa, HI 96778 • 808-965-8756 • juggler@aloha.net • www.hawaiianjugglingfestival.com or www.hvcircus.org

Tankless Is In

Jennifer Weaver

Tankless water heaters, such as the Takagi T-K2, are perfect for backing up domestic solar heating systems.

It takes effort to be environmentally conscious—especially when it comes to hot water. Perhaps Kermit the Frog stated it best when he lamented, "It's not easy bein' green." Is it possible to be environmentally responsible without having to give up the modern convenience of a nice, long, hot shower?

With their low operating costs, moderate initial investment, long life span, and high energy efficiency, tankless, on-demand water heaters offer a simple solution for domestic water heating. Why not heat water only when it is needed instead of maintaining a whole tank of hot water for potential use? With the ability to meet the hot water needs of any size household, tankless water heaters are a smart and viable alternative to conventional water heaters or as a backup to a solar hot water system.

For most people, choosing a new water heater is a hasty decision made when their current water heater fails. According to the Department of Energy (DOE), a conventional tank-style water heater accounts for about 20 percent of the average household's energy usage. Comparatively cheap and easy to install,

Flow Rates

Item	Flow Rate (GPM)
Bath tub	4.0
Shower	2.0
Washing machine	2.0
Dishwasher	1.5
Kitchen sink	1.5
Lavatory faucet	1.0

From 1997 Uniform Plumbing Code

conventional tank-style water heaters yield water quickly and powerfully, but keeping 75 to 120 gallons (280–450 l) of water heated is expensive and energy intensive.

Traditional storage tank systems heat and store water for later use. As water sits around waiting to be used, the water cools and has to be reheated. Known as standby heat loss, a typical tank system spends about 20 percent of its daily energy replacing this heat. Standby heat loss also contributes to higher cooling bills in the summer if the water heater is located in a conditioned living space. On-demand units simply eliminate the problem of standby heat loss by operating without a tank.

Popular in Europe and Japan, where energy costs are high and space is more precious, tankless water heaters have been widely available in the United States for only the last several years. They currently make up just 1 percent of the estimated 6 million gas water heaters sold each year. With the interest in on-demand systems growing, tankless water heater manufacturers expect to see their sales double in America over the next year. Manufacturers who had originally resisted the move towards tankless technology have recently developed new products to supply this increased demand.

Typical Water Heater Characteristics

Characteristic	Electric Tankless	Electric Tank	Gas Tankless	Gas Tank
First hour rate (gal. / hr.)	120	90	250	135
Size (c.f.)	2.0	24.0	2.2	24.0
Dimensions (in.)	16 x 16 x 4	69 x 26	24 x 16 x 8	69 x 26
Shipping weight (lbs.)	13	150	45	150
Energy factor*	0.98	0.86	0.82	0.65
Standby heat loss (% of heat in)	0%	20%	0%	20%
Avg. monthly elect. usage (KWH)	329	436	–	–
Avg. monthly gas usage (therms)	–	–	5	24
Avg. annual operating cost (US$)	$460	$535	$154	$235
Suggested price (US$)	$700–1,200	$200–600	$800–2,400	$250–700

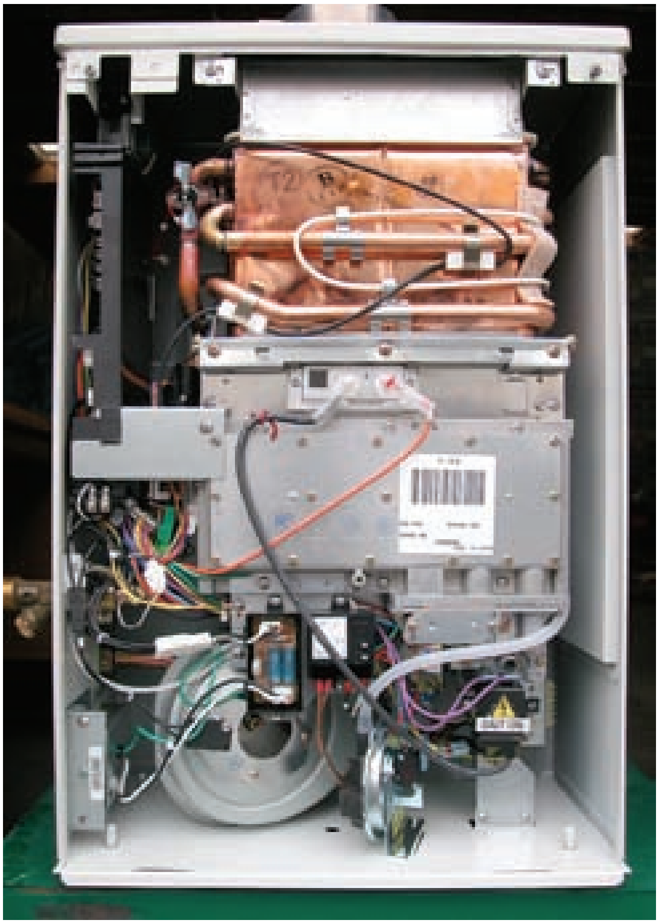
* Numeric representation of efficiency level—higher number is more efficient

Nuts & Bolts

With modern tankless water heaters, when the user turns on the hot water, a flow sensor detects the demand and turns on a computer that calculates the incoming water temperature versus the desired output water temperature. Then the correct amount of gas (or electricity) is supplied, heating the water as it passes through a copper coil. By using a digital thermostat and modulating burners, tankless systems are able to produce a constant water temperature output.

Gas Tankless Water Heater Specifications

Model	BTU Input	KW Equiv.	Effic.	Max. GPM	Ignition	Solar Preheat?
AquaStar 125BS	117,000	34.4	82%	3.5	Standing pilot	Yes
AquaStar 125FX	125,000	36.8	80%	3.5	AC spark	No
AquaStar 125HX	117,000	34.4	82%	3.5	Hydro-electric	No
AquaStar 240FX	165,000	48.6	84%	5.0	AC spark	No
AquaStar 250SX	175,000	51.5	87%	6.4	AC spark	No
Noritz N-063	194,000	57.1	81%	6.3	AC spark	Yes
Noritz N-069	194,000	57.1	82%	6.9	AC spark	Yes
Paloma PH12	89,300	26.3	80%	2.8	Standing pilot	No
Paloma PH16FS	118,000	34.7	80%	4.0	AC spark	Yes
Paloma PH24	178,500	52.5	80%	4.7	Standing pilot	No
Paloma PH28R	119,900	35.3	84%	7.4	AC spark	Yes
Rinnai 2424	180,000	53.0	82%	6.0	AC spark	No
Rinnai 2532	199,000	58.6	84%	6.2	AC spark	No
Takagi T-K Jr.	140,000	41.2	83%	5.8	AC spark	Yes
Takagi T-K2	185,000	54.5	84%	6.9	AC spark	Yes
Takagi T-K1S	190,000	55.9	85%	7.2	AC spark	Yes
Takagi T-M1	235,000	69.2	82%	9.6	AC spark	Yes



Tankless water heaters use "flash heat" technology to heat water on demand.

While both gas and electric on-demand systems are available, electric tankless water heaters are high power appliances, and peak electricity usage is substantial. Electric units can draw as much as 20 KW, so multiple circuits and heavier wire are necessary for installation. Gas tankless water heaters offer a greater output flow, and typically have lower overall operating costs.

Temperature-modulated tankless systems function by applying only the appropriate energy needed to heat the water up to the programmed water output temperature. Conventional water heaters kick on at full BTUs (British thermal units), regardless of whether the water demand is for running a dishwasher or washing your hands. With tankless water heaters, you only burn the BTUs necessary to get the job done.

Solar Backup

Tankless water heaters are an ideal choice for backup to solar water heating. The DOE recommends installing a tankless system as a backup to solar water heating for cloudy days. And many building codes actually require a backup system (electric or gas-powered) to accompany a domestic solar hot water system.

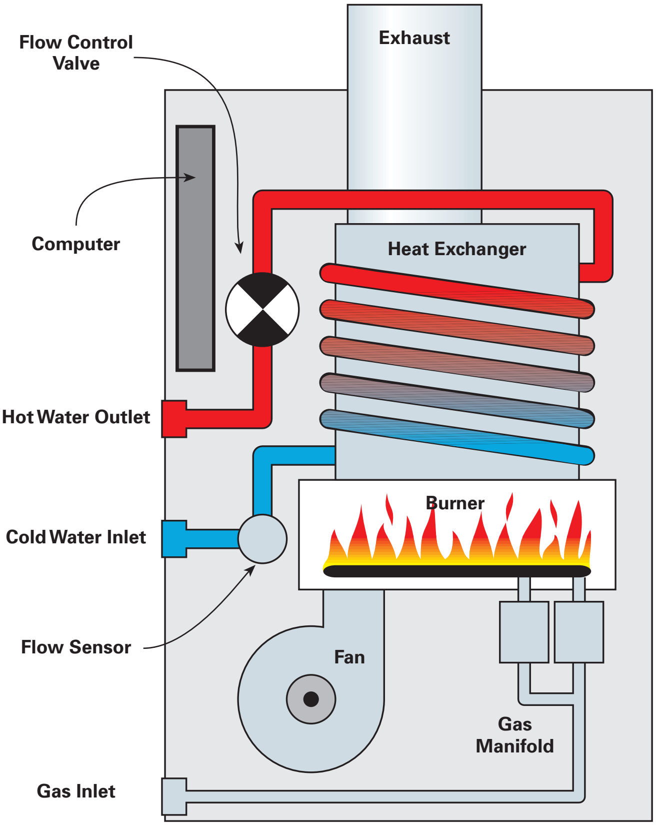
When choosing a tankless water heater as backup for a solar hot water system, look for a model that is thermostatically controlled. This allows the on-demand heater to register incoming water temperature and apply heat as needed to reach output water temperature. If the incoming water has been preheated, the gas will be modulated down to compensate. If the water coming into the unit is at the set temperature, the unit stays dormant and allows the water to pass through. Without this feature, preheated water that comes into the unit would be heated, which besides wasting energy, also pushes the outgoing water temperature too high, which could lead to scalding.

Most manufacturers design their system with a heat limit to prevent scalding. If incoming water temperature is too hot, the unit will automatically shut down water flow to fixtures. Installing a step-down mixing valve will prevent this, and is recommended to prevent scalding when tankless water heaters are used as backups to domestic solar hot water systems.

Investing in Efficiency

Choosing to install a tankless water heater system is an investment. The upfront cost of a tankless system is considerably more than a tank heater, but the initial expense will be balanced out by the immediate reduction of energy bills once the unit is installed. You can often recoup your initial investment within the first few years of the unit's use.

Basic Components of a Gas Tankless Water Heater



Tankless Water Heater Ignition Issues

Tankless water heaters offer different ignition systems, including pilot lights, electrical spark, hydro spark, and battery spark. The advantages and disadvantages of different ignition systems are summarized in the table. Units with electrical ignitions are usually equipped with devices like power vents, freeze protection, and temperature control, which digitally monitors water output temperature to prevent fluctuation in water flow and temperature as additional faucets are turned on and off.

Unfortunately for homeowners who live off-grid, increased generating capacity and batteries may be necessary to accommodate the additional electrical draw. Infinion offers a unit that uses a battery spark ignition, and AquaStar makes a hydro spark ignition as alternatives to the pilot light or AC electric spark most units have.

Tankless water heaters are commonly used as a backup heat source for solar hot water systems. Some tankless heaters are specifically designed to work in conjunction with solar heating systems. These units are thermostatically controlled and compare the tankless heater's output temperature to the incoming water temperature (most pilot light models do not have this feature). The result is that these solar-ready units can accept preheated water, and will not turn on if the incoming water is at the set output temperature already. AquaStar manufactures a model specifically designed for use as a solar backup that uses a pilot light.

Ignition Characteristics

Advantages	AC Spark	Pilot Light	Hydro Ignition	Battery Ignition
Doesn't waste gas	✓		✓	✓
Reduction in emissions	✓		✓	✓
Digital temperature control & freeze protection	✓			
No electrical connection needed		✓	✓	✓
No running pilot light	✓		✓	✓
Disadvantages				
Requires electrical connection	✓			
Significant electrical load for off-grid homes	✓			
Constantly consuming gas		✓		
Higher emissions		✓		
Lower efficiency		✓		
Only available on one model (AquaStar 125HX)			✓	
Does not modulate temperature for solar/wood preheated water			✓	
Battery will need replacement				✓
Manufacturers				
AquaStar	✓	✓	✓	
Infinion		✓		✓
Noritz	✓			
Paloma	✓	✓		
Rinnai	✓			
Takagi	✓			

Whether or not you plan to use a tankless water heater system as the sole source of hot water for your household or as a backup for a solar water heating system, there are two major considerations for determining which tankless water heater is right for you. Determine how many fixtures the unit will supply hot water to, and what the incoming ground water temperature is. Tankless water heaters are restricted by water flow. Each unit has a maximum output capacity. If you try to use too many fixtures simultaneously, you will exceed the output capacity of the unit and will get a drop in water pressure and temperature.

It is important to stress proper sizing. If homeowners do not first determine what their hot water demand is before looking at the other features, they may find themselves with a unit that does not meet their needs.

Considering the number of manufacturers and models available, it is best to have a professional handle the installation. A seasoned installer cautions, "Tankless water heaters are complicated, so weekend warriors are better off having a professional install the unit. When it's installed properly, there shouldn't be any problems." Some manufacturers will void or lessen the warranty when their units are installed by

Hard Water & Scaling

On-demand water heaters can have scaling issues in hard water areas. For an instantaneous water heater to be effective, the waterways need to be fairly small. A gas heater incorporates an air-to-liquid heat exchanger transferring the heat from the flame (air) to the water (liquid). Small copper waterways, rise in temperature, and hard water can cause dissolved solids in the water to stick to the inside walls of the copper exchanger. Over many years (I've seen it happen in less than five years), the buildup of scale can completely clog the heat exchanger.

While certainly a hassle, a clogged heat exchanger can be descaled by circulating a mild acidic solution, similar to the household method of using vinegar for cleaning automatic drip coffee makers. We have used mild solutions of muriatic acid and a product called Intech 52 Dry Acid Descaler to successfully clean copper heat exchangers of all types. Caution should be used when attempting to descale anything with acidic solutions, since some fairly robust bubbling can be produced. And acids in their strong forms require correct procedures for mixing and handling.

Chuck Marken • chuck.marken@homepower.com

homeowners. For hard water areas, water conditioning can lengthen the life of a tank or tankless heater.

While it is impossible to live without making a mark on the environment, technologies like on-demand tankless water heaters offer many advantages for homeowners looking to save money, reduce energy consumption, or who are simply in need of replacing their current water heater. We can take a lesson from a favorite children's character and realize that even though it's often not easy to be green, like Kermit, ultimately we wouldn't want to be anything else. On-demand water heaters just make it a littler easier.

Warranty Length (Yrs.)

Manufacturer	Heat Exchanger	Other Parts
AquaStar	12	2
Rinnai	10	5
Noritz	10	3
PowerStar	10	1
Paloma PH28R	10	3
Takagi	7	2
Paloma (other)	5	3
Eemax	5	1

On-demand water heaters can be installed indoors, or outdoors where the average winter temperature stays above 5°F.

Access

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Gas Appliance Manufacturer's Association, David Suluta, 2107 Wilson Blvd. Suite 600, Arlington, VA 22201 • 703-525-7060 • Fax: 703-525-6790 • information@gamanet.org • www.gamanet.org • Rates water heaters

United States Department of Energy, Energy Efficiency and Renewable Energy Clearinghouse • 877-337-3463 • www.eere.energy.gov

Industro Tech Inc., 317 N Bridge St., Grand Ledge, MI 48837 • 800-292-5908 or 517-627-8444 • Fax: 517-627-8037 • admin@enercocorp.com • www.enercocorp.com/industrotech/products.htm • Descaler

www.tanklesswaterheaters.com • Comparison info

Tankless gas water heater manufacturers:

AquaStar, PowerStar, and Powerstream brands • www.controlledenergy.com
Bradford White • www.bradfordwhite.com
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Noritz • www.noritz.co.jp/english
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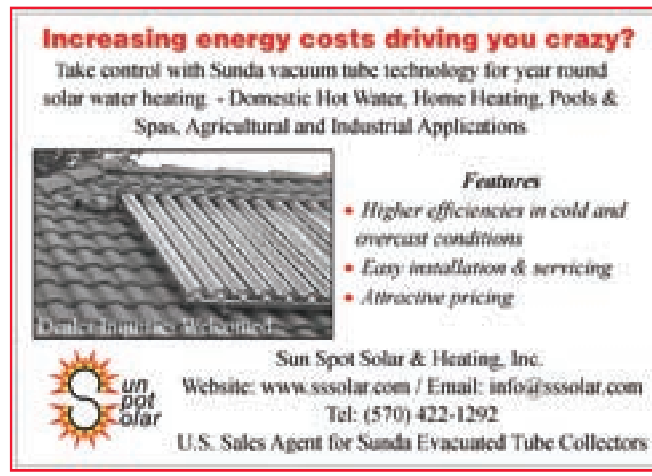

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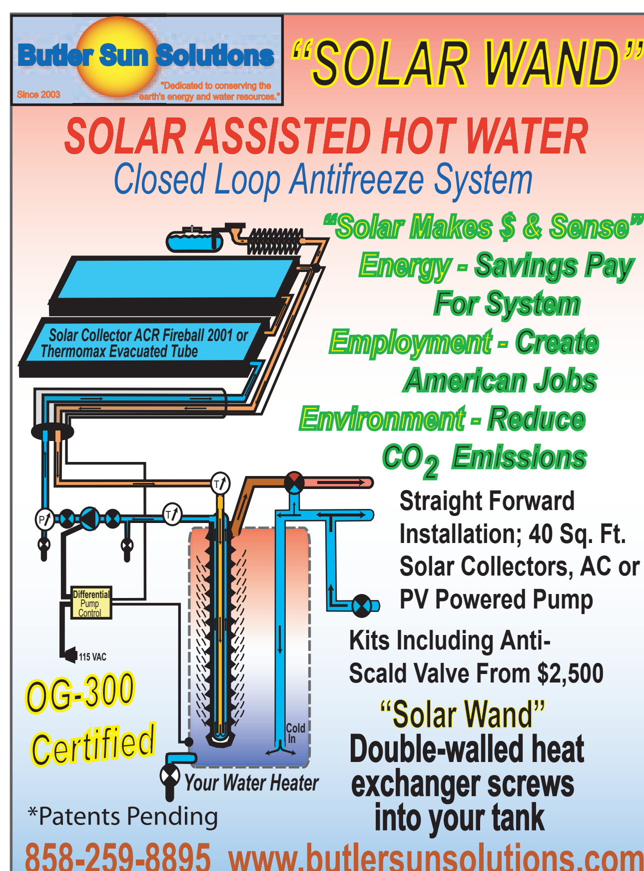

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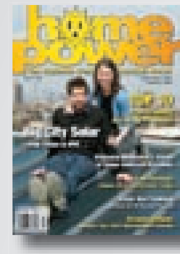

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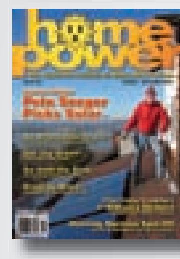

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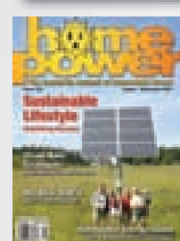

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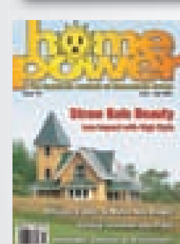

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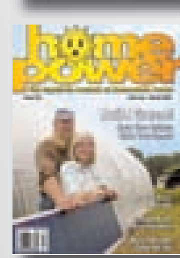

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Bornay Inclin 1500 Neo

Wind Generator

Ian Woofenden

Application: I installed a Bornay, Inclin 1500 Neo wind generator at my off-grid home in Washington's San Juan Islands in March 2002, on a 150-foot guyed tower. The average wind speed at the site is 7 mph (3 m/s).

System: The Bornay wind turbine is connected to my home system, which consists of two PV arrays totaling 1,220 watts, an older Whisper 1,000 wind generator, eight Dyno L-16 batteries, and a Xantrex SW4024 inverter. Average wind speed was recorded by an NRG Explorer anemometer/data logger. An OmniMeter was used to measure wind generator output (KWH).

J. Bornay Aerogeneradores has been manufacturing wind turbines in their off-grid plant in Castalla, Spain, for about 30 years. Their turbines have been installed in Spain, Portugal, France, Morocco, Angola, Mali, Tanzania, Venezuela, Antarctica, and other places. My interest in expanding the choices for U.S. wind energy equipment consumers lead me to try out their Inclin 1500 Neo wind turbine.

With help from some local renewable energy friends and family, I installed the turbine on our 150-foot guyed pole tower. We used a gin pole and davit to lift the machine completely assembled onto the tower top. Some installers prefer to assemble the machine on the tower, to avoid damaging the blades or other components during the lift. I prefer to hoist machines fully assembled, taking great care during the lift. We used tag lines to control the machine, keeping it away from the tower and nearby trees as we lifted.

The Bornay Inclin 1500 Neo.

The installation went smoothly. The wind generator has a flange that conveniently bolted onto the stub tower flange I had welded up for a different wind turbine I'd been testing. A notch in the Bornay's flange allows the electrical transmission wires to go down the tower. I notched our stub tower to match, and made an opening in the tower tube to slip the wires into. The leads from the wind generator are quite short, making connections a bit difficult. All wind generator manufacturers would do well to make 10-foot (3 m) leads standard on all machines, to facilitate installation on a variety of towers.

Machine Details

The Inclin 1500 Neo is a two-bladed, upwind, horizontal-axis wind generator. It uses neodymium magnets, which give excellent power output in a relatively small and light

Features

High Points:

- High output for size
- Rugged design
- Passive governing (with shock absorber)
- Aesthetically pleasing

Low Points:

- High speed, two-bladed design
- Moderately noisy
- U.S. support is new and uncertain

alternator. Made from a "rare earth," neodymium magnets are stronger than "normal" (ferrite) magnets. Since they are stronger, they make more electrons move. Output is three-phase wild AC down the tower to the controller, where it is rectified to 24 VDC to charge my system's batteries. Construction is fairly heavy duty throughout.

In high winds, the machine governs by tilting the generator head and tail to spill excess wind. A shock absorber slows the governing process and reduces stress on the machine. The machine weighs about 93 pounds (42 kg), and has a 9.4-foot (2.86 m) rotor diameter. High-quality yaw slip rings allow the machine to turn around the tower without twisting the transmission wires. All exposed parts are stainless steel, bronze, or coated with marine grade paint, and the fit and finish of the machine are excellent.

Bornay Inclin 1500 generator and shock absorber in governing position (tilted back).

The Inclin 1500 comes in models from 12 volts to 300 volts. Mine is a 24-volt machine, with a transmission wire run of #6 cable running about 250 feet. A diversion controller with built-in dump load and metering comes with the machine, though I did not use it, since my system was already set up with rectifier/controller/metering equipment. J. Bornay also manufactures smaller and larger wind turbines in this line.

Short wires out of the wind generator make for difficult tower-top connections!

Blemishes

I was skeptical about this machine from the start because it has two design features that are questionable to me. First, the machine is two-bladed. Most modern wind turbine manufacturers have gone to three-bladed designs, since they run more smoothly, eliminating "blade chatter" when the machine yaws. I have not seen any signs of this being a problem with the Bornay machine, but a two-bladed rotor will put more stress on the machine over the long haul.

The issue that concerned me more was the furling system, in which the alternator head and complete tail tilt back to spill wind. I'd experienced bad results from this method with another machine I run. The power output goes to nothing when it governs, and the whole machine may yaw (turn around the tower top, normally to face the wind) 360 degrees when it governs. I was pleased to notice that the Bornay machine does not usually turn sideways out of the wind when it governs, and there is still some energy production while it furls.

This is a relatively high-speed machine (650 rpm at rated output), so there is definitely some blade noise, and some "roaring" when the machine governs. It is not unusually noisy for a machine of this speed, and the blades don't whistle or make irritating noises.

J. Bornay is a Spanish company, and they are in real need of an English translator for their printed materials. Their documentation is in Spanglish, with many bloopers and unclear wordings. My favorite is the notice on the controller case that warns users not to "modificate or manipulate inside the box."

While several of these machines have been sold into the North American market, there is not yet a solid distributor/dealer base here. Two small companies are starting to import these turbines, but so far, we have no parts, repair, and support infrastructure on this side of the Atlantic. J. Bornay is a well-established company with inventory and parts, but communication is not always easy, and shipping costs can be significant.

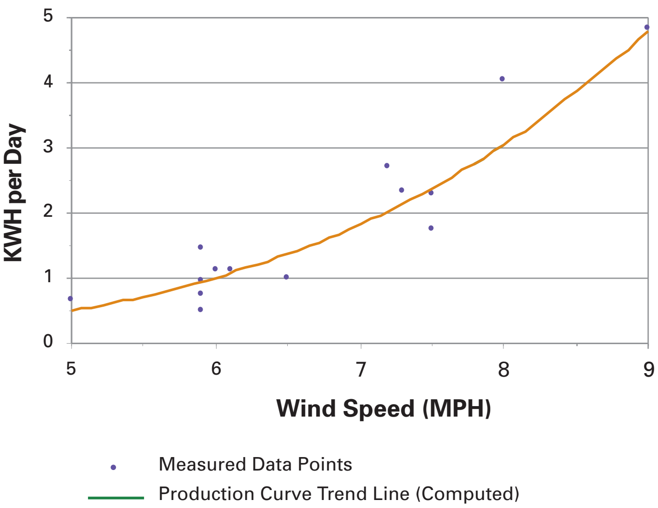
Solid Production

I have been running this wind generator for more than 2-1/2 years now. It has given me absolutely no trouble, and has been a good performer. Though I don't believe that the peak output of a machine is really a key data point, it's an easy one to look at. I've seen this machine hit 1,750 W. This is above its rated output, but not alarmingly so—too much output is not always a good thing!.

More important is the daily energy generated. See the energy curve for data from my site, a relatively low wind site. The machine has generated an average of almost 2 KWH per day in our 7 mph (3 m/s) average wind site. It's a significant part of our energy mix, and we've come to rely on the solid performance of this machine. We do not live in a high wind area, but we have seen sustained winds above 30 mph (13 m/s), and gusts over 50 mph (22 m/s), which this machine has handled easily.

My conclusion is that this machine is a step above some of its lightweight, high-speed competition in the United States. Adventurous wind energy users may do well to consider this alternative. I look forward to the development of U.S. support for this wind turbine line.

Average Daily Production



Tech Specs

Turbine Configuration: Two-bladed, up wind, tilt-back furling

Average Output: 129 KWH per month at 12 mph (5.4 m/s) average wind speed

Rated Power: 1,500 W

Rated Wind Speed: 27 mph (12 m/s)

Rotor Diameter: 9.4 feet (2.86 m)

Cut-In Wind Speed: 8 mph (3.5 m/s)

Blade Construction: Carbon fiber composite

Alternator: PM, 3-phase, 30-70 Hz

Voltages: 12, 24, 48, 120, 240, or 300 VDC

Tower-Top Weight: 93 pounds (42 kg)

List Price: US$4,660 with controller and dump load

Warranty: 2 Years

Access

Reviewer: Ian Woofenden, PO Box 1001, Anacortes, WA 98221 • ian.woofenden@homepower.com

Manufacturer: J. Bornay Windturbines, Paraje Ameradors, s/n, 03420 Castalla (Alicante), Spain • 34-965-560-025 • Fax: 34-965-560-752 • bornay@bornay.com • www.bornay.com

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Roasting Coffee on Sunshine

Mike Hartkop


The finished product—freshly roasted coffee.

Like many great ideas, this one started in a bar—drinking beer in complete desperation trying not to think about life's failings. My brother Dave and I were sitting at a table outside around dusk, reveling in the fact that it was finally cool enough to go outdoors (it gets too hot in southern Oregon). I had recently returned from Australia, where I had been living for the past three years, and my brother was up from L.A., working on an invention for his company.

My life's goals to date have always been coffee inclusive, and my brother's have mostly been centered on renewable energy. The night this all began, we were discussing the possibilities for renewable energy, and we got to talking about how hot the sun is! A pint or two later, the idea struck us—what about focusing the sun in such a way as to roast coffee? From that night to the first successful roast, only six weeks passed. Solar Roast was born!

Using Solar Energy

Before this idea came along, most coffees were roasted in one of two ways—large traditional drum roasters heated by propane burners or electric-drum roasters. Both methods almost always use energy derived from polluting, fossil fuels. I decided that it was finally time to stop burning the earth's resources to process coffee. It is truly amazing what you can do with a little motivation and a large parabolic solar collector!

Mike Hartkop shows off the Helios version 1.2 in action.

Our roaster produces superb tasting coffee for sale, but unlike other roasters, we make our own heat and electricity using renewable energy. A solar collector is focused to create the heat needed to roast coffee, while a 12-volt, 45-watt photovoltaic system is used to power the motors for drum rotation, chaff collection, and cooling. This enables the roaster to be not only solar powered, but also to run completely off-grid.

Helios 1.2

We named our coffee roaster Helios after the young Greek god of the sun. Helios version 1.2 is a 10-foot (3 m) diameter, recycled satellite dish that has 133, 8-inch (20 cm) Mylar mirrors attached to it. These mirrors reflect the sun's rays onto a drum roaster to create 4.1 KW of focused energy, producing an evenly roasted coffee. The heat created from the collector is enough to melt aluminum—1,220°F (660°C).

During the summer, Helios tracks the sun from 9 AM until 6:30 PM, allowing a roasting window of 9$^1/_2$ hours. The roasting drum is an encapsulated and blackened stainless steel drum. It is mounted on firebricks and held in a steel frame attached to the solar collector. To hold in the heat created from the solar collector, the drum is insulated using foil-wrapped fiberglass, aluminum flashing, and pottery-kiln firebricks.

The solar collection surface uses a high-temperature black paint where the solar energy is focused on a 10-

Helios Coffee Roasting Process

1. Align the dish to the sun, focusing the energy onto the drum.
2. Heat the drum to 450°F (232°C). This can take up to 30 minutes, depending on the heat of the sun, and clouds, because you have to continually refocus the dish and track the sun.
3. Pour 2 to 3 pounds (1–1.4 kg) of green coffee (raw, unroasted) into the drum through a spout mounted on its front.
4. The drum rotates at roughly 60 rpm, but the roaster speed is adjustable. This is important because when the beans roast, water evaporates, making them lighter and causing the drum to spin too quickly. We adjust the speed accordingly to create an even roast.
5. A sampling device is inserted into the drum to catch a few of the beans. The sample is then extracted and the progress of the roasting process is noted. For a Sumatra bean, roasting is nearing completion when the beans start to crackle. This is like popping popcorn—the coffee gets hot and pops open. Roasting is very intense at this time. If you allow the beans to stay in the roaster too long, the flavor will become bitter. Under-roasting will create a sour, insipid flavor. Roasting generally takes 20 minutes per batch for a long-roasted bean such as Sumatra. A Peru or a Peaberry bean's roasting time generally is shorter at 15 to 18 minutes.
6. Once the coffee is roasted, the roaster is taken out of the sun (this prevents the roaster from getting too hot).
7. The drum is then opened, and the beans are poured into a metal barrel.
8. It's important to cool the beans off quickly to stop further roasting, so they are squelched with cold water, which immediately evaporates on the hot beans.
9. The beans are stirred and air cooled until they are cool enough to handle. After about 20 to 30 minutes, the beans are placed into sealed bags, labeled, and ready to ship to customers.
10. The dish is cranked back into position, and spun to refocus the sun onto the drum to heat it for another roast. The process continues as long as the sun is shining.

The focusing window, where all the light is aimed, heats the surface of the roasting drum inside to more than 1,200°F.

square-inch (65 cm^2) area. This area is covered and insulated with a collector window made from 3/8-inch (10 mm) polyceran glass, good to 1,500°F (815°C). Within the outer drum is a stainless steel and aluminum inner drum where the coffee is roasted.

In the winter months, when the sun is not a frequent visitor to southern Oregon, Solar Roast moves its operations to southern California to roast in the deserts outside of Los Angeles. Production continues, unencumbered by the clouds and rain affecting much of the country.

Solar Coffee

With traditional roasters, the threat of a dreaded roaster fire is a daily fear, so great care is taken to remove all chaff during the roast, which unfortunately removes all the smoke and steam from the drum. This process creates a dry flavor prevalent in all coffees roasted using traditional methods.

Our method of roasting heats the coffee up more gracefully, and gives the coffee time to breath while roasting. Because no flame or fire is used to heat the roaster, there is no chance of a roaster fire. Solar roast is aroma roasted, which means that airflow is limited. The coffee basically roasts in its own steam, so it has a higher level of moisture, and the flavor is locked in. Solar Roast's coffee has a rounded flavor, which is apparent upon the first sip.

Solar Roast provides a fossil-fuel-free method to roast coffee. The organic coffee guarantees that no pesticides or fertilizers were used in the production of the coffee, which guarantees no pollution or worker exposure to poisons. Using fair-trade coffee means that the coffee growers obtain a fair price and payment for their coffee, providing a livable wage in some of the poorest countries in the world.

The goal is to provide the most environmentally and socially friendly coffee to a consumer base that demands a more sustainable future. We use the sun to create a freshly roasted coffee without the use of any fossil fuels.

Access

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Smart SUV?

The Ford Escape Hybrid

Shari Prange

For some people, an SUV is a fashion statement. They think "mpg" is an energy beverage. For other folks, like many *Home Power* readers, an SUV is a necessary embarrassment—although you believe in living an energy-efficient lifestyle, you might truly need the cargo capacity and the rugged characteristics an SUV offers, especially if you live off grid and off road.

Escape

Now there's a vehicle that provides most of the functions of an SUV with the fuel economy of a compact car—the Ford Escape Hybrid. Ford first announced plans for this vehicle several years ago, but the program was halted and revived many times along the way from concept to showroom. With the 2005 model year, it is finally at dealerships—at least briefly. The first runs at many dealerships (4,000 vehicles) are pre-sold, and it may take some time before models hit the showroom floor for test driving. A total of 20,000 vehicles are scheduled for production during the first year.

The Escape Hybrid is available as a two-wheel drive (front wheels) model, or with "intelligent four-wheel drive," which uses sensors and a computer control system to detect traction conditions at all wheels and feed power to the rear wheels only when needed. Acceleration is comparable to a conventional internal combustion engine (ICE) Escape.

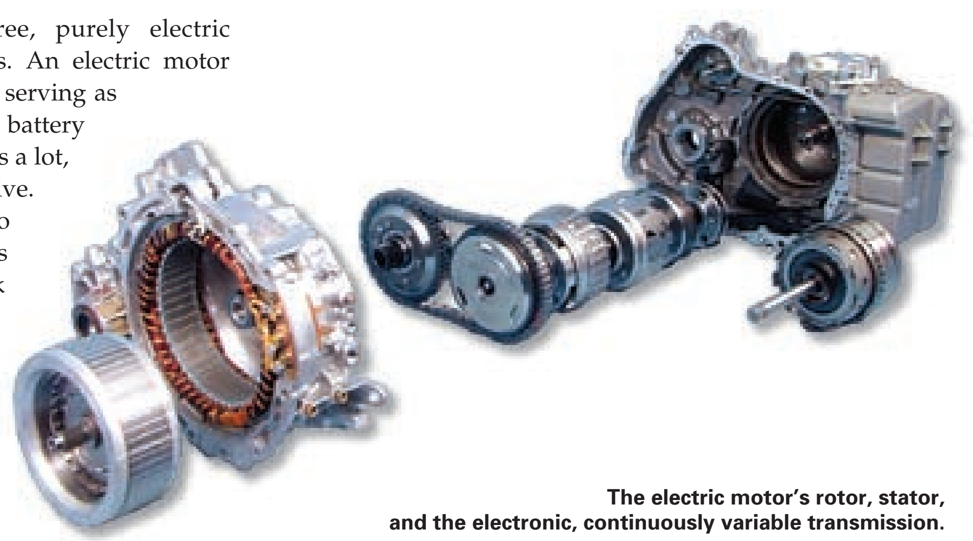
The Escape Hybrid seats five and offers an additional cargo capacity of more than 27 cubic feet (0.76 m^3) behind the rear seat. With the rear seat folded down, the Escape has a total cargo volume of 65 cubic feet (1.84 m^3). It can also tow up to 1,000 pounds (454 kg) of additional weight, like a motorcycle or small utility trailer. For comparison, the ICE Escape can tow between 1,500 and 3,500 pounds (680–1,588 kg) depending on the engine's size. At 15 gallons (57 l), the hybrid's gas tank is slightly smaller than the ICE version's tank (16.5 gallons; 62 l), but the electric assist means the hybrid can go farther than the ICE Escape before needing a fill-up. But the important aspects of the Escape Hybrid are not the features that it shares with other SUVs, but the things that make it different.

The Lowdown on Hybrids

The hybrids currently available on the market—Toyota's Prius, and Honda's Civic and Insight—are all powered by gas engines. Their ICEs generate the electricity that charges a battery pack (the cars cannot be plugged in for charging), so *all* of the energy comes from gasoline. What makes a hybrid special is that it uses the ICE and the electric motor to compensate for each other's weaknesses.

The Ford Escape Hybrid is the first vehicle to address the need for an SUV with the efficiency of hybrid technology.

Although they are emissions-free, purely electric vehicles do have their disadvantages. An electric motor requires a large battery capacity if it's serving as the vehicle's sole power source. This battery pack takes up a lot of space and weighs a lot, or if it is small and light, it's expensive. Batteries also take several hours to recharge. Hybrid-electric vehicles can use a much smaller battery pack because the ICE does most of the work. The system constantly sips a little electricity, and then puts it back, so recharging happens while you drive, and refueling just means filling the gas tank.



The electric motor's rotor, stator, and the electronic, continuously variable transmission.

The two main complaints about ICEs are the amount of pollution they produce and their inefficiency at low speeds, which is where passenger vehicles spend most of their time. Also, if it serves as the sole source of power for the vehicle, an ICE needs to be sized to handle maximum power needs, even though maximum power is only used briefly and infrequently. In a hybrid, the electric motor takes command of the low-speed driving, and can boost power to meet momentary maximum needs.

Although hybrids can't rival electric vehicles for their clean operation, they are cleaner and more efficient than a comparable pure ICE vehicle. The Escape Hybrid is 61 percent cleaner than the ICE version.

Hybrids are categorized as "mild" or "full." Mild hybrids, like the Honda Insight or Civic, use the electric motor to boost power and efficiency, but always rely on the ICE running. At speeds under 25 mph (40 kph), full hybrids, like the Ford Escape Hybrid and the Toyota Prius, run solely on the electric motor.

Inner Workings

While the hybrid components in the Ford Escape are Ford's own, the system has many similarities to the first generation Toyota Prius hybrid. This is not surprising, since Ford and Toyota signed a technology-sharing license agreement involving these two vehicles.

The Ford Escape Hybrid uses seven microprocessor control units to monitor various aspects of the vehicle, such as speed and battery pack voltage, and change the operating configuration, optimizing the balance between the electric motor and combustion engine to achieve maximum efficiency and acceleration. For example, from a standstill up to 25 mph, the electric drive system powers the vehicle. A 4-inch (12 cm), color LCD screen on the dash gives the driver a graphic display of real-time energy consumption and operating mode.

The control system also prolongs battery life by constantly monitoring the state-of-charge, never allowing the pack to be too deeply discharged. When the ICE system has power to spare, or the batteries get too low, an onboard generator (powered by the ICE) kicks on to charge them. The batteries also get charged by regenerative braking any time the car slows. So electricity flows back and forth constantly, out of the batteries for a little while, then back in again.

The electric drive motor is a permanent magnet, AC synchronous motor, rated for 94 horsepower (70 KW) at 3,000 to 5,000 rpm. It draws its energy from a sealed 330 V pack of NiMH (nickel-metal-hydride) batteries hidden below the rear floor. The battery pack is warranted for eight years or 100,000 miles in most states, and ten years or 150,000 miles in some states, where required by law.

Driving the Escape Hybrid is similar to driving the ICE version—you start by turning the key, putting the gear selector into drive, and depressing the throttle. The main differences you'll feel in the hybrid are the smoothness of acceleration and the quiet, experienced when the ICE is not running—as you coast to a stop and travel up to speeds of 25 mph. At 25 mph, without the increased emissions an ICE produces upon start-up, the ICE engages with the help of a 38-horsepower generator. This is the same generator that automatically kicks in to charge the battery pack as the sensors indicate need.

The cockpit with the color LCD screen that displays operating mode and continuous data on performance.

The 2.3 liter internal combustion engine only provides 133 horsepower—the electric motor adds 94 more.

As the hybrid accelerates, gears shift seamlessly, using an "electronic continuously variable transmission" (ECVT). Rather than moving between four distinct gears, this system varies speed by means of belts that move up and down a smooth, continuous spectrum. While you are driving, the vehicle's computer continuously monitors and adjusts the drive system.

Depending on road conditions and the needs of the battery pack, it may drive in pure ICE mode or ICE combined with the electric drive. When needed, the generator starts automatically to charge the battery pack. When you release the throttle to coast to a stop, the ICE automatically shuts down to conserve fuel, unless the batteries need charging.

The ICE is a 2.3-liter, inline 4-cylinder engine rated at 133 horsepower at 6,000 rpm. This is smaller than the engines in the various versions of the standard ICE Escape, which range from 153 horsepower for the inline 4-cylinder to 200 horsepower for the 6-cylinder. In the hybrid, the electric motor makes up the difference in horsepower.

The Escape Hybrid weighs 225 to 550 pounds (102–250 kg) more than the various ICE versions of the model, due to the battery pack and the extra components in the electric portion of the drive system.

The 330-volt, nickel-metal-hydride battery stores energy for low-speed driving, and additional top-end power.

A Solution for Less Pollution?

According to the California Air Resources Board, the Escape Hybrid qualifies as an AT-PZEV, which stands for "advanced technology–partial zero emissions vehicle." Although it's not as clean as a zero emissions vehicle (ZEV), it does use some advanced technology to produce fewer emissions. Ford claims that the Escape Hybrid emits 97 percent fewer hydrocarbons and nitrous oxides, and half the carbon dioxide (greenhouse gas) of Tier 1 vehicles, the federal emission standard for light-duty vehicles that was phased in between 1994 and 1997. Tier 1 vehicles fall at the bottom of the clean-emissions ladder, below low emissions vehicles (LEVs) and far below ZEVs. So this means the Escape Hybrid is much cleaner than the least clean, light-duty vehicles produced between 1997 and 2003.

But for a vehicle of its size, the Escape Hybrid outperforms its competitors in fuel economy. The two-wheel-drive version gets a remarkable 36 mpg (6.53 l/100 km) in the city and 31 mpg (7.6 l/100 km) on the highway—fuel economy that's comparable to many other compact cars. The four-wheel-drive version gets a very respectable 33 mpg (7.1 l/100 km) in the city and 29 mpg (8.1 l/100 km) on the highway, which is much better than the 20 to 22 mpg (11.8–10.7 l/100 km) in the city and 25 mpg (9.4 l/100 km) on the highway the ICE versions of the Escape get. The difference between the hybrid and standard ICE versions is most obvious in city driving, because that's where the electric drive contributes the most. It's also where most vehicles are driven, although that may not be true for someone who needs an SUV because they live off grid and off road.

How Does It Add Up?

The Escape Hybrid manufacturer's suggested retail price starts at US$26,380 for the front-wheel-drive version and US$28,005 for the four-wheel-drive version. This compares to a range of US$19,265 to US$26,365 for the various ICE Escape versions. So the hybrid costs about US$7,000 more at the low end and about US$2,000 more at the high end of the scale. This is offset, however, by a US$1,500 federal income tax credit, as well as tax credits or sales tax exemptions in some states.

Because the ICE does less work in the hybrid, oil changes are spread out to 10,000 miles (16,100 km), instead of 3,000 to 5,000 miles (4,800–8,000 km). There is an extra air filter in the battery's thermal management system that needs to be replaced at 20,000-mile (32,186 km) intervals. Other than those items, service is the same as for the ICE versions.

Like the other hybrids currently on the market, the Escape is not an alternative or renewable fuel technology in the way that home photovoltaic or wind turbine systems, or biodiesel vehicles are. Instead, it introduces a new technology that uses a conventional fuel (gasoline) more efficiently, and that produces less pollution.

As with many things, this improvement comes at a price. The vehicle costs somewhat more than its conventional counterparts, although government incentives and fuel savings offset this. And the hybrid engine can't provide a great deal of pulling power—if you need to tow your trailer and two horses, this Escape won't do the job. However, if you need a vehicle that works for a living instead of merely looking cool, with four-wheel-drive capability and substantial cargo capacity, the Escape Hybrid can deliver, with the fuel economy of a compact sedan.

Access

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Ford Motor Co. • 866-6ESCAPE • www.fordvehicles.com/escapehybrid/home/

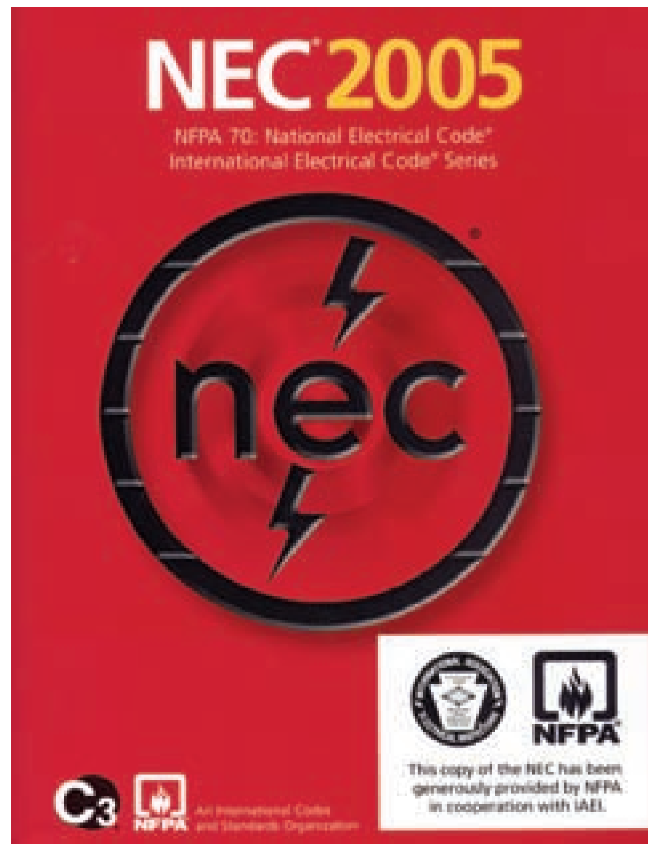
PV Systems

And the 2005 National Electrical Code

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

The 2005 *NEC* has been published and will take effect as jurisdictions adopt it, beginning as early as January 2005. Article 690, which covers solar-electric systems, has some changes that will benefit the PV industry by making the code easier to understand, and by allowing modified installation procedures. A few new requirements have also been added. These major changes and new requirements will be covered here.



Inverter Accessibility

Section 690.14(D) is a new provision in the code that allows utility-interactive inverters to be mounted in areas that are not readily accessible. A readily accessible area is one that can be approached without opening a locked door, removing building materials, or using a ladder or other device to reach the location. For example, utility-interactive inverters may be mounted on the roof of a building near the PV array.

However, DC and AC disconnects must be located at the inverter, and an additional AC disconnect must be located in a readily accessible location as required by 690.14(A) through (C)—usually within easy reach of the ground or floor (6.5 ft; 2 m). These disconnect requirements were covered in *Code Corner* in *HP97* and *HP99.*

Rooftop Conductors

Section 690.31(E) is a new paragraph that permits conductors from a roof-mounted PV array to be run inside the building before reaching the first readily accessible disconnect if those conductors are installed in metallic raceways. Metallic raceways include the various types of metal conduit and metal-jacketed, armored cables, like types MC and AC.

Nonmetallic raceways (PVC) are not allowed by this provision because they do not provide the physical protection, fire containment, or ground-fault detection afforded by metallic raceways. Under the 2005 *NEC*, the PV installer can legally hide the conductors, coming from the roof, inside the building without running unsightly conduits down the outside of the structure.

Ungrounded PV Arrays

Section 690.35 was added to permit the use of ungrounded PV arrays in systems where neither of the circuit conductors is grounded, as is currently required for systems operating over 12 volts nominal. This permissive (not mandatory) requirement was added to the code to allow utility-interactive inverters that have no internal or external isolation transformer to be used. Without a transformer, the inverter efficiency will increase while the weight and cost will go down.

The equipment grounding system still must be present, and several other requirements, listed below, will help to ensure that these ungrounded systems are as safe as the grounded systems.

1. Disconnects and overcurrent protection will be required in both of the ungrounded conductors.
2. A ground-fault protection device will be required on all ungrounded PV systems, even when the PV array is not mounted on the roof of dwellings, where such a device is currently required.
3. The conductors from the PV array must be installed in raceways (conduit) or be part of a multiconductor

sheathed cable. This requirement is to duplicate the protection provided by a double-insulated cable that is not presently available in the United States. Underwriters Laboratories (UL) is developing a new standard for double-insulated cables being designed for use with PV modules. Until these cables are available, the current use of modules with pigtail wiring and Multi-Contact connectors will not be allowed on ungrounded PV arrays.

4. Because many people think that ungrounded PV systems are inherently safer than grounded systems, a warning label will be required at all points where the ungrounded conductors are terminated. Labels will have to be attached by the installer at points where the conductors are attached to terminals that may require service, like junction boxes and disconnects. The warning label must read: *Warning: Electric Shock Hazard. The direct current circuit conductors of this photovoltaic power system are ungrounded, but may be energized with respect to ground due to leakage paths and/or ground faults.*
5. Inverters or charge controllers used in ungrounded systems must be specifically listed for that purpose by UL or another acceptable testing and listing agency, such as ETL or CSA.

Installers should note that most of the currently available PV equipment intended for use on 12- to 48-volt PV systems is designed to be used only on grounded PV systems and would generally not meet the requirements listed above for ungrounded PV systems. Also, most 12- to 48-volt PV systems will continue to use inverters that have transformers.

AC & DC Grounding

Section 690.47(C) clarifies the requirements for grounding systems that have both AC and DC grounding requirements. Typically, all systems with inverters must have both the AC and the DC sides of the system grounded since the internal transformer in the inverter isolates the DC grounded conductor from the AC grounded conductor. The code allows the DC grounding electrode conductor to be routed to one of two locations:

1. To a DC grounding electrode, which then must be bonded to the AC grounding electrode, or
2. Directly to the AC grounding electrode, where it is connected to that electrode with a separate clamp.

The size of the grounding electrode conductors is determined by sections 250.66 (AC) and 250.166 (DC). The bonding conductor must be sized the larger of the two. See *Code Corners* in *HP102* and *HP103* for additional details on grounding.

Backfed Circuit Breakers

A revision to Section 690.64(B)(5) takes precedence over the code requirement in Section 408.16(F) that all backfed circuit breakers must be clamped to the internal busbar. This revision no longer requires that backfed circuit breakers be clamped to the internal load center busbar if they are connected to a listed utility-interactive inverter, and all circuit breakers in the panel are secured with a front panel.

Diversion Loads

The changes to Section 690.72(B)(2)(2) clarify the requirements of diversion loads in relation to diversion charge controllers.

- The current rating of the load must be equal to or less than the current rating of the controller,
- The voltage rating of the diversion load must be greater than the maximum battery voltage, and
- The diversion load must have a power rating of 150 percent of the power rating of the PV array.

Summary

These are the major changes for the 2005 *NEC*. I encourage all PV system designers and installers to get a copy of the 2005 *NEC* and better yet the 2005 *NEC Handbook*, which has significantly expanded comments on the intent of the code requirements.

The PV Industry Forum has already started formulating proposals for the 2008 *NEC*. These must be finalized before the end of November 2005. Send me your comments and suggestions for the 2008 *NEC* and I will ensure they get the thorough review they deserve.

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NABCEP Certification

First-Year Report

Don Loweburg

It has been a little more than a year since the launch of the North American Board of Certified Energy Practitioners' (NABCEP) certification for solar-electric system installers.

Since that time, more than 143 people have been certified nationally, indicating a strong acceptance of the value of certification. Many of these early certificants are among the most experienced installers in the industry, including several Independent Power Providers (IPP) members. The early adoption of NABCEP certification by the most qualified in the field attests to the value and quality of the certification.

Perhaps even more telling are these words from a recent candidate:

I was pretty surprised at the comprehensiveness of the test. I'm embarrassed to say that I think I did very poorly on it. I hit the books pretty hard and I participated in the online review session, so I thought I had a good command of the information. But I certainly have a lot of respect for people who have NABCEP next to their names. Your organization is to be commended for the job they did putting together the certification. I need to know about the retest procedure, since I will be needing it. I'm very determined, especially after seeing the quality of the exam. I see a great deal of value in the NABCEP name, and will continue with my pursuit of PV studies.

Maintaining Proficiency

In addition to a high level of technical and professional expertise, NABCEP requires eighteen hours of continuing education, at least one installation with electrical permit and inspection per year, and retesting every three years to maintain certification. This policy supports certificants by requiring that they keep up with the most current standards and technologies.

The continuing education courses include workshops and seminars presented by manufacturers, code professionals, and master installers, and courses at training centers like Northeast Sustainable Energy Association (NESEA) and Solar Energy International (SEI). New courses continue to be accepted after review by NABCEP. The primary criteria for acceptance are that the materials be presented in a teacher-student format and that the course content be relevant and distinguished from sales fluff. More details for securing course approval are listed on the NABCEP Web site.

Strong Role for Certificants

NABCEP is evolving, and as the number of certificants increases, it is expected that more of them will be invited to sit on the board of directors. Two seats are now held by certificants—Bob-O Schultze and me. As NABCEP becomes more certificant-centric, plans are in the works to provide benefits beyond just certification.

Presently, all certified installers are listed on NABCEP's Web site. By this spring, certified installers will have the capability of displaying more information about the services they provide, including graphics and photos. The listing service will enable customers to find and connect with qualified local installers. There is no charge for this service.

Insurance

NABCEB is exploring the possibility of group insurance for its certified installers. The high cost and sometimes lack of coverage available for solar installers was discussed in this column in *HP103.*

NABCEP may provide the platform and leverage necessary to overcome some of the resistance experienced by installing contractors when they seek insurance. Pete Sheehan, NABCEP's executive director, invites certificants to contact him if they are interested in working on this project.

Building an Installer Workforce

Evolving out of a workforce development study recently completed by the Interstate Renewable Energy Council (IREC), NABCEP is developing an "entry level" certificate. The purpose of this certificate is to provide high school and junior college students with the ability to become formally involved in renewable energy while they are still in school.

The entry level certificate would demonstrate an understanding of the basics of PV technology and the terms that accompany it. By demonstrating a basic understanding of PV technology, those students may be better equipped to obtain part-time employment in the RE field while continuing their studies.

The entry level certificate is not NABCEP "lite." Rather, the two programs complement one another. NABCEP installer certification identifies an individual with both field experience and extensive knowledge of PV system design, installation, and service, as verified by both examination and documented work experience. The NABCEP entry level certificate identifies a student with an interest in entering a career in renewable energy.

Solar Thermal Task Analysis

NABCEP certification for a given specialty always evolves from a task analysis (TA). A NABCEP solar thermal technical committee has begun developing a task analysis for solar thermal installations. Like the TA for photovoltaic installers, the TA for solar thermal installers will develop a detailed listing of skills, knowledge, and abilities required of those who install and maintain systems for hot water and pool heating.

Once the TA is completed, a national certification program will be developed if there is sufficient support within the solar thermal industry. Members of NABCEP's solar thermal technical committee are listed on the Web site. Solar thermal professionals interested in having input to this process should contact Pete Sheehan.

Revised Study Guide

NABCEP provides a study guide on its Web site for those preparing to take the exam for PV installer certification. The study guide has been recently updated and revised reflecting input from past examinees. The study guide includes the PV task analysis, detailed materials designed to prepare for the exam, a sample exam with answers, and explanations of how the correct answers were determined. Anyone considering PV installer certification should make sure they understand the topics outlined in the study guide and that they can successfully complete the included sample exam.

Why Certification?

It is human nature to believe that what you "know" is how it is. And people think they are "experts" if they know a bit more than you. In a growing field like PV, experts and know-it-alls seem to be proliferating in a way that is unhealthy for the industry.

For example, recently at a trade show, I heard a PV-experienced contractor remark that the largest sized PV system that could be installed was limited to 2,500 watts. His explanation was that the limitation was due to the inverter's capacity. His final remark was, "Solar energy is cool, but you can only do so much with it."

All too often, I have had other "solar experts" explain to me that homes need to have special wiring and 12-volt appliances to use solar electricity. A big part of the problem is that these speakers are enthusiastic, pro-solar folks, who speak with authority, but have it all wrong.

On other occasions, I have seen PV modules mounted facing south, but directly behind a large tree. I have also seen modules mounted in a north-facing orientation. In fact, a large installation done at a California county fair site has many modules facing north. Poor installations, besides being an embarrassment to knowledgeable professionals, will ultimately harm the industry.

Certification will not guarantee that these sorts of problems will stop. However, by "raising the bar" and creating a standard for PV installation, the frequency of poor installations and misinformation will decrease.

Access

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What the Heck? 18

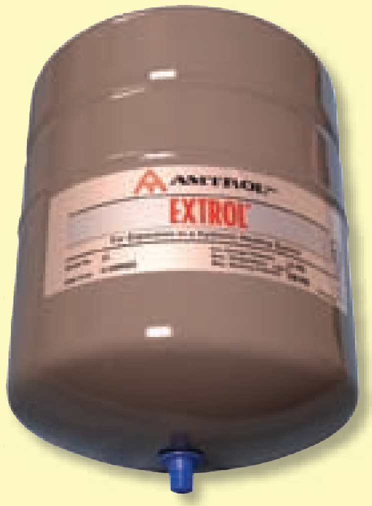
Expansion Tank

Used In: Hydronic solar heating and solar domestic hot water systems

AKA: Bladder tank

What It Is: A tank in a heating system that provides space for the physical expansion of water or a water solution

What It Ain't: A good Valentine's Day gift.



An expansion tank gives a solar water heating system elbow room, preventing burst pipes when pressure rises as the water gets hotter.

Water physically expands when heated. In closed-loop systems like hydronic heating and antifreeze-type solar water heaters, this expansion needs to be accommodated. Without provisions for expansion, the heated water can burst a joint or weak point in the piping, valves, or fittings.

Older expansion tanks were simply small tanks mounted in a horizontal orientation and plumbed from the bottom only, which left the top of the tank full of air to allow for the expansion of liquid. Newer tanks incorporate a rubber bladder that separates the air and water. This keeps air from entering the water, a condition that can be especially problematic in hydronic heating systems. If an air bubble becomes lodged in a pump impeller housing, it can cause the system to shut down completely. Air in the system also can lead to corrosion and noisy operation.

An expansion tank should be sized based on a thermal expansion coefficient, and the total fluid volume and range of temperature fluctuation in the system. A small one- or two-collector solar hot water system will use a #15 expansion tank (about 2 gallons); larger systems may require a #30 or #60 tank. Multiple expansion tanks can be used to increase the system's capacity.

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The Way It Works

& What We Can Do About It

Michael Welch

The U.S. federal elections are over, and we've sipped the last of our teardrop-tainted beers, or had our noses tickled by celebratory champagne bubbles. In the aftermath, some are asking many questions. Why are things as they are, and what can we expect from our government as a result? If we don't like it, what can we do about it?

Power Politics readers already have a sense of where things are going for the future of RE and the need for energy efficiency. We realized long ago that we need to take matters into our own hands, doing for our communities and ourselves what governments should be helping us with. We have been frustrated as we watch our politicians increasingly lean toward the big players in the energy industry, leaving behind the needs of the common person and Mother Earth.

Big Money

This situation is unfortunate for a clean and safe energy future, but it makes complete sense from a strictly political viewpoint. The big players have the big money, which is what most politicians and their parties need to get elected. Money talks, and politicians listen. Competing candidates either do the same, or they will not be able to compete effectively.

After accepting big money, politicians find themselves needing to give their supporters favors that may not be in the best interest of the majority of their constituency. But if big business doesn't see a return on their investment in politics, they will take their money elsewhere.

To get away with favoritism, politicians have to paint a positive picture of a negative deed for their constituency. They have been able to convince many of us that this favoritism is good for us by claiming that our economy would fail without greasing the wheels of commerce.

Double Whammy

Unfortunately, renewable energy interests have not yet gained the status of big players with significant influence and cash to spend. This means that the RE industry cannot expect significant returns from their relatively small investment in politicians.

To add insult to injury, our government's involvement with the big interests actually creates a backlash *against* the RE industry. The public is smart enough to figure out on its own that RE and efficiency are good for the world. Nonrenewable energy interests and many politicians actively campaign against the good stuff so that it will not gain significant footholds. Statements like, "Global warming is not real," and "Renewable energy and efficiency may work for us some day, but now we need to move toward energy independence in the real world," are designed to counteract the truth that the public would otherwise believe, support, and vote for.

It's a double whammy, an insidious mess that seems self-perpetuating and attacks a safe and sane energy future from all sides. But as bad as it looks, and as poor as the results have been to date, the RE industry is like a determined little David, looking for ways to slay the Goliath. The hope and perseverance of our industry is amazing. We recognize that the growth of the RE industry is a *need*, not a nicety.

Do More!

We can expect little help from government, and we have to put up with all it does against us, but we will not give up. Knowing that growth in RE is not going to get any big favors, our industry needs to ramp up exactly the kinds of things we've been doing for years. We don't need to change what we've been doing, just how much of it we are doing. The job rests squarely on us. Here are a dozen ideas for things we can do.

Michael and his daughter Emilly in front of Redwood Alliance's first PV demonstration system. A second row of identical Shell Solar modules is being installed on the building's roof.

Idea #1. Continue working with the major industry groups like the Solar Energy Industries Association, the American Wind Energy Association, and the American Solar Energy Society. These groups are on the front lines of trying to get a bigger slice of the pie for renewable energy. Renew your membership, and help them out with your thoughts when you can. Encourage them to keep fighting for RE and supporting energy legislation that increases funding—but not if it means endorsing something that helps the competing, polluting industries even more. In other words, don't support an energy bill just because it throws a bone to RE while giving a herd of fat cattle to the nuclear and fossil fuel industries.

Idea #2. Support and work with national groups, like Public Citizen's Critical Mass Project and the Nuclear Information Resource Service, that are fighting against the competing technologies of nuclear and fossil fuels.

Idea #3. Join and help steer the Sierra Club, Friends of the Earth, and other national and international open membership groups, so that they too will become more interested in promoting RE and demoting the other harmful technologies. What these groups need is leadership that is not so willing to sell out as they wheel and deal in political arenas. The Sierra Club has regional chapters that are involved in local projects and able to influence the national organization.

Idea #4. Join Greenpeace, Earth Island Institute, and other of the more action-oriented environmental groups. They are doing great work in the energy sector and sticking their fingers in many dikes, and really need our support. Or if these aren't your flavor, find groups that you can support that will help renewable energy become the national norm. It takes all kinds to save a world.

Idea #5. Support or start working with local organizations that focus on RE and energy education. Many communities have citizen groups that work on energy issues, or at least have missions that can include them. Join, contribute funds, and start getting involved with them—help guide them toward creating a new energy future.

Idea #6. Start a little energy fair in your town, or help other events, like fairs that focus on sustainable living, to add an energy component. The energy fair concept has been going on for more than fifteen years, and is a very successful promotional tool.

Idea #7. Organize a Tour of Solar Homes in your area, joining in with hundreds of communities and the American Solar Energy Society's national effort. Now is the right time to make that commitment, though the tours are in October.

Idea #8. Invite local energy experts to give workshops and lectures on renewable energy and energy efficiency. Publicize them with press releases, public service announcements, and flyers on community bulletin boards and other places. Work with other groups to do mailings about these events to their members.

Idea #9. Encourage your town council to start an energy task force or energy committee to look at what can be done within their government structure to start saving money

What's That on Your Neighbor's Roof?

Here's a new idea for promoting home-scale RE in your community, especially in those areas where rooftop solar electricity and hot water have gained some interest. Many folks are curious when they see panels on city rooftops, but haven't discovered a way to find out the hows and whys. A pamphlet aimed at them, listing solar energy projects in the community could encourage even more solar roofs.

A *What's That on Your Neighbor's Roof?* booklet could give other folks in your community an idea of what each kind of solar energy system does, and how it might apply to them. It should be widely available in the area, and have as many home examples as possible.

Each page of the booklet could be devoted to a single home, with a map in the front to show where they are so people can view them. The page would include the home's address, a photo, a description of the systems, what kind of energy and CO_2 savings have been realized, and whether or not the home owners are available to talk to neighbors about their systems.

A publication like this can be simple and cheap, with copies made at the local photocopy center, or in full color to really be attractive to neighbors. Distribution could come through the city government, local nonprofits, or sympathetic businesses, like stores that sell green products. Projects like these are readily fundable by local foundations, local governments, and other organizations. To make funding easiest, it pays to work with already established groups on projects like this. The information to start the research can come from the local building department, design review committee, or from local installing dealers of RE systems. Then it is a matter of contacting the homeowners to fill in a template for each home, taking some digital photos, and then sitting down with computer page layout software to put it all together.

This idea comes from the guide books I have seen handed out at the annual, one-day tours of solar homes that are gaining popularity. But this is a way of continuing the effort beyond one day per year. Please feel free to contact me for the info templates or to discuss any other thoughts on this kind of project.

on energy. This will improve the economic well-being of the government, and demonstrate to community members what can be done. Eventually, these kinds of committees can naturally progress to promoting RE, educating about and protecting against climate change, and helping to adopt RE-friendly laws.

Idea #10. Work for solar access laws and RE-friendly building codes, and start developing a strong energy component for your local government's planning process when it is ready for an update.

Idea #11. Start educating the builders and designers in your community. If architects and construction companies see the benefits of RE, they can promote their inclusion, or at least learn to make the homes they build and design ready for eventual installation of solar-electric panels and solar thermal collectors. It's a lot easier to design and install the necessary plumbing and conduit during construction than it is to retrofit a home.

Idea #12. Install a solar-electric or solar thermal system on your home or business. There's nothing like walking the talk to encourage your neighbors to follow.

These are just a few ideas for helping to turn around the bad shake that our environment is getting from corporate control of our national political system. There is a lot to be done nationwide, but this is a movement that is being built from the ground up.

Access

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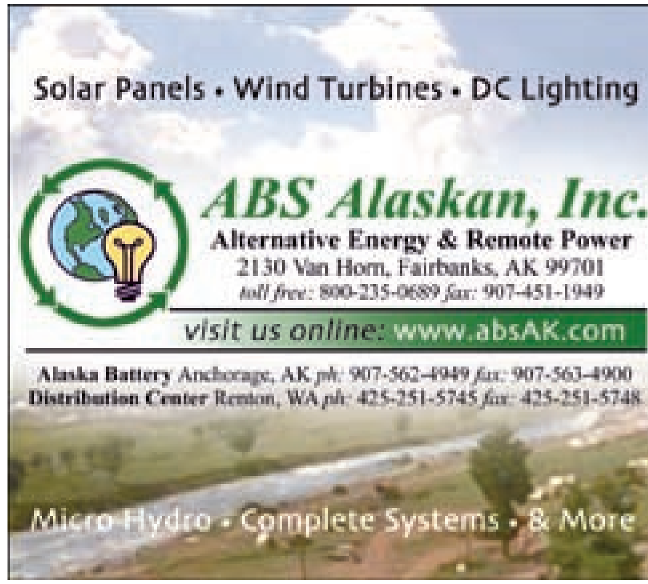
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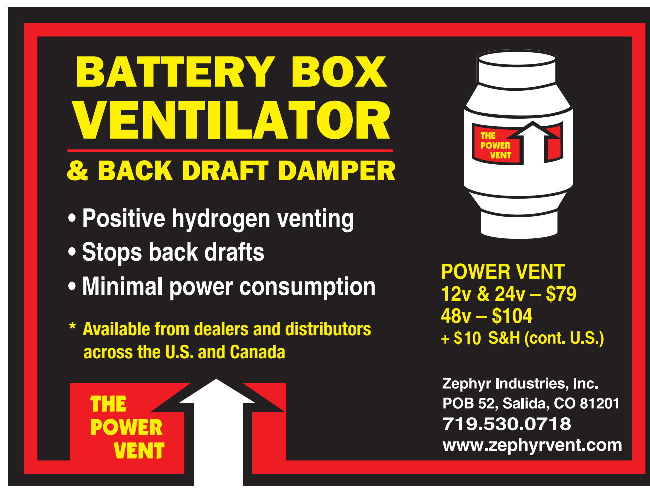
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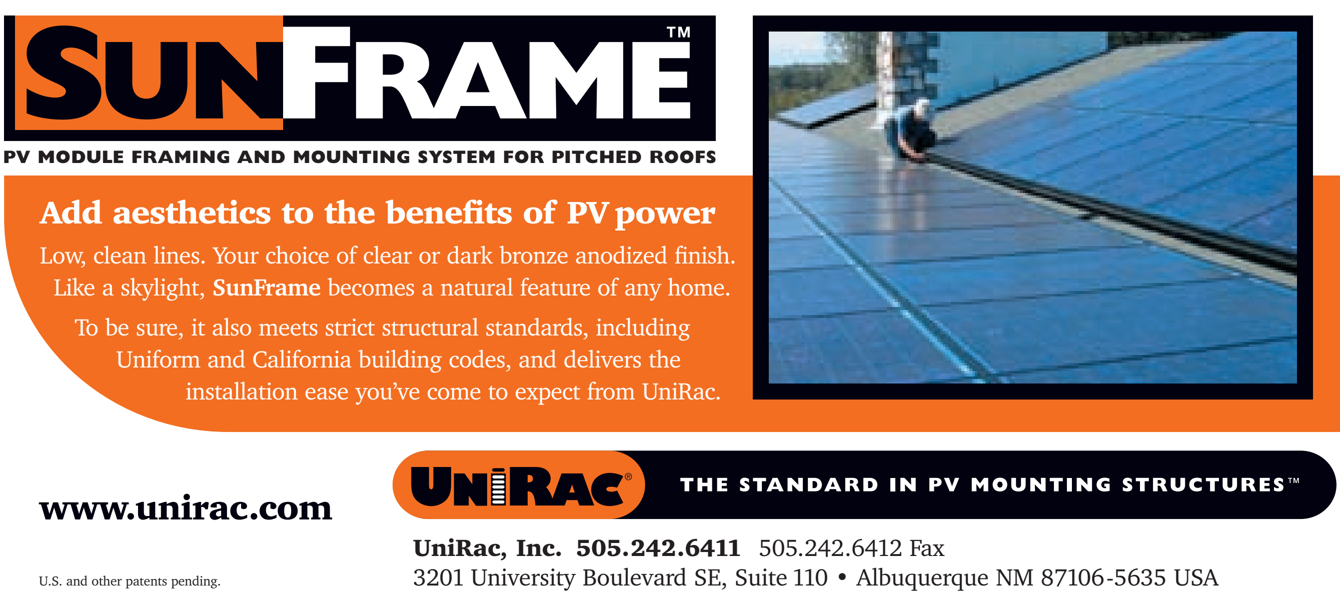
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Altitude & Azimuth

Ian Woofenden

Derivation: Altitude is from Latin altitudo*, height or depth; azimuth is from Arabic* as-samt*, the way.*

When talking about solar siting, altitude and azimuth are just fancy ways of saying height and direction. They both refer to angles, and they both describe the relationship between the sun and your site.

Altitude refers to the angle of the sun above the horizon. (It is sometimes called "declination" or "elevation.") It is specified in degrees, and varies depending on what time of day it is, what time of year it is, and where you are on earth.

When the sun is just rising or just setting, its altitude is 0 degrees. When the sun is at its highest in a given day, we call it "solar noon."

Northern latitudes get the most direct solar exposure during June, and southern latitudes get it in December, because the earth's tilt makes the sun's altitude highest in each hemisphere's summer. The opposite occurs in December in northern latitudes and June in southern latitudes, when the sun's altitude is at its lowest.

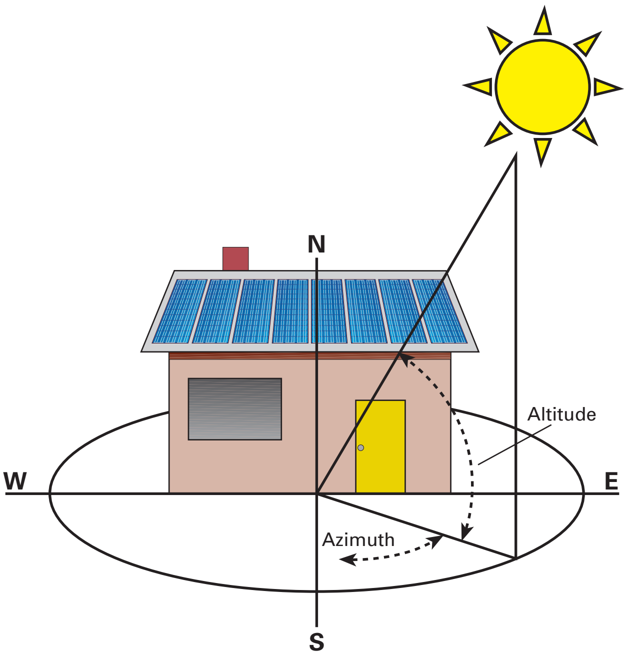
Because the earth's rotational axis is not exactly aligned with the earth's orbit around the sun, your latitude affects the altitude of the sun. In January, for instance, the sun's altitude at solar noon at the equator is about 65 degrees. At the same time, it's about 35 degrees in San Diego and about 20 degrees in Seattle.

Azimuth, when talking about solar energy in the northern hemisphere, refers to the angle between where a surface (such as a solar collector) is facing and true south. The term is also sometimes used to mean the angle between true south and where the sun is at a given moment.

The goal when you site a solar thermal collector or solar-electric module is to capture the most energy possible. The ideal is to have the collector or array perpendicular to the sun's rays. When you're at the beach trying to soak up the rays, you'd like to do the same thing.

Unless you have a mechanical mount that moves to change both altitude and azimuth, you have to make a compromise and pick the angles that will give you the most energy for the season or year. For a fixed, nonadjustable array, a good rule is to make the *altitude* angle the same as your latitude. For seasonally adjustable arrays, use latitude for the spring and fall angle, adding 15 degrees for the winter angle and subtracting 15 degrees for the summer angle.

Generally speaking, setting your fixed array or collector to true south—0 degrees *azimuth*—is going to give you the most energy. But local weather and site conditions, like if you get morning fog, or trees shade your site either early or late in the day, will affect your siting decisions. And even if you are 15 degrees off of true south, you will still get about 90 percent of the available energy.



It's not really much more complicated than what you do every time you use a solar oven. You tilt and turn the oven to where the sun casts the smallest shadow possible, so you can get the most out of your investment in solar energy equipment.

Access

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Vining & Wining

Kathleen Jarschke-Schultze

It was during the fall, three years ago that I met Ernie. My friend Myna and I had gone to an evening of art at a local gallery in our county seat, that teeming metropolis of Yreka, California. Along with the *objets d'art* were a few finger foods. But what caught our attention was the wine. It was a local wine, which made it heretofore unheard of. Even more astounding—here was the winemaker himself, Ernie Neveu, talking about his wines.

I made my way over and began grilling him. What were the best wine grapes to grow here? Why? What varieties was he growing? How long did it take to get a crop? Was winemaking easy or difficult? Weren't the cold weather and late frosts in our particular area a problem? Ernie smiled and sighed, knowing he was in for a long haul.

My husband Bob-O and I had planted a small orchard at the bottom of a large sloping side hill in our yard. We have fifteen trees altogether, with several varieties of apples, pears, plums, and cherries, all semi-dwarf. The slope above the orchard gets very good sun, but seemed too steep for more trees. We had spoken about planting a small vineyard there.

Even though I actually grew up in the Napa Valley, I knew nothing about wine, except what I liked to drink myself. You can believe me when I say I am not a wine snob. So I was pumping Ernie for all the information I could get.

I had passed his vineyard on the long back road to town many times. I always meant to stop in and ask my questions. Somehow, town trips are always full of errands and have no time for unscheduled stops.

Bottling Buddies

Ernie could see that I was interested and asked me if I'd like to come to his winery the next day and help bottle up some Pinot noir. Boy, would I! I asked if I could bring my friend.

The next morning, Myna and I showed up ready to go. We met Ernie's wife Maryann. We were instructed on our given tasks, and we bottled up dozens of cases that day. Our pay was some of the wine we had bottled. By the time we were finished, Ernie had hired me to help with the winter pruning in his vineyard.

I was only able to work on weekends and a patchwork of days when Bob-O was in the office that winter. One day, it was snowing as we pruned along the rows. It was great working with Ernie. He had retired from teaching at a San Diego university and couldn't help but be a teacher when talking about winemaking (and any other subject we touched upon) as we spoke. He covered not just how to do something, but also the "why" of it.

Our Own Vineyard

That spring I got a call from Ernie. A friend of his had planned to plant some Pinot noir vines near Ernie's place. Then the man realized he couldn't take care of the planting the way he should from his distant home. He had already

Bob-O inspects the vines a month after planting.

bought the year-old Pinot noir cuttings to plant. Ernie resold as many as he could at fifty cents apiece. He told me to come by and grab whatever I wanted from the remainder.

Bob-O was going to a job over Forest Mountain and down into Scott Valley the next day, so I told him to swing by Ernie's on the way back and get me a few bundles of vines. Ernie had told me where they were, bare root and wrapped in wet burlap. Bob-O brought home seven bundles.

We assumed each bundle would contain ten cuttings. Oh no—each bundle had twenty-five cuttings. We scrambled.

Wine & Mead Basic Methodology

The basics of making either wine or mead are the same. One difference is that with honey you add water, with grapes you crush them for their juice alone. For both, you make a "must." The must is the crushed grapes or honey/water prepared to receive the yeast. Sometimes you need to add sugar to the grapes or yeast nutrients to the honey and water mixture.

Then the natural yeasts must be killed. This is accomplished by heating for the mead, and by adding sulfites to the crushed grapes. In France, they mostly just use the wild yeasts on the grapes for their wine. However, they have made the same kind of wine in the same regions for hundreds of years. Any lees (spent yeast in the bottom of the secondary fermentation vessel) were thrown out to the farm animals and dissipated into the air. Interestingly enough, air samples in America's wine regions are now beginning to show concentrations of wine yeasts.

The next step is to "pitch" the yeast. This means to proof it (just like when making bread) and add it to the prepared must. Your primary fermentation begins. The brew bubbles and gases a great deal. With wine, you press the juice from the grape skins, which adds their color and flavor. Then the wine or mead goes into a carboy, a large bottle with a small neck.

Fermentation locks are placed securely in the necks and filled with vodka. A fermentation lock blocks out airborne bacteria and yeasts, using a barrier of fluid. The carbon dioxide gas build-up is dissipated through the lock with a bubbling action.

When the bubbling slows or stops, the brew is racked (carefully siphoned into another carboy or cask for aging). After aging, the wine or mead is bottled, labeled, and ready for drinking or further aging.

The hypnotic bubbling carboys.

Bob-O spent several long days on the tractor. He leveled terraces and dug the rows for the rootstock.

I heeled the vines into a bed in the garden so they wouldn't dry out. We ended up getting a total of 102 vines into four rows on the side hill. The rest, I heeled in for the year, inside the deer fence of the garden proper. We laid a drip watering system on the rows right away. But it took two more years before we found the time to get the posts and a trellis system in.

Meadium Diversion

I knew it would be literally years before we would be able to harvest grapes and make wine. So I decided to try making mead. Mead is a honey wine. Arguably, mead was the first manmade alcoholic spirits. I got on the Internet, I bought books, and I dove right in. I started with 3 gallons (11.4 l) of mead.

It took a long time to process, but it turned out quite well. We were very pleased. I had begun acquiring the equipment needed for all my brewing ventures. In addition, I shopped online, found brew Web sites, and discovered a local (50 miles away) store that carries a limited supply of brew gear. I read a lot.

Bob-O Nose

As we began really learning about wine, we realized we knew nothing. What winemakers say about American wine drinkers is "90/24." This means that 90 percent of wine bought in America is drunk within twenty-four hours. I built a small wine cellar in the basement and paid more attention to what wine I was buying and storing.

Origins of Mead

The monks of the European Middle Ages became accomplished mead makers. They kept bees for the beeswax harvested from the hives. They made candles to keep the light of knowledge burning through those dark times. I picture the monks in their cramped carrels copying manuscripts by the light of a single beeswax candle.

Since waste is a sin, they harvested the honey by crushing the combs and draining them through baskets. The crushed combs were then washed with water. That honey water was made into mead for medicinal purposes.

Bob-O turned out to have an excellent nose for wine. Ernie was impressed that Bob-O could discern the subtle nuances in a wine right off. I am no good at this. There is a wine aroma wheel of the most common tastes in wine. If you do not have a good nose naturally, like Bob-O, you can train your nose.

I know what tastes good to me. Those descriptions of wine have always cracked me up, as in, “Poignant, but not overbearing... With a hint of filet mignon and Cuban cigar... A buttery blackberry finish.” Hock patooey.

First Shot Pinot

The second year, through our mismanagement, we had a very small harvest. By mismanagement, I mean we did not pinch the little bunches of grapes when they first appeared. We should not have had any harvest at all. You should not allow any fruit to mature the first two years, so that all the growth goes into the main trunk of the vine.

I couldn’t help myself. We picked the grapes, and I made wine. When all was said and done, I had twelve bottles of Pinot. I wanted to call it Pinot Bob-O, but Bob-O nixed that. So we printed up labels for “First Shot Pinot.” When it was finished, we eagerly poured, studied, and drank some. Bob-O calls it a good “vin ordinaire.” Our friend Jerry Igo said, “Well, that’s a lot better than ‘Vin-á gar.’” He’s right, of course.

I’m pleased with the result and hope to improve my technique with this year’s harvest. I’m now keeping records of what I do and when I do it. It’s surprising how important that is. Live and learn, eh?

Vintage 2004

This year, we have about seven gallons (26.5 l) of Pinot bubbling through the fermentation locks in a neutral corner of our living room. Next to it and considerably more active is this year’s batch of sweet mead. Soon, I’ll start a larger batch of dry mead. This year, I want to try sparkling mead. They say its taste can rival the best champagnes. I harvested 276 pounds (125 kg) of honey from four hives this fall. I have plenty to experiment with.

The Winery

My old *Home Power* office in our basement has become our wine cellar. I keep my honey bottling equipment there also. Of course, this is all for our own use and gifts for friends. We do not sell the wine or mead, just the honey.

When we were designing our wine label, Bob-O wanted to call our venture Windy Winery. Well, yes, it is very windy here. All our trees are flagged. But I just couldn’t do it, as much as I like alliteration. The name brings flatulence to my mind.

When we first moved to the creek, someone told me it had once been called Otter Creek because of all the otters that used to frolic there. So, we have become Otter Creek Vineyards. I like that a whole lot better.

I have found brewing wine and mead to be quite enjoyable. There is something positively hypnotic about watching a fermentation lock bubble. I found out Pinot noir vines live about 35 years, so I’ll get plenty of opportunity to learn the art.

Access

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Biodiesel Wedding

Dear fellow *HP* readers, My wife Deb and I were married in September and are excited to share this photo with you. In keeping with tradition, our friends decorated our car while we were still in the church, and this was by far my favorite "decoration." As you can tell from what they wrote, I am a biodiesel enthusiast and burned B100 in our Jetta all last summer. Indeed, the tank was full with it on our wedding day! It was hard to switch to B20 with the onset of cool weather this fall. B100 runs much quieter and the exhaust is noticeably less noxious.

We are also heating our house with B20 and I am in the process of connecting a 55-gallon drum so that we can also heat with waste grease from a local restaurant (I have about 60 gallons of it stockpiled in the basement). My aspiration is to follow in the footsteps of my friend Ames and heat with B100 next winter.

I can't close this letter without acknowledging the influence that *HP* has had on where I find myself today. About three years ago, I was looking for a new job. I had just left the United States Antarctic program after five tours to the icy continent (where I met my wife) and was trying to figure out what I could do that wouldn't be a disappointment after such an adventure. I couldn't imagine going to sit behind a desk at some engineering firm.

Well, thanks to *HP*, it didn't take me long to figure it out. One day while reading the magazine, a lightbulb went off that told me in no uncertain terms that I should pursue a career in renewable energy. Two months later, I had a job working for a company in Vermont that was manufacturing 50 KW wind turbines, and now I work for a company that specializes in wind resource assessment (www.awstruewind.com). It's comforting to work in such a positive industry when so many questionable things are happening in the world. Thanks *HP!* Peace, Love, and Renewables! Gary and Deb Winslow, White River Junction, Vermont • winsloga@yahoo.com • P.S. We are expecting our first renewably powered baby in June!

Lightning

Greetings from Bujumbura, Burundi, where I read your magazine now as the vocational skills training coordinator for a community-based peace and reconciliation initiative funded by USAID Office of Transitional Initiatives (OTI). I eat your magazine every day for breakfast and it is cause for many discussions around my coffee table in a country where solar energy is almost unheard of. I have been using your articles as a template for eight of my projects. Thank you for your hard work, which serves as a text reference for my work.

I have a question regarding the "Inverter vs. Lightning" sidebar by Rudy Ruterbusch on page 30 of *HP98*, which caught my eye since there are areas here with sandy soil, high lightning risks, and static buildup at the start of every rainy season. So I found this discussion appropriate. I have a light background in RE due to my studies with Carl Bickford at San Juan College in Farmington, New Mexico, but could not finish them due to my new job offer, which I could not refuse earlier this year. So, I know enough to be dangerous—enough to get me in trouble as well. I have two basic questions.

Q1: Does lightning protection necessarily need to be on the load or supply side of the inverter? I am assuming that by the fact that a DC disconnect is on the supply side, but that brings me to my next question.

Q2: I see that the article is recommending bonding the AC neutral and the DC negative to the same ground with the chassis. Does that make a difference if both load and supply sides are bonded together? Is this what is creating an easier path around the inverter? Thanks for your work. Greg Seelhorst • gseelhorst@yahoo.fr

Hi Greg, Regarding your first question, in our experience, lightning protection should be installed any place you can fit it. We have surge arrestors on both sides of our inverter, and on all charge controllers as well now. Living on a 350-foot high sand dune, we get tons of lightning hits. In the past fifteen years, we've burned up two TVs, three phone answering machines, two charge controllers, two inverters, one modem, and the circuit card on our furnace. Our installer now refers to our property as "lightning hill." Lightning generally hits the ground around our home, and since sand is such a lousy conductor, it finds its way up telephone lines, AC lines, and low voltage lines from the wind generator and solar-electric array. You never know where it's coming from. The important thing is that it has a way to get back out.

We've had two direct hits since rewiring our system as described in the sidebar, resulting in some of the damage listed above, but nothing in the RE system has been damaged. Our inverter kept running through both of those storms, and continues to operate today. As for bonding DC negative and AC neutral, most municipal codes suggest or require that they be bonded as long as they are both going to be grounded anyway. Some inverter manufacturers, such as Vanner, actually have a removable bonding plate installed inside the inverter, accomplishing this for you. It is removable only because some installations have a need to keep them separate.

This path around the inverter you mentioned is exactly what prevents damage to the device in the first place, so long as you have a good, low-resistance ground to connect it all to. In many radio tower installations in sandy soils, installers actually hire a private well drilling company to drill a well several hundred feet deep and install a steel casing, minus the pump. Then they use the well casing only as a ground rod, but not just for lightning dissipation. With sensitive electronics, one culprit is all that wind blowing over the metal tower day and night creating a static charge. The steel well casing continuously wicks that energy off before it has a chance to build up too much, finding its own way home. So bond everything that will be grounded in your system together at one location someplace, then run a large copper ground wire from there to the best ground location you can find—it's the only thing that worked for us. Good luck. Regards, Rudy Ruterbusch • windycabin@aol.com

Increasing Appliance Efficiency

Greetings *Home Power* crew! I hope all is well. This is a little lengthy, but your thoughts would be appreciated. We the little people cannot always afford the latest and greatest efficient appliances, but looking at the new stuff, we can modify what we have to improve their efficiency.

Example 1: I was shocked to discover that the most efficient Kenmore water heater only has insulation of around R-12. Well, for US$20, I found an aftermarket water heater blanket that has foil backing on the outside to reflect heat back into the water heater and an R-19 insulation value. It's only 1/4-inch thick, so it easily fits between a wall and the tank. It is also easy to tape into place because of the foil outside.

The other blankets I found are only R-12, have a white vinyl outside that does not reflect heat back well. They require special tape to stick to it, and are at least 1-inch thick. They are also heavy and bulky, requiring additional support to stay in place on the heater (like wrapping a support string around the whole thing, which crushes the insulation). Upon installing the foil blanket, we were able to turn down the water heater's temperature.

Too many people have their water heater installed right up against an outside cement wall, which acts like a sponge, siphoning the heat out of the water heater. Too many people use the hot/cold integral type faucet to reduce water temperature at the tap. I have my water temperature turned down so that at "full hot," I have hot water but I don't get burned.

Example 2: My old-style refrigerator was modified as follows to increase its efficiency. The heat coils are mounted to the back of the refrigerator with, at most, a 1-inch air gap. The coils were modified directly by gluing the above-mentioned 1/4-inch thick R-19 water heater insulation to the refrigerator's back to insulate it and reflect the coil heat. I added 1-inch standoffs to the bottom coil brackets and added 2 1/2-inch standoffs to the top coil brackets to move the heat coils away from the refrigerator's back.

The top and bottom coil offset allows heat to rise, yet it allows cooler air to reach the top coils. The additive temperature-building effect when the coils are perfectly vertical above each other is eliminated. I added a quiet US$5, 6-inch fan underneath to draw in cool air and blow it up the heat coils on the back. It is wired in parallel with the compressor. I removed the big old-style defrosting water tray (it sits under the refrigerator on top of its own heat coils to evaporate the defrosted refrigerator water) and I put a smaller tray on the floor directly below where it had been. The air pulled through by the fan evaporates the defrosted water and the now "open" defrosting coils dump heat into the air stream.

I glued the water heater blanket underneath as well so it reflects and insulates the refrigerator from the compressor heat and the defrost water evaporative coil heat. I wrapped water pipe insulation around the 48-inch-long "exposed" cooling compressor tube that takes cooled Freon up to the freezer section. I put the refrigerator up on appliance rollers, which allows easy access for cleaning the dust off the heat coils, leaving more room to draw cool air from under the refrigerator and blow it across the heat coils located on the bottom and back.

After doing all this, I had to turn down the refrigerator setting because the freezer section's temperature came down to the point that my ice cream was too hard to scoop out to eat. The refrigerator does not run as long, and does not turn on as often. The compressor temperature used to go over 120°F and now does not go over 105°F with an ambient temperature of 85°F. At 70°F ambient, the compressor temperature does not go over 95°F. Regards, Warren • bluemule1@netzero.net

Moonstruck

In the October 2004 issue of *Popular Mechanics*, an article by former astronaut and U.S. Senator Harrison Schmitt proposes a massive, unproven, high-tech, mining operation on the moon for traces of Helium 3 for use in third generation fusion reactors. Total starting costs are estimated at US$15 billion. Additional billions were tossed out as necessary to fully develop the program. With astronomically far supply lines, logistics problems, and probable loss of life and vehicles, I can't buy trusting our energy future to this system when solar-electric cells are available now for around US$3 per peak watt! Craig Daskalakis • cjdask@juno.com

Bad Battery Cells

Hello Richard, Karen, and crew, I can see from photos of you in the magazine from time to time that we are all growing older together. That's a good thing. My question is about my battery system. I have eight Trojan L-16 batteries that are run in parallel and series to provide us with a 12-volt system. Recently I've noticed that the Hydrocaps on one 12-volt group (of two) are getting hot. That is, five of the six caps are hot, while one remains cool. The 6-volt L-16 that contains that one cool cap is consistently low in voltage. The other 6-volt L-16 with three hot caps is consistently high in voltage. The combination of the two add up to the same voltage as the other 12-volt teams. If my system is reading 12.4 volts, the cold cap battery may read 5.4 and a hot-capped one may read 7.0 to compensate. I'm thinkin' I have a bad cell. I know I should get a hydrometer and check, which I plan to do tomorrow. If that cell is bad, should I drop both L-16s out of the system and run six L-16s for now? What action can I take to remedy my problem? Thanks for being there. Bruce Brummitt, Ponsford, Minnesota • bnc@arvig.net

Hello Bruce, You probably have one or more bad cells. Use individual cell voltage (or a hydrometer) to determine which cells. Just remove those weak batteries from the pack until you get around to replacing the entire pack. Getting older is cool—after all what other choice is there? Richard Perez • richard.perez@homepower.com

Datalogging Systems

Hi everyone, Let me start by saying how much I enjoy each issue. I put together an off-grid system about a year ago to run my new home in Carlisle, Ontario. I have 1 KW of solar-electric modules (fixed mount), a Whisper H80, and a Lakota. The two wind turbines are mounted side by side on 80-foot tilt-up towers. These feed a 70 KWH sealed gel-cell battery bank in my garage that powers a Xantrex SW5548 inverter and then a 120/240 transformer. Electricity is then fed at 240 VAC from a subpanel in the garage to the house panel, a distance of about 180 feet.

Part of the reason that I put up two wind turbines was because each manufacturer claimed to have a superior product. I could not find any comparisons on two or more turbines that were conducted in the same location, at the same height, and at the same time. So I decided to do my own product testing.

Here is my problem. Datalogging systems are prohibitively expensive, especially if I want to monitor all three sources at the same time. I would like to be able to monitor the kilowatt output of all three—either daily, weekly, or monthly—to do product comparisons based on yearly output vs. cost. Any suggestions from your staff or readers would be greatly appreciated. Thanks, Grant Jobb • grantjobb@hotmail.com

Hi Grant, Doing this inexpensively is not easy! I've run into it several times with workshop projects, and in my own system. I don't have a currently available, inexpensive datalogging system to recommend. I feel that this is the biggest technology gap in the renewable energy industry. A variety of systems are out there, but from my experience, they fall down when it comes to ease of use, versatility, or cost.

We need affordable metering that is user friendly and allows users to measure energy usage and generation from multiple sources, as well as measuring the resources. I hope our readers speak up with their successes and needs, and that manufacturers come forward with well-designed and integrated packages so we can keep track of our renewable energy systems. Ian Woofenden • ian.woofenden@homepower.com

Hydro Scheme

I have just started my own solar heating company in South Africa (at 56 years old). I dabble in everything renewable. I'm wondering if it is possible to fit a hydro generator to the water circuit of my swimming pool pump, which runs for at least nine hours a day in summer and consumes 9.75 KWH a day. Maybe I can recoup some energy for lighting at night. I thank you kindly. Anwar Arnold • aarnold@webmail.co.za

Hi Anwar, The problem with your idea is that the pump will need to work just as much harder to make up for the amount of work you get out of the hydro generator. In fact, it would have to work harder than the hydro generator output because of the inefficiencies involved, so you would actually use more *energy with that scheme. Michael Welch • michael.welch@homepower.com*

Turning Out the Lights

Michael, I just wanted to congratulate you on your column in *HP104*. It is interesting that a Hollywood scriptwriter came up with a film called "The Day After Tomorrow" that portrayed a similar scenario. It is unfortunate that the film was not prefaced with something along the lines of "based on a Pentagon report called 'Imagine the Unthinkable.'"

I am not telling you anything new by saying we are seeing the start of something very alarming going on in Alaska and the entire polar region. Most Americans are just unaware of what is happening in our 50th state, which is shrinking in land mass as I type. So it is always good to see that *Home Power* cares about the environment and is always recommending a lessening of our CO_2 footprint on the planet.

I especially liked your recommendations on curbing climate change. All were transportation related, as we are nearly all driving internal combustion engine automobiles. We all aspire to move ourselves around as efficiently as possible, especially since each gallon of gasoline we burn creates 20 pounds of CO_2. This is why we want fuel-efficient vehicles, so we can move ourselves a much greater distance on a gallon of gas, therefore burning less.

In the meantime, a billion cars throughout the world go on as always, some of us driving as little as possible, while most of the rest do not give it a second thought. I travel quite a bit to Europe, Asia, and Central America. I have noticed a phenomenon in America and Northern Europe that is getting increasingly more common—automobiles with their headlights on during the day. We chalk it up to being safety conscious (though there is substantial evidence that the benefit is negligible at best), but do not take the environmental cost into account (imagine that?).

Headlights require electricity. The consequences are staggering and the benefits of daytime vehicle lighting are debatable. The sad thing is that even though the Department of Transportation and the Oregon drivers' manual only recommends headlights in rain or fog, many Americans drive with them on all the time. The average cost of headlights is a 2 percent reduction in fuel economy. Even if it were only 1 percent, the fuel usage is huge! My hometown of Portland, Oregon, has been adding responsible headlight use to their agendas at monthly meetings of the motor pool for about six months now. I worked with the manager of the city fleet for over a year to accomplish this small feat.

Do you think it might be possible to mention something about this in upcoming article, or an addendum to "Imagine the Unthinkable"? It is my contention that most people simply do not know the environmental consequences of driving with their headlights on all the time. It would be wonderful to see *Home Power* recommend judicious use of headlights. Regards, Michael Haynes • raincity@theguttercleaner.com

Hi Michael, That Web link you sent me in a subsequent e-mail was pretty astounding. The page at www.howstuffworks.com/question424.htm is titled, "If daytime running lights were mandatory in the U.S., and all vehicles had them, how much extra gasoline would that use each year?" Putting it in terms that our readers are already familiar with, if all cars in the U.S. used their headlights in the daytime, the headlights would consume 4.26 billion kilowatt-hours each year. That would also mean an additional 8 billion pounds of carbon dioxide each year. Wow. Michael Welch • michael.welch@homepower.com

Inspiration

Greetings Linda. Your review of SEI's online courses in *HP103* inspired me to stop being a "mug-wump" (a bird that sits on a wire fence with his mug on one side and his wump on the other) and get going to do what I have wanted to do for the past several years. I need to take the next step and start using solar energy.

I began electrical conservation back in the mid 1980s. Each compact fluorescent bulb in our home then cost me between US$18 and US$22. I can buy four 24-watt to six 13-watt bulbs for that same amount of money. My home, garage, and outside security bulbs are almost all CF bulbs—a few are tube fluorescent. I am proud to match my utility bills with anyone now. The reduction is all done through conservation of turning off lamps and not leaving taps running.

Your review gave me the final push I have been needing. The push to get going and do what I really want to do—solar energy. I retired in January 2004. My retirement hobby will be renewable energy. I have done lots of reading and research, but no courses. Further, I have not done anything except asking questions and spreading the news. I want to put up a couple of solar-electric panels and connect to the grid. I also want to do some solar hot water.

We have a total of seven solar energy systems in a city with a population of 205,000. I have encouraged the local library to obtain a subscription to *HP*. Now I am encouraging them to get SEI's *Photovoltaics Design & Installation Manual* and *When the Lights Go Out*, together with *Solar Hot Water: Lessons Learned.* I am planning to take an SEI PV course in the spring of 2005. I am signing up for the on-line course also. I hope others will take up your challenge. Thank you for your inspiration! Jim in Saskatoon, Canada • purple2@sasktel.net

Hi Jim, It's great that you are motivated to do something—that's half the challenge or more to changing how people in this world get their energy. It's inspiring for us to hear from readers who are doing something.

I also started my venture into RE by reducing use. I was in the middle of editing Andy Kerr's financial analysis of CF bulbs in HP85 *(the issue I started working for* Home Power*) when I decided to drop everything and go buy CF bulbs for the entire house. I reduced our household electricity use to half what it was by doing the same things you mentioned.*

We are very excited at Home Power *to see the renewable energy bug catching on. It's truly the direction to go for new energy sources. I think Canada's government is progressive enough for renewables to really take off there as more incentives are offered.*

Keep us posted about how your hobby progresses. Solar hot water is definitely a great place to start because of its extremely fast payback. Make sure to take pictures and write up your projects for us. Thanks for writing. Linda Pinkham • linda.pinkham@homepower.com

Clearing Snow off PVs

Dear *Home Power* readers, I just read the letter about clearing snow off of PV panels. We live in mid Missouri at the Lake of the Ozarks, where we have been totally off-grid for eighteen years. We receive a varying amount of snow each winter, which is in the changeover area where the precipitation often starts out as freezing rain. We watch the local news for weather every day. When snow is anticipated or right when it begins, we go out and close the covers on our 87 photovoltaic panels, which are in arrays of 6 and 7 panels each. The covers are lightweight corrugated metal roofing hinged to the bottom of each array. At the top of the closed cover we have a 6-foot piece of plastic coated wire with a knot at the end (rope would work) to make it easy to pull the cover open and closed.

After the snow quits, we go out and pull the covers open and the snow just falls off the cover. The rest of the residual snow melts off easily as the sun hits the panels. We make lots of electricity from reflection when snow is on the ground and the sun is shining, so it is important to get the snow off right away. We use the wire or rope to tie the cover down for times of the year when we have high winds, to keep the covers from blowing shut. Also, we close the covers during the spring and summer when we have severe thunderstorms to prevent hail damage. This system works wonderfully—we have had some storms with softball-size hail.

We rarely neglect to close the covers because we really don't like cleaning snow and encrusted ice off of our panels. We use a squeegee or a broom and wait for a melt when this happens. Of course, our panels are not mounted to the roof, but instead on the ground alongside the garden. We have a solar hot water panel that sits on a second story deck with an insulated cover that we close for protection from light frost during the spring and fall. The panel is drained during the winter. So we wouldn't have to climb up on the deck each morning and evening to close the cover, we attached a long rake handle to the end of the cover. This makes opening and closing the cover in this situation easy from the ground. Something like this could possibly be adapted to close panels on a roof for snow.

A few years ago at the Midwest Renewable Energy Fair in Madison, Wisconsin, we showed pictures of our solar home and photovoltaic array. The advice we got from several experts was to take those covers off because the reflective heat could cause damage to the panels. We believed them, even though we had already used the covers for years, and we took them off. Well, the experts must not have seen some of the hail, freezing rain, and snow that we get here in Missouri. A friend of ours lost some panels during a hailstorm one spring. We wanted to protect our investment, so we put the covers back on. We recommend this method after eighteen years of use through many snow and hail storms. Just don't use a highly reflective color that will make intense heat in the summer, and we put the cover at a 120-degree angle for this reason. Sincerely, Stan and Karen Kramer • kramer@socket.net

Clearing Snow off PVs 2

We built our off-grid, passive/active solar, adobe home last year. To save on construction costs, we installed the solar-electric system first. The wind generator didn't come till later, but we put the PVs in right away.

One Monday morning last February, right after a snow storm, my contractor called from the construction site in a half panic... the batteries were down to 60 percent, the sun was shining, and we were not charging! I raced from Albuquerque up to the building site near Madrid, New Mexico. I swung by my brother's and borrowed his generator just in case. Once on the building site, the contractor and I huddled over the Xantrex inverter and the Tri-Metric hitting every button. We were trying everything to figure out how to get it to start charging and why it wasn't to begin with.

The batteries were low for a number of reasons. The construction crew was setting tile over the weekend using a water saw (lots of electricity). A coffee maker had developed a fault and was drawing 20 amps *all* the time and not automatically shutting off. The laundry room light had been left on (with the laundry fan on as per code). And of course, nobody was checking energy use. By the time I arrived, the saw, coffee pot, and lights had been turned off. Though we'd gotten 2 or 3 inches of snow, the storm had passed and the sun was out and shining bright, but we were not charging.

After I don't know how long we stood there pushing buttons, testing circuits, and scratching our heads, my contractor finally looked at me and asked, "Did anyone knock off the snow?" Duh! Naturally there was an inch of snow completely covering the panels. The twelve BP panels mounted in a freestanding frame stand close to 15 feet high. Hmm. I grabbed a soft bristled push broom and carefully tossed it up onto the panels. The broom slid down, clearing the snow. We started charging! I never did use my brother's generator (for that emergency).

This is our second winter living on the land—we call our home "Milagro del Sol." I am prepared. I am using the same soft-bristled push broom. I bought a "painter's friend" from the hardware store. It is an extension handle used by painters. It is two lightweight but strong tubes that slide into one another with a locking device and threads at each end.

It is designed to thread into the handle of a paint roller, so a painter can roll out ceilings and tall walls from the ground. Turns out that the thread is standard for push brooms also. My wife, all 5 foot 1 inch of her, has no problem reaching the top of our panels. Since both ends are threaded, two extensions can be joined to double your length. Good Luck, Grey Chisholm • GreyChis@aol.com

Thanks Stan & Karen, and Grey. Good solutions, and good storytelling. Michael Welch • michael.welch@homepower.com

Liability Insurance

Dear *Home Power*, We have put up a small grid-tied wind generator on our property in Hudson Township, Wisconsin. We are looking for information on reasonably priced general liability insurance in the amount of US$1,000,000 per occurrence and property loss insurance in the amount of US$300,000. We are required to provide proof of insurance to St. Croix Electric Cooperative, our electric company, in these amounts. We would appreciate any assistance you could give us in finding sources of information regarding any group rates that we could get. Is any such thing out there?

We would also appreciate any information you can give us that would make getting this type of insurance easier to obtain. We've read an article informing us about the type of insurance that is required for wind generators, but cannot for the life of us find it again! We thought it was in *HP*, but it could have been off the Internet.

Thank you in advance for your consideration to these concerns. Your answers will be highly regarded. We appreciate your entire magazine from cover to cover each and every issue! Sincerely, Steve and Sandra Peterson • steveandsandrapeterson@msn.com

Hi Sandra & Steve, I believe that what your utility is looking for is a standard household policy. A nonprofit I work with just went through this very same thing with a PV system. Most of the time, utilities do not need anything special, do not need to be added as additionally insured, but do need to verify that the property has liability insurance. If your household insurance does not go up to those amounts, a nominal additional premium will probably bring them up to the expected amount.

If this does not jive with what your co-op is telling you, then I suggest that you contact the Midwest Renewable Energy Association (MREA; 715-592-6595). They should be able to help you or refer you to someone local that can help you with more information. They, or a local RE dealer/installer, are more well versed in Wisconsin rules and regulations, and might even be able to help you with getting the co-op straightened out. Michael Welch • michael.welch@homepower.com

Send your letters to Home Power magazine at letters@homepower.com or PO Box 520, Ashland, OR 97520

RE happenings

INTERNATIONAL

Solar On-Line (SóL); Internet courses on PV, green building & international development. Info: SóL, PO Box 217, Carbondale, CO 81623 • 720-489-3798 • info@solenergy.org • www.solenergy.org

Solar Energy International online; Internet courses on PV Design & Solar Home Design • Info: see SEI in Colorado listings.

BRAZIL

Feb. 15–17, '05; Latin America RE Fair; Rio de Janeiro. For RE businesses in Latin America—in conjunction with RIO 5 World Climate & Energy Event. Info: RIO 5–LAREF Organization, a/c PML, Av. Rio Branco, 25/18° andar, 20093-900 Rio de Janeiro, RJ, Brazil • (55-21)-2233-5184 • info@rio5.com • www.rio5.com

CANADA

Alberta Sustainable Home/Office; Calgary. Open last Sat. every month 1–4 PM, private tours available. Cold-climate, conservation, RE, efficiency, etc. Info: 9211 Scurfield Dr. NW, Calgary, AB T3L 1V9 • 403-239-1882 • jdo@ecobuildings.net • www.ecobuildings.net

COSTA RICA

Feb. 21–27, '05; Homebuilt Wind Generators workshop; Fundacion Durika, Costa Rica. Build wind generators from scratch. Info: Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org • Coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Mar. 7–13, '05; RE for the Developing World: Hands On; Rancho Mastatal, Costa Rica. Solar electricity, hot water & cooking, biogas, & other RE technologies. Info: Solar Energy International (see above).

GERMANY

Feb. 25–27, '05; Erneuerbare Energien 2005; Böblingen. Consumer & trade fair for RE; Energy-efficient building & reconstruction. Info: www.erneuerbareenergien.com

Mar. 16–18, '05; ENEX–New Energy 2005; Polen. RE trade & consumer fair. Info: www.enex-expo.com

Jun. 21–22, '05; European Solar Thermal Industry Conference, Frieburg. Solar thermal energy markets, promotional policies, marketing, technology, & certification. Info: European Solar Thermal Industry Assoc., RE House, 26, Rue du Trone, B-1000 Bruxelles • 32-2-546-19-38 • Fax: 32-2-546-19-44 • info@estif.org • www.estif.org-solar.de

ITALY

May 5, '05; SolarExpo; Vicenza. Int'l. Conf. & Exhibition on RE, distributed generation, & green building. Info: Chiara Borsato • 39-0439-849-855 • press@solarexpo.com • www.solarexpo.com

SOUTH AFRICA

Apr. 18–22, '05; RE World Africa 2005; Midrand, Johannesburg • Conference, exhibition & energy fair. Info: Christopher Raubenheimer • 27-11-463-2802 • chris.raubenheimer@terrapinn.co.za • www.powergenerationworld.com/2005/renew_ZA

UNITED KINGDOM

Apr. 18–21, '05; Int. Power Sources Symposium & Exhibition; Brighton Corn Exchange. Storage of RE. Info: www.ipss.org.uk

May 5–7, '05; Clean Energy Technology & Investment Exhibition, London. Info: LPB Events 18 King Edward Buildings, 629 Fulham Rd., London SW6 5UH • 0207 751 9998 • www.clean-energy-expo.com

U.S.A.

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

Info on state & federal incentives for RE. North Carolina Solar Center, Box 7401 NCSU, Raleigh, NC 27695 • 919-515-5666 • www.dsireusa.org

Ask an Energy Expert; online or phone questions to specialists. Energy Efficiency & RE Network (EREN) • 800-363-3732 • www.eere.energy.gov

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

ARIZONA

Apr. 23, '05; Tucson Solar Potluck; Catalina State Park, Tucson, AZ. Solar potluck. Bring solar oven &/or bring a dish. Music, food, PV demo, solar fountains, & kids' activities. Info: 520-885-7925

Scottsdale, AZ. Living with the Sun; free energy lectures, 3rd Thurs. each month, 7 PM, City of Scottsdale Urban Design Studio. Info: Dan Aiello • 602-952-8192; or AZ Solar Center • www.azsolarcenter.org

CALIFORNIA

Apr. 8–10, '05; Alternative Fuel Summit, Firebaugh, CA. Biodiesel, SVO, ethanol, & electric propulsion. Workshops: engine conversion & fuel processing. Info: Mercey Hot Springs, 62964 Little Panoche Rd., Firebaugh, CA 93622 • 209-826-3388 • www.merceyhotsprings.com

Apr. 23, '05; Sustainable Living & Arts & Music Festival; Humboldt State Univ., Arcata, CA. RE workshops and exhibits, RE-powered music. Info: Associated Students, HSU, Arcata, CA 95521 • 707-826-4221 • hsuas@humboldt.edu

Arcata, CA. Campus Center for Appropriate Technology, Humboldt State Univ. Workshops & presentations on renewable & sustainable living. CCAT, HSU, Arcata, CA 95521 • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Ongoing workshops, including beginning to advanced PV, wind, hydro, alternative fuels, green building techniques & more. Info: Solar Living Institute, 13771 S. Hwy. 101, Hopland, CA 95449 • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO

Denver. Windhaven RE seminars; Solar Energy Basics, Biodiesel & Alt. Fuels, Wind Energy Basics, Alternative Building, others. Info: Windhaven Foundation for Sustainable Living, 6795 S. Field Ct., Littleton, CO 80128 • 720-404-9971 • windhavenco@yahoo.com • www.windhavenco.org

Carbondale, CO. SEI hands-on workshops & online distance courses on PV, solar pumping, wind power, microhydro, solar thermal, alternative fuels, green building, & women's courses. Info: Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

Mar. 12–13, '05; Green Living & Energy Expo; Coral Shores High School, Tavernier, FL. Environmental education, incl. workshops, vendors, & more on efficiency, RE, & resource conservation. Info: Cristina Lindley • 305-292-4501 • www.keysglee.com

ILLINOIS

Chicago, IL. Urban Enviro Living Workshops. 2nd & 4th Thurs. each month, 7 PM. Sustainability, energy efficiency & conservation, RE & green building. Info: 312-842-8727 • hometown.aol.com/ecadvocate

IOWA

Prairiewoods & Cedar Rapids, IA. Iowa RE Assoc. meets 2nd Sat. every month at 9 AM. Call for changes. Info: IRENEW, PO Box 3405, Iowa City, IA 52244 • 563-432-6551 • irenew@irenew.org • www.irenew.org

MICHIGAN

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

MINNESOTA

Apr. 30–May 1, '05; Living Green Expo, St. Paul. Sustainable living fair, incl. workshops, exhibits, & info on RE, transportation, & green building. Info: 612-331-1099 or 651-215-0218 • www.livinggreenexpo.org

NEW MEXICO

Feb. 18, '05 (again Aug. 19); Earth-Based Vocations 10-week certification training, Santa Fe. Whole systems approach to RE & other areas. Info: Ecoversity, 2639 Agua Fria, Santa Fe, NM 87505 • 505-424-9797 • admin@ecoversity.org • www.ecoversity.org

May 20–22, '05; Conf. of the Adobe Assoc. of the Southwest; El Rito, NM. Info: Northern New Mexico Community College • Quentin Wilson • 877-806-2987 or 505-581-4156 • info@adobeasw.com • www.adobeasw.com

Feb.–Mar. & again Oct.–Nov. each year. Intro to Homemade Electricity; Deming, NM. 5 Thurs. eves. Info: Mimbres Valley Learning Center • 505-546-6556 ext. 103

NORTH CAROLINA

Pittsboro, NC. RE, biofuels, green building, & other sustainable living courses at Carolina Community College. Info: Piedmont Biofuels Coop • 919-542-6495 ext. 223 • www.cccc.edu or www.biofuels.coop

Saxapahaw, NC. How to Get Your Solar-Powered Home. Info: Solar Village Institute, PO Box 14, Saxapahaw, NC 27340 • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

NORTH DAKOTA

Feb. 23–24, '05; Conference on RE in the Upper Midwest, Grand Forks, ND. Wind power, biofuels, H2 from RE, & more. Info: EERC, 15 N. 23rd St., PO Box 9018, Grand Forks, ND 58202 • 701-777-5246 • lfoerster@undeerc.org • www.undeerc.org/re

OREGON

Cottage Grove, OR. Adv. Studies in Appropriate Tech.; 10 weeks, 14 interns per quarter. Info: Aprovecho Research Center, 80574 Haxelton Rd., Cottage Grove, OR 97424 • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Mar. 4–5, '05; (again Oct. 14–15) Passive Solar Greenhouse Workshop; Spring Grove, PA. Design, construction, & year-round production. Info: Steve & Carol Moore, 1522 Lefever Ln., Spring Grove, PA 17362 • 717-225-2489 • sandcmoore@juno.com

Philadelphia, PA. Penn. Solar Energy Assoc. meetings. Info: PO Box 42400, Philadelphia, PA 19101 • 610-667-0412 • rose-bryant@erols.com

TEXAS

El Paso. El Paso Solar Energy Assoc.; meets 1st Thurs. each month. Info: EPSEA, PO Box 26384, El Paso, TX 79926 • 915-772-7657 • epsea@txses.org • www.epsea.org

Houston. Houston RE Group meetings. Info: HREG • hreg04@txses.org • www.txses.org/hreg

WISCONSIN

Feb. 1–2, '05; Better Buildings, Better Business Conference, Wisconsin Dells. Info: RENEW Wisconsin, 222 S. Hamilton St., Madison, WI 53703 • 608-819-0748 • www.renewwisconsin.org

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. Info: MREA, 7558 Deer Rd., Custer, WI 54423 • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

Send your renewable energy event info to happs@homepower.com

questions & answers

Heat Recovery Drains

I have been reading your magazine for about a year now, ever since I put in a ground source heat pump. I'm wondering what you think of those heat recovery drains. The one I am looking at fits in the main waste line of the house and as the hot shower water runs down the inside of the drain, circular pipes mounted on the outside of the drain pipe (everything is copper) transfers the heat into the cold incoming water of the house (or the cold side of the shower).

Does it work? I really hate the idea of all that hot water just running down the drain. I used your instructions to build a pipe-in-pipe heat exchanger, and I did not quite get the results I was expecting due to the fact that I was dealing with low water temperatures (120°F max) and high flow rates, but this thing has a lot more pipe to it with a lot more surface area. If you could run an article on these things, and really give us the dirt on 'em, it would be great. Thanks, Dave Lotte • dave_lotte@yahoo.com

Hi Dave, Yes, those heat exchangers work. How well they work and the value of their installed cost is another question. You are right about the exchange area of copper being important, and installed cost is the other important factor affecting the value. All of these products I have seen are single-pass exchangers and only work effectively when recovering shower drain water. They do not recover heat from tub water since there is typically no incoming water when the tub is draining. The same would be true for normal dishwashing and clothes washing—the fill and drain cycles are at different times. We should also keep in mind that single-pass or instantaneous exchangers do not have the overall efficiency of multipass pumped or thermosyphon exchangers.

With shower drain water about 95°F and incoming water about 70°F, I would estimate that, at best, a single pass heat recovery unit would boost the incoming water about 15°F. If the water used in the shower amounted to 6 gallons (48 pounds), this would recover 720 BTUs (48 x 15). If this were saving natural gas at 90 cents a therm (100 cu. ft.) with a 70 percent efficient water heater, the savings would be about a penny a shower. A family of four averaging a shower a day per person would save about US$15 a year. Displacing electricity at 10 cents a KWH would give a savings of about 2 cents a shower or about US$30 a year for our well-scrubbed family. These units can cost from US$95 to several hundred dollars, depending upon type and capacity.

All of these products should be double-wall exchangers since drain water is not considered potable. Keep in mind that these are only estimates and what I would expect as best case at incoming 70°F water for a well-made, double-wall instantaneous exchanger. The exchangers come in different sizes, and the larger the heat exchange surface area, the more it will save. A heat recovery exchanger like this will save more or less depending on the incoming water temperature, daily usage, and cost of the water-heating fuel. Cheers, Chuck Marken • chuck.marken@homepower.com

Using Automotive Regulators

I like your magazine and I have picked up lots of ideas out of it. One thing I have not been able to find anywhere is this. Is it possible to use a voltage regulator from a car in place of a charge controller in my solar-electric system? It seems to me that they both serve the same purpose. Bruce Wade • aap@gci.net

Hello Bruce, While a car voltage regulator serves the same general purpose as a PV regulator, they are radically different. The car regulator controls by regulating the amount of energy fed to the alternator's field. The PV regulator works by pulsing the PV output when regulating. They have the same basic purpose, but they are radically different circuits for the two very different charging sources. A car regulator also is limited to a relatively low voltage for your starting battery's charge cycle, while a home electrical system battery bank needs to be charged at a higher voltage, and in a more sophisticated way. Richard Perez • richard.perez@homepower.com

Phone Noise

The cordless phone I have requires 9 VDC input. To avoid using my inverter, I bought a 12 VDC to 9 VDC converter. Evidently, the PWM function creates so much interference and noise that the phone is unusable. Is there some other way to do this, or do I have to scrap the phone and look for one with a 12 VDC input? By the way, can you recommend any brands that meet this requirement? Vincent Valentino, Lovingston, Virginia • valentinomasonry@hotmail.com

Hi Vincent. First, there are different kinds of DC-to-DC converters. You should be using one with an LM 7809 (or similar) linear series dissipative regulator because it has no switching transients. Check with your electronics supply store for an RFI-free converter. I know that I have purchased Radio Shack converters that had little or no interference.

Also, this could be a ground contention problem since the 120 VAC supply offers isolation that the DC-to-DC supply doesn't. Try the DC converter on a small 12 VDC battery separate from your system to see if inverter noise doesn't feed through. Maybe you can bring your car battery in temporarily. It might be inverter interference. Sometimes those battery cables act like big antennas, putting out a lot of RFI.

I used to use a 12-to-9-volt DC converter for my answering machine, but someone convinced me that the voltage regulation in my answering machine could handle the straight 12 V. It did just fine, but I was always sure to unplug it when I equalized my batteries. I didn't know if it would harm it, but didn't want to take the chance of putting over 15 VDC into the machine. If you are going to scrap the phone anyway, you might give that a try. Michael Welch • michael.welch@homepower.com

Positioning PVs

Can you answer a question that puzzles me about solar-electric panels? Everyone I have spoken to says that they must be situated in a straight line, but I have not had a definitive answer as to why. Can you, for example position the panels in a bit of a semi-circle, so that one or more panels face the sun throughout the day from morning to evening? This, I think, would be particularly beneficial in winter when the sun is low in the sky. Thanks, Paul Billinge • paul@kal.forthnet.gr

Hi Paul. First, an operative word in your question is "must." There is no "must" to this, but rather what works best and is most convenient. It is not so much that PVs need to be in a straight line, as it is that they should be pointed south (in the northern hemisphere) for maximum energy production.

Two things are going on with this. First, the most solar exposure happens when the panel surface is at right angles to the sun, and the maximum solar radiation comes at solar noon when the sun's rays travel through the least atmosphere. So facing the panels due south gives peak output at solar noon from any solar-electric panel, and this holds true whether there is one panel or a bunch of them—what is best for one panel in a PV system is best for all of them. Further, if you face some or all of the panels away from south, that means that you are decreasing the amount of sunlight hitting them during some hours of the day, even though you may be increasing it for another part of the day.

There are some situations where it could pay off to not face the modules due south. One example is if you live in a place that is foggy at one end of the day, but has bright sun at the other. In this case, it may be best to face the panels more toward where the sun is when it is not foggy. Still, it would be best if all *the panels faced that direction. Once again, what is best for one panel is best for all of them.*

Another example is if you did not have a convenient place to mount the panels so they faced due south. Some folks have north-south roof lines, which makes it easiest, cheapest, or most attractive, to mount the solar panels facing east or west. This will work, but will not gather as much energy as they could if they were oriented due south. Make sense? Michael Welch • michael.welch@homepower.com

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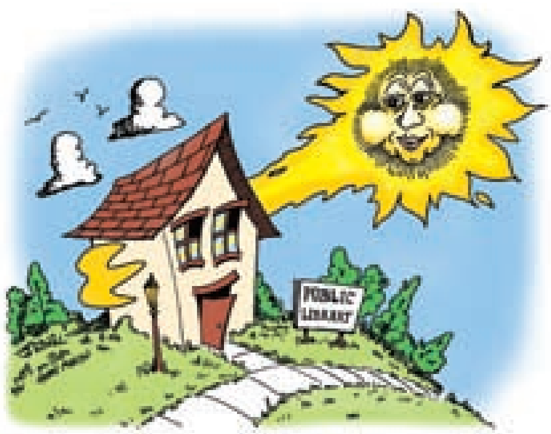

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Energy Survey

The following optional questions about your renewable energy use help us tailor the magazine to meet your needs. All information is kept confidential. We appreciate your input.

I use, or plan to use, renewable energy for:

Now	Future	
☐	☐	All electricity
☐	☐	Most electricity
☐	☐	Some electricity
☐	☐	Backup electricity
☐	☐	Recreational electricity (RVs, boats, camping)
☐	☐	Vacation or second home electricity
☐	☐	Business electricity
☐	☐	Transportation
☐	☐	Water heating
☐	☐	Space heating

My site(s) have the following renewable energy resources:

- ☐ Solar power
- ☐ Wind power
- ☐ Hydro power
- ☐ Biomass
- ☐ Geothermal power
- ☐ Tidal power
- ☐ Other (explain)

Electric utility grid use:

☐ I have the utility grid at my location.

I pay ______¢ for grid electricity (cents per kilowatt-hour).

______% of my total electricity is purchased from the grid.

☐ I sell my excess electricity to the grid.

The grid pays me ______¢ for electricity (cents per kilowatt-hour).

I use, or plan to use, the following renewable energy products (check all that apply):

Now	Future	
☐	☐	Photovoltaic modules
☐	☐	Wind generator
☐	☐	Hydroelectric generator
☐	☐	Battery charger
☐	☐	Instrumentation
☐	☐	Batteries
☐	☐	Inverter
☐	☐	Controls
☐	☐	PV tracker
☐	☐	Engine/generator
☐	☐	Methane digester
☐	☐	Thermoelectric generator
☐	☐	Solar oven or cooker
☐	☐	Solar water heater
☐	☐	Wood-fired water heater
☐	☐	Solar space heating system
☐	☐	Hydrogen cells (electrolyzers)
☐	☐	Fuel cells
☐	☐	RE-powered water pump
☐	☐	Electric vehicle

Feedback

Please write to us here. Tell us what you like and don't like about *Home Power*. What would you like to read about in future issues? Thanks for your attention and support.

☐ It's okay to print my comments as a letter to *Home Power.*

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