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Atlantic Solar Products, Inc. - Maryland
Toll Free: 800.807.2857
Phone: 410.686.2500
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Internet: www.atlanticsolar.com

Dankoff Solar Products - New Mexico
Toll Free: 888.396.6611
Phone: 505.473.3800
E-mail: pumps@dankoffsolar.com
Internet: www.dankoffsolar.com

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Toll Free: 888.824.0090
Phone: 504.537.0090
E-mail: esp@effectivesolar.com
Internet: www.effectivesolar.com

Hutton Communications - Georgia
Toll Free: 877.896.2806
Phone: 770.963.1380
Fax: 770.963.9335
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Internet: www.huttonsolar.com

Intermountain Solar Technologies - Utah
Toll Free: 800.671.0169
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Fax: 907.561.4233
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HOME POWER

THE HANDS-ON JOURNAL OF HOME-MADE POWER

Issue #90 August / September 2002

Features

More Features

Solar Thermal

Homebrew

Cover: Some of the thirteen home-scale wind generators compared in “Apples & Oranges” on page 50.

Access and Info

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Fax: 541-512-0343

E-mail: hp@homepower.com
Web: www.homepower.com

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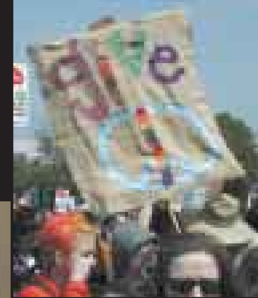
Sunshine gold, not black gold.



A time to mend.

Caitlin Grooms of Chico Peace Works offers peaceful alternatives.

Unite in peace.

Pump sunshine.

Solar is Peace

On April 20, 2002, many thousands of people converged on Washington, DC, San Francisco, California, and other communities all over the country to be heard and seen in the name of peace. The big media was a bit confused by the diversity of groups attending, assuming that it meant the message wasn't cohesive. But the members of the *Home Power* crew who made the pilgrimage to San Francisco knew better; everybody there had the same purpose—an end to violence.

Violence comes from two things: oppression of others, or reaction to being oppressed by others. Which is which continues to be debated. But eliminate oppression, and the debate becomes moot.

The opposite of oppression, freedom, is the ability to control our own lives—to provide our own food, shelter, and other needs, including energy. If we can provide these things for ourselves and our communities, then we are free. And, if we can provide for ourselves without oppressing others' ability to provide for themselves, then we all are free.

Renewable energy technologies allow everyone, everywhere to provide for their own energy needs. The energy is given freely, and to harvest it doesn't infringe on the freedoms of others. Gone is the oppression over control of limited resources, their polluting effects, and their related monies.

Solar is independence...is security...is freedom...is peace.

—Ben & Joe, for the *Home Power* crew

People

Philip Angell
John Bertrand
Mike Brown
Sam Coleman
Richard Engel
Marika Febus
Rick Germany
John Gislason III
Eric Grisen
Henry
Kathleen Jarschke-Schultze
Stan Krute
Don Kulha
Bill Layman
Don Loweburg
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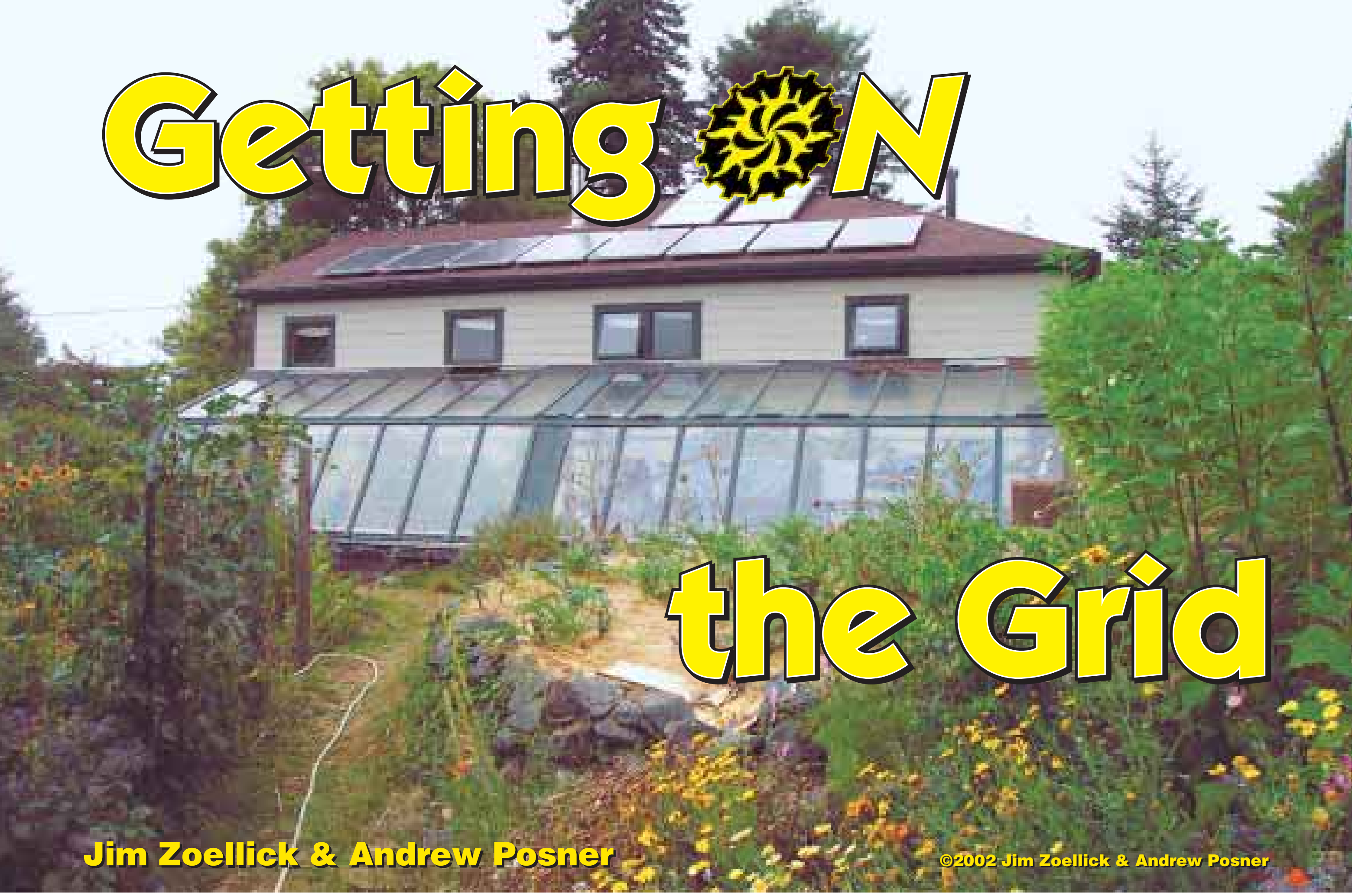
Richard Perez
Linda Pinkham
Andrew Posner
Shari Prange
Benjamin Root
Mick Sagrillo
Connie Said
Joe Schwartz
Jeremy Smithson
Brian Underwood
Michael Welch
John Wiles
Dave Wilmeth
Ian Woofenden
Rue Wright
Jim Zoellick
Solar Guerrilla 0021

"Think about it..."

"Turn your face to the sun and the shadows fall behind you."

— Maori proverb



Humboldt State University's Campus Center for Appropriate Technology wanted to create a model for small-scale, distributed electricity generation. After ten years of off-grid living, they reconnected to the utility grid.

In May of 1991, students at the Campus Center for Appropriate Technology (CCAT) at Humboldt State University (HSU) cut the wire connecting them to Pacific Gas and Electric Company (PG&E), their local electric utility. For ten years, CCAT demonstrated energy self-sufficiency by getting the majority of its electricity from sun and wind. To supplement the renewable resources, they produced electricity using a backup generator running on biodiesel fuel made on-site with waste oil from local restaurants. In June 2001, after ten years of energy independence, we reconnected to PG&E.

Why the change? We are now demonstrating a state-of-the-art, grid-connected photovoltaic system. Although solar-electric systems are more cost competitive in remote applications where grid electricity is not available, the majority of us are connected to the utility grid. When you're on the grid, batteryless PV systems are the most efficient and cost effective strategy. By demonstrating such a system, CCAT now has the opportunity to reach a much larger audience of prospective PV system adopters.

Over 3,200 people visit CCAT every year, either on self-guided or docent-led tours. The home and grounds are open six days a week to students and the community. Besides the renewable electricity generation equipment, some of the systems featured at CCAT include solar hot water, solar ovens, pedal-powered appliances, organic gardens, a solar greenhouse, vermicomposting, greywater recycling, a composting toilet, and straw bale construction.

Like other systems at CCAT, the PV system has been designed as a demonstration, accessible to our visitors. We track our electrical energy use and PV production, and document this data using a dry erase board that is updated weekly. From October 17, 2001 through April 23, 2002, the new PV system generated 901 KWH of clean electricity. In the future, we plan to have a small electronic display that will show real time data on the house electrical demand and PV system output, as well as weekly totals.

The Old Stand-Alone System

The old stand-alone PV system at CCAT consisted of 22 Solec International photovoltaic panels, a Whisper wind turbine, and a backup generator. The PVs were donated in the 1980s from the Flat Plate Array Project at the Jet Propulsion Lab.

The output from the 22 panel array was about 700 watts peak on a sunny summer day. The Whisper H500 wind turbine, standing 43 feet (13 m) tall and using a World Power control box, generated very little, due to the site's poor wind energy potential. Part of the problem was that the surrounding trees had grown considerably since the original wind generator was first installed on that tower in 1984.

Energy generated during the day was stored in a 24 volt battery bank consisting of twelve, Trojan L-16 batteries. A Trace C40 charge controller regulated the battery voltage during charging. Twelve volt DC loads were supplied via a Vanner battery equalizer, and AC loads were supplied using a Trace SW4024 inverter. A biodiesel engine generator was used to charge the battery bank as needed.

The solar-electric modules from the old system are now being used for learning opportunities at CCAT. Students in a variety of classes and workshops will have a chance to wire up the panels and test their output. The panels that are still performing well will be used for future projects.

The New Grid-Connected System

Design of the new system was centered around a generous donation of eight, large area (4 x 6 foot; 1.2 x 1.8 m) modules from ASE Americas, Inc. The modules, model number ASE-300-DGF/17, are each rated at 300 W at standard test conditions (STC). STC are an irradiance of 1,000 watts per square meter, and a cell temperature of 25°C (77°F).

These are 12 volt nominal modules, with a rated maximum power point voltage of 17.2 V. Four of these modules wired in series create a roughly 1 KW, 48 V building block for a grid-connected system (derated by

The installation crew gained some hands-on experience as they learned about utility-interactive PV systems.

12 percent from STC rating to better represent PV output under normal operating conditions at our location). We planned to use two series strings of four modules each, giving us a 48 V, 2 KW system.

The first and biggest design decision was to choose an inverter for the system. CCAT already owned a Trace SW4024 inverter that had been used in the stand-alone PV system, so obviously we considered this as a prime candidate. It is rated for grid-tied applications, and has more than enough capacity to handle the total rated array output of 2,400 W.

However, most Trace SW series inverters require at least a small battery bank. We wanted to put in a system that set a good example for other potential grid-connected PV adopters. Unless you have a serious

Stick a meter on those PVs! Checking out the 300 watt ASE PV modules.

need for backup power (you really have some critical loads), it doesn't make any sense to install a grid-connected system with battery backup.

Batteries complicate PV systems. They add significantly to system cost. They need to be maintained regularly and replaced periodically. And they add significant inefficiencies to the system. In most places, the grid is not down very often or for very long, so batteries add no benefit most of the time.

After speaking with an engineer at Trace, and studying the capabilities of the Trace SW4024, including the adjustable software settings such as float voltage, sell mode voltage, and grid usage timer, we decided against this option. This inverter is simply not optimized for PV systems installed in grid-connected applications. When the PVs are not charging, this inverter constantly float charges the batteries with electricity from the grid.

At best, with a minimum sized battery bank capacity of 100 AH (per Trace specifications), we expected to lose at least a few hundred watt-hours per day and perhaps as much as 1 to 2 KWH per day due to battery charging. This was simply unacceptable to us. It represented a system efficiency loss of anywhere from 5 to 25 percent.

We did consider adding a voltage-controlled relay system that would connect the inverter to the grid only when the PVs were charging, thereby minimizing any battery charging from the grid. We decided against this because it would complicate the system and make it less representative of a standard grid-connected system. In addition, the SW4024 does not offer maximum power point tracking, and would require charge controllers to provide battery overcharge protection in the event of a grid failure.

We also considered the Trace Sun Tie ST2500. This is a utility-interactive inverter that does not require any batteries. However, Trace has had some serious problems with the maximum power point tracking feature in the Sun Tie series inverters. After talking to Trace and other experts in the field about the problem, we decided that we were not willing to take a risk with a Trace Sun Tie unit.

This left only one other option for a California Energy Commission (CEC) certified utility-interactive inverter that was configured to accept 48 VDC input. This was the GC-1000 manufactured by Advanced Energy. This inverter came highly recommended from a couple of our industry contacts. It is rated at 1 KW single-phase 120 VAC output, features maximum power point tracking, and has a peak efficiency of 93 percent.

One of these inverters is a good match with four, 12 volt nominal ASE Americas 300 W modules wired in series, so we chose to use two of these inverters. We contacted Advanced Energy and they generously agreed to donate two refurbished GC-1000 inverters, along with a data monitoring system for our demonstration project.

Since the majority of our equipment was donated, we did not apply for CEC buydown funds. However, we still decided to use equipment that was certified by the CEC. The Advanced Energy inverter is well accepted, and we wanted our electric utility to approve our equipment without question.

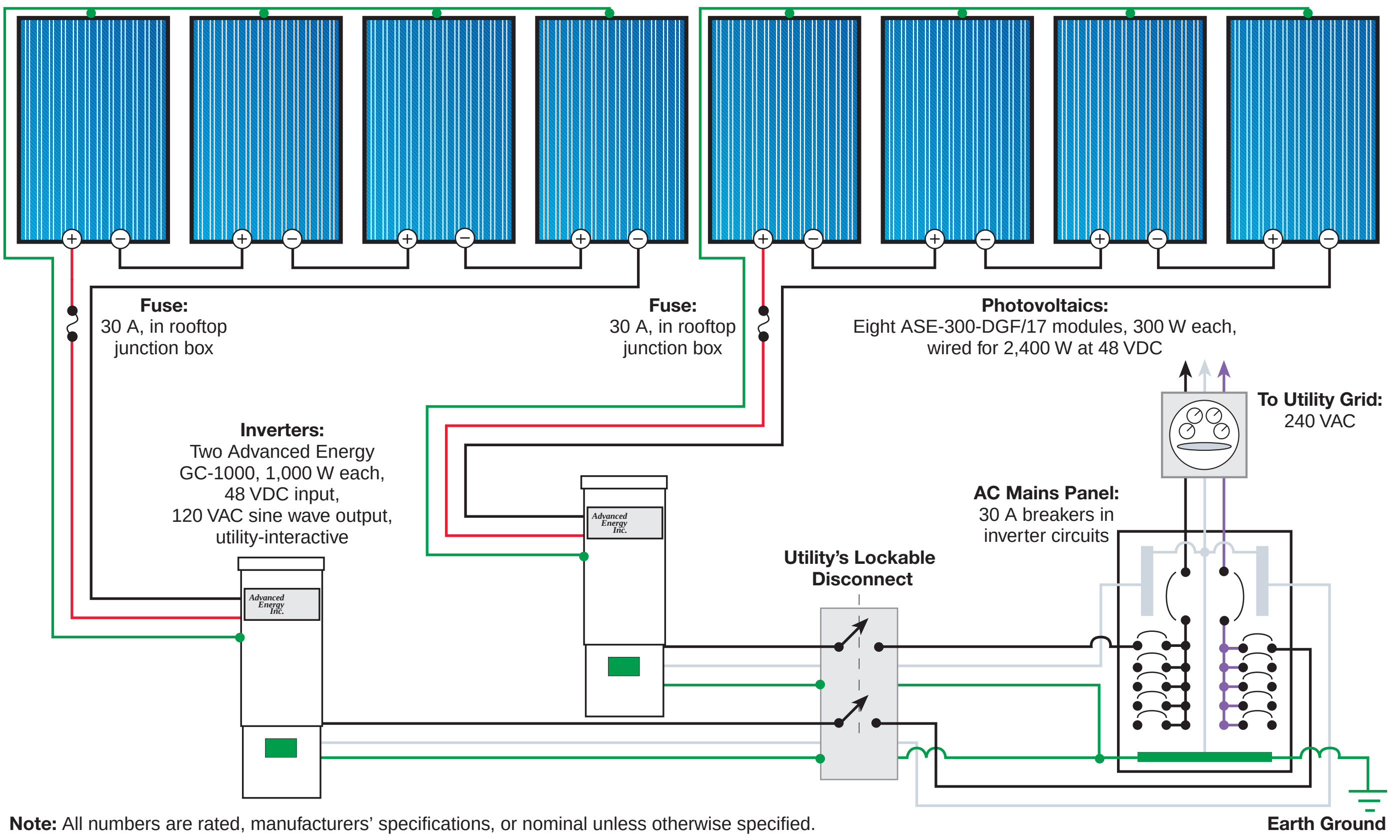
New System Description

Each of the two inverters is independently connected to four PV modules wired in series. The inverters are factory-equipped with a 25 A breaker, a 30 A fuse and ground-fault protection on the DC input. They have a 15 A breaker, 15 A fuse, and surge arrestor on the AC output.

The hot legs of the two inverter AC outputs are switched using a PG&E approved, 30 A, double pole disconnect switch. This is a lockable, visible disconnect switch,

Proper planning and many, many hands made for a smooth installation day.

CCAT's Utility-Interactive PV System



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

mounted alongside the main service panel next to PG&E's meter, and meets PG&E's interconnection requirements. The AC output from each inverter is wired to a 30 A breaker in the main service panel.

The CCAT roof is conveniently oriented due south, with a slope of 26.5 degrees from horizontal. At our Arcata latitude of 41 degrees north, the roof slope falls just within a recommended array slope of ±15 degrees of our latitude. In addition, analysis of Arcata solar insolation data (obtained from the National Solar Radiation Database) indicates that the annual amount of insolation received on a sloped surface in Arcata is nearly identical for slopes ranging from 20 to 40 degrees.

With this background information, we chose to mount the PV modules parallel to the slope of the roof, using the Schott Applied Power (formerly Ascension Technology) pitched RoofJack mounting system. A junction box, also purchased from Schott Applied Power, mounts to the center RoofJack. It contains 30 A fuses, and serves as a combiner box where we terminate the array leads and start our DC wire run, enclosed in conduit, to the inverters. (See the system schematic.)

CCAT Electrical Loads

The electrical loads at CCAT vary with the seasons. In general, energy use is higher when school is in session due to an increase in activity. Loads include fluorescent lights, stereos, computers, power tools, and other miscellaneous equipment. During the summer, we run a Sun Frost refrigerator, while the other eight months of the year we use a cold box with a natural convection cycle to keep food cold. A variety of pedal-powered appliances, such as a TV and a blender, also help to conserve electricity.

As CCAT continues to expand and demonstrate alternatives for living lightly, new energy demands sometimes arise. For example, we recently joined efforts with the campus recycling program to greatly reduce food waste on the HSU campus. The project involves use of an electrically driven shredder that prepares the food waste to enter an industrial-sized vermicompost (worm) bin capable of handling up to 150 pounds (68 kg) a day. The bin itself also requires electricity to run a motorized unit that forces the finished compost out of the bin for collection.

Our best estimate of our itemized electrical use is in the load table. Our actual usage between October 2001 and April 2002 averaged 1.9 KWH per day, which agrees closely with our estimate.

Net Metering Rate Options

After adjusting for an expected array operating temperature of 122°F (50°C) and an average inverter efficiency of 84 percent, the new grid-connected PV

CCAT System Loads

Load	*Watts*	*Hrs./Wk.*	*KWH/Wk.*
Industrial vermicomposter	2,800	1.5	4.2
19 Lights, 17–55 W	45	55.0	2.5
Power tools	1,000	2.0	2.0
Sun Frost refrigerator*	67	28.0	1.9
2 Stereos	33	40.0	1.3
2 Laptop computers	30	40.0	1.2
3 Alarm clocks	6	168.0	1.0
Garden water pumping*	55	16.0	0.9
Fax & phone	4	168.0	0.7
*Summer use only		*Winter Total*	12.9
		Summer Total	15.6

system is expected to provide approximately 1.8 KW of peak AC power. Given our annual average of about four peak sun hours per day in Arcata, we expect an average daily energy output of 7.2 KWH. This is well beyond CCAT's current energy needs of 1.9 KWH per day, so the system should produce a significant excess of solar electricity.

The PV system is definitely oversized. It would not be a cost effective design for the typical homeowner because PG&E won't pay for any excess electrical generation. If you're running a net metered system in California, the best you can do is net your energy cost to zero on an annual basis and pay the utility's minimum monthly charge. In PG&E territory, this amounts to US$5 each month. Most of our equipment was donated, so it did not cost us any extra for the excess clean solar electricity we feed into the grid.

This results in a modest benefit to the environment and, inadvertently, to PG&E's pocketbook. We're looking forward to the day when the utilities are required to pay a premium rate for excess electricity generated using renewable resources. They could sell this electricity through their green power programs.

Our rate options for net metering included the standard residential rate, or the residential time-of-use (TOU) rate. We considered both of these options. The TOU rate would have required installation of a TOU meter at a cost of US$277. Because we generate an excess of solar electricity, the TOU rate will not benefit us.

It's a different situation for residential PG&E customers whose electricity usage is primarily during the evening and weekend periods (people who work during the daytime and minimize their phantom loads). The TOU rate can allow them to install a smaller PV system and still reduce their electricity bill to the minimum US$5 service charge. This is because the TOU rate puts a higher value on electricity used or generated during the summer peak hours. The optimal way to minimize your bill is to have electricity costs exactly cancel out electricity "revenues" on an annual basis.

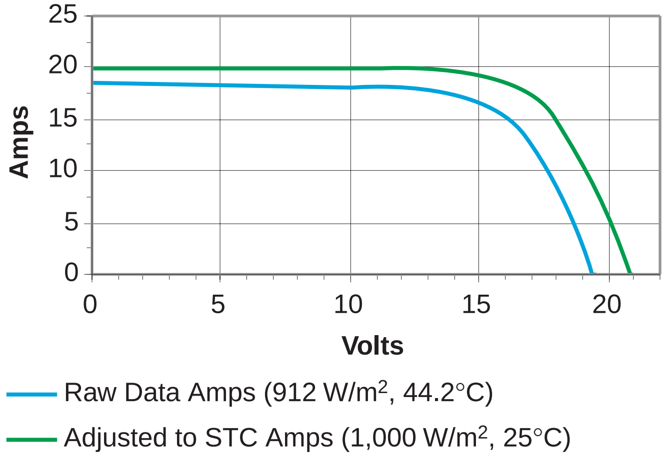
The summer peak period for TOU customers is May 1 through October 31 from noon to 6 PM, Monday through Friday. Peak usage during this period is driven by the high cooling load in much of California. During this period, the TOU rate is about US32¢ per KWH. During the winter peak period, the TOU rate is about US12¢ per KWH, and during the off-peak periods it is about US9¢ per KWH. So, if most of your energy usage is during the off-peak periods and a substantial amount of your PV electricity is generated during the peak periods, you can significantly decrease the optimal size of your PV system (and the associated capital costs).

For example, we have estimated that a PV system facing due south at a slope of 41 degrees in Arcata will generate approximately 27 percent of its annual energy production during the summer peak period, and another 17 percent during the winter peak period. Assuming you are on the TOU rate and use all of your electricity during the off-peak periods, this would allow you to decrease the size of your PV array by 41 percent.

With an average daily electrical usage of 10 KWH per day on the standard rate, you would need about a 2.9

RoofJacks were installed before the PVs, so the crew could simply slide the PVs into place.

CCAT I-V Curves for ASE-300-DGF/17 PVs



KW system (rated at STC) to net your electricity cost to zero and thereby lower your bill to the US$5 minimum per month. On the TOU rate, you could decrease your system size to 1.7 KW, and still limit your bill to US$5 per month.

Module Testing

Because we are part of a university, we have an interest in testing and evaluating systems. We made sure not to miss this opportunity with our new system. We measured individual current versus voltage curves (I-V curves) for each of the eight ASE modules prior to installation.

Although the donated ASE modules were reportedly manufacturer's seconds due to cosmetic defects, they performed remarkably well. Our measurements showed that module output was within 1 percent of the manufacturer's measurements supplied with the modules, and within 2 percent of their nameplate rating. ASE uses a plus or minus 4 percent tolerance for rating the output of their PVs. Most other PV manufacturers use a plus or minus 10 percent tolerance rating. We think that ASE's truth in advertising is laudable. ASE sets a high standard for rating the output of their PVs. We hope that the other module manufacturers will follow suit.

Handing up the last PV!

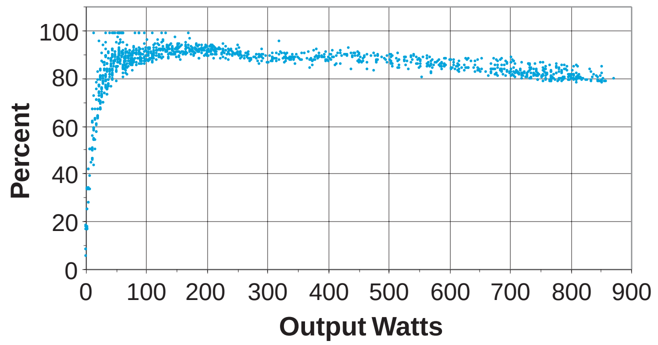
Andrew Posner and a student installing the first Advanced Energy GC-1000 inverter.

The I-V curves were generated in ambient sunlight in Arcata, California near midday in June 2001, using an electronic DC load device. As the load was varied, the module traversed its operating curve from short circuit current to open circuit voltage. During the tests, we also measured the radiation incident in the plane of the module as well as the module operating temperature. These measurements were then used to standardize the performance curves to STC. (See the module I-V curve.)

System Installation

For a number of reasons, we took a team approach to system installation. The CCAT house is an old structure, and the AC electrical wiring needed some work to bring it up to code before we could reconnect to PG&E. We had Peter Brant, a local electrical contractor, perform this work. While he was at it, we had him install the AC

GC-1000 Inverter Efficiency



Advanced Energy's AM100 Inverter Monitor (left) and the interior of the GC-1000 inverters.

disconnect for the PV system, prepare the AC panel for interconnection, and run the AC wiring from the inverter room to the AC disconnect.

We had Bob-O Schultze, a solar-electric contractor, run the DC wire and conduit, assist with the inverter and PV module installation, and ensure that our installation was code compliant. We installed the array mounting structure, PV modules, and inverters ourselves, with help from students in a PV Design and Installation class offered through the Environmental Resources Engineering Department at HSU. The equipment we chose allowed for a rather quick and easy installation procedure.

The RoofJack mounting system is designed for pitched asphalt shingle roofs like CCAT's. It supports the modules about 3 inches (7.6 cm) above and parallel to the roof, allowing for adequate air circulation between the modules and the roof to promote module cooling. The RoofJacks came complete with self-drilling fasteners ($2^1/_4$ inch, #12) and sealing washers, preapplied butyl-rubber sealing pads, and pipe nipples for wire pass-through between modules.

Our eight, large area modules were installed in one continuous row. Each module is supported by four RoofJacks, one placed near each of the module's four corners. There are two types of RoofJacks—end and interior. We used four end RoofJacks at the extremities of the array. A pair of shared interior RoofJacks support the module edges that are located next to other modules, for a total of 14 interior RoofJacks.

To properly locate the RoofJacks on the roof, we built a jig with the bolt hole pattern for one set of RoofJacks. After installing the first set, we simply moved the jig over and installed the next set, and so on. According to the manufacturer, securing the RoofJacks directly to the sheathing (a minimum of $^5/_8$ inch; 16 mm thickness) is adequate, but we felt that it was prudent to add reinforcement. We located the array on the roof so that four of the interior RoofJacks were secured directly to two rafters. To secure the remaining RoofJacks, we either scabbed 2 by 4 blocks to a rafter or added strips of plywood sheathing on the underside of the roof sheathing to provide a more secure attachment.

Once the RoofJacks were installed, the modules were outfitted with their mounting bolts. Four bolts were attached to each module, two on each side near the corners. These bolts protrude about $^1/_2$ inch (13 mm) with a sleeve. To install the modules, we simply lifted them into place and slid the four mounting bolts into slots on the RoofJacks.

Wiring the array was just as easy. Our system consists of two separate subarrays, each comprised of four modules wired in series and connected to an inverter. The first set of four modules in the row make up one subarray, and the second set of modules make up the second subarray.

We mounted the array combiner box in the center of the row of eight modules between the two arrays. This box houses fusing for the arrays, and provides a place to terminate our array wiring before running wire to the inverters.

The wiring between modules was provided by the module manufacturer, and came equipped with weatherproof connectors designed for series wiring of modules. Once the modules were in place, we simply snapped these connectors together, added our solid copper grounding wire between modules, and terminated these wires in the combiner box.

We wall mounted the Advanced Energy GC-1000 inverters in a room in the basement that has historically been used to house PV system equipment. The inverters came with PV string combiner boards. These were sized to handle up to six individual strings rated at 10 amps each. However, we had a single module string with a short circuit current rating of 19.1 A, so we removed this board. It was a little tricky to figure out how to wire the inverters without it and still use the GFI protection and AC and DC circuit breakers that were provided with the units.

The crew testing the utility's lockable disconnect switch—and watching the utility meter spinning backwards!

After examining the units and speaking with the manufacturer, we found that we could wire the DC input directly to the DC breaker, bypassing the combiner board while still using the other features. AC surge arrestors were supplied with the units. Since we are not in a lightning prone area, the inverter manufacturer suggested that DC surge protection was unnecessary.

In addition to donating the inverters, Advanced Energy included their AM100 Inverter Monitor. This unit monitors up to six inverters, and features an LCD display and a four-button keypad as a user interface. It logs DC current, DC voltage, AC current, AC voltage, AC power output, inverter efficiency, and cumulative AC energy output. When it collects data at 15 minute intervals, the AM100 is able to store about 30 days worth of data.

The data is downloadable via a serial communication port. To access the data, Advanced Energy provides their PVMON software that runs on any DOS or Windows-based personal computer. Data files are stored in Excel compatible (.CSV), comma delimited format. A single data file is recorded for each day. The data is easy to download and access.

System Performance

The new grid-connected PV system first started generating on October 17, 2001. Of the 901 KWH total solar-electric energy generated as of April 23, 2002, 358 KWH were used on-site, and the other 543 KWH were fed back into the PG&E grid. During this period, we averaged 1.9 KWH per day of electrical energy use, while the PV system generated an average of 4.8 KWH per day.

Data for about a one-month period in mid-February to mid-March of 2002 was examined to evaluate the performance of the system. During this period, the PV system generated an average of 4.9 KWH per day. The maximum AC power output was 1,745 W, with a corresponding maximum DC input power of 2,155 W (81 percent average inverter efficiency). The inverters, with a rated peak efficiency of 93 percent, averaged 83 percent and 85 percent, respectively. About 99 percent of the time, the input voltage to the inverters was within their maximum power point tracking range of 55 to 70 VDC. Inverter efficiency varies as a function of AC power output. (See the inverter efficiency plot.)

CCAT System Costs

Item	Cost (US$)	Value (US$)
8 ASE-300-DGF/17 modules, 300 W	$0	$14,400
2 Advanced Energy GC-1000 inverters	0	3,400
Labor; solar installer & electrician	700	700
Advanced Energy data monitor	0	540
18 Schott Applied Power RoofJack mounts	454	454
Misc. hardware; wire, conduit, etc.	120	120
Square D disconnect, 30 A	40	40
Total	$1,314	$19,654

The highest points in the graph are clearly aberrations in the data. However, there are over 1,400 total data points, of which only 30 show efficiencies greater than 96 percent. In all cases, these abnormally high efficiency readings are recorded at very low power outputs (always less than 171 W).

Since startup, we have experienced only one minor problem—a blown fuse on the DC input to the inverter. We suspect that this was due to enhanced insolation conditions associated with cloud reflection.

We are very pleased with the performance of our new PV system and our decision to reconnect to the grid. We do realize that our reconnection to the grid threatens to make us less aware of our energy use patterns and lax in our energy efficiency efforts. So we are making a concerted effort to keep track of our usage and to maintain our efficient ways.

About CCAT

CCAT is a student-initiated, student-run, and student-funded demonstration home at Humboldt State University, dedicated to resource and energy-efficient living. The Center was started in 1978. Today, CCAT is a thriving household and educational center that has been integrated into the University's curriculum.

People contact CCAT from around the world, seeking information on sustainable living techniques. Locally, CCAT is a demonstration home showing appropriate technology in action. It provides tours, workshops, and experiential learning opportunities to the local community. CCAT's solar and other systems have been featured in *HP32* and *HP43.* If you're ever in the neighborhood, check it out!

Acknowledgments

We are grateful to ASE Americas, Inc. for the donation of eight, ASE-300-DGF/17 PV modules, and Advanced Energy for donating two GC-1000 grid-tied inverters with monitoring equipment. Without these donations, the system would not have become a reality.

In addition, we would like to thank the Schatz Energy Research Center for their help in designing and installing the system, Bob-O Schultze of Electron Connection and Peter Brant of Brant Electric for their help in installing the system, and the CCAT codirectors and volunteers who helped with this project.

Access

Jim Zoellick, Schatz Energy Research Center, Humboldt State University, Arcata, CA 95521 • 707-826-4345
jiz1@humboldt.edu
www.humboldt.edu/~serc

Andrew Posner, Campus Center for Appropriate Technology, Humboldt State University, Arcata, CA 95521 • 707-826-3551 • ahp4@humboldt.edu
www.humboldt.edu/~ccat

Bob-O Schultze, Electron Connection, PO Box 203, Hornbrook, CA 96044 • 800-945-7587 or 530-475-3402
Fax: 530-475-3401 • econnect@snowcrest.net
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Peter Brant, Brant Electric, PO Box 66, Arcata, CA 95518 • 707-822-3256 • Fax: 707-826-1180
pbrandt@foggy.net

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COMM.POWER

Saving Energy with a Notebook Computer

John Bertrand

A year ago, when we finally settled into our still incomplete solar powered house, we set up our trusty three-year-old computer. Then, having no landlines (electricity or telephone) we installed a wireless broadband Internet connection. So we were sitting pretty, right? Wrong.

In fifteen years of home computer use, we have never just left the computer on all day. But times and uses have changed. Our computer has become more and more of an appliance rather than a specialty tool. In our new home, it became apparent that we needed it available constantly for Internet research and e-mail. Yet leaving the system on, even in sleep mode, used too much energy. Our fairly typical desktop system draws 180 to 190 watts.

Flipping it off and on was too much of a hassle because of the almost 2 minute boot up each time we needed to check something. Besides, even turning it on and off as needed was a serious drain on our 1.2 KW PV system. Expanding our PV array (sixteen, 77 watt modules) was not an option because the present rack and wiring are maxxed out, not to mention the hassle of having to submit a new electrical permit application, complete with engineering stamp.

The Search

So I began researching notebook computers. Without a doubt, they would provide a much better energy use scenario. I wanted the lowest possible energy use in a quality unit.

I have always purchased desktop systems from smaller companies that offer good quality parts for the money. I could always make changes later if necessary. But notebooks are a different animal, since they are more or less a closed package. So it is very important that it has all the functions you will need.

For many people, the notebook can replace the desktop unit. So a 14 or 15 inch (36 or 38 cm) screen, 5 to 7 pound (2–3 kg) "desktop replacement" machine will work. For others, a really lightweight 3 to 4 pound (1.4–1.8 kg) unit with a 10 to 12 inch (25–30 cm) screen is fine, since the desktop unit is not being displaced, but supplemented and networked. The former will certainly save watts over a desktop unit, but with its built-in drives and large screen, will use considerably more energy than the latter.

For us, keeping the desktop unit for graphics-intensive tasks seemed desirable, since the screen is larger, and CRT monitors generally handle graphics better. So I researched what was available in the smallest of the Windows-based notebooks.

Our personal parameters included finding a highly rated, quality product from a well-known company (such as Dell, IBM, Gateway, Micron, Sony), long battery life, no built-in drives other than the hard drive (but with an attachable CD/DVD drive for loading programs, etc.), at least 256 MB RAM and a 20 GB hard drive, a touchpad pointing device, and a high quality graphics card that will not drop frames when playing a DVD movie.

I began looking more than six months ago. Because of their customer satisfaction record, I was somewhat predisposed to look most seriously at the Dell offerings, in particular the Latitude L-400. But it was weak on graphics and, having been on the market quite awhile, was not tops in energy efficiency. We came close to trying a Sony unit available from Costco for less than US$1,000, but it only had a 10.4 inch (26.4 cm) screen, older chip sets, and mediocre graphics. That finally kept it out of the running.

A Small Gem

In November 2001, Dell introduced a new model, the Latitude C-400. It was much like the earlier L-400, but had updated processors (866 MHz or 1.2 GHz, running on half a watt), a new generation of energy-saving Intel support chips (830M), graphics adequate for DVD movies, both a touchpad and a pointing stick, and some other goodies I found desirable.

I watched the prices, including the Dell “refurbished” units. In January, after the Christmas rush was over, I kept close track and finally bit on a good offer. (Remember, if you buy on the phone rather than off the Net, you may be able to negotiate for even better than the current sale prices, but beware of the frustrating sales-speak even from reputable firms.)

This particular model best met our needs. The US$2,300 price is in the midranges, with basic economy models available around US$1,000, and corporate road-warrior models well above US$3,000. (Note: laptop prices continue to fall, so you may be able to do even better by the time you read this.)

In terms of energy usage, though, this model has to be near the lower limit. We measured usage with a Watts up? meter. The meter isn’t extremely accurate when measuring loads drawing less than 20 watts, but it’s close enough for general use. In any case, the C-400 uses just 15 to 18 watts when in regular use.

This figure, when compared to the desktop system, is cause enough for joy. But when we close the case, putting the system in standby (it goes to hibernation in 15 minutes, or whatever you want to set), the usage is too low to measure with this meter.

The radio system’s receiving dish. The wireless Internet system only draws 1 to 2 watts total.

The D-Link router and the radio transceiver allow completely wireless Internet use.

Wireless Internet

When it comes to broadband Internet service, there are three major routes and one minor route. Leading the charge these days is cable modem service from the cable TV companies. This is followed closely by DSL (digital subscriber line) service from the telephone companies. Satellite service from the two satellite TV companies has made inroads mainly where the other two services are not available.

Finally, in a few areas, ISPs have established fixed wireless service, which uses a line-of-sight radio link between their operation and subscribers. The radio signal is in the same frequency range as a microwave oven, and can be fairly characterized as a “microwave link.” It conforms to the IEEE 802.11b standard used for wireless networking within the home or office, and is theoretically capable of 11 MB per second information transfer. A radio transceiver and small antenna are required.

We had a choice of going to Starband satellite service or Interlink Hawaii (local ISP) fixed wireless service. Starband was just becoming available with no track record, high upfront costs of more than US$1,500 (installation is less expensive in the continental U.S.) and a monthly cost of US$70. Interlink’s fixed wireless service had been around for several years, had an installation package of US$500, and cost US$50 a month. Needless to say we went with the latter, which uses a Breezenet Pro.11 radio.

Overall, we have been very satisfied with the service. When our radio was failing after less than a year (it is leased and was used), they were slow to replace it. But otherwise, we have had mostly speedy surfing, with very little downtime. And being a local company, they are usually easy to work with. Power draw of the wireless system is 1 to 2 watts.

Bertrand Computer Specs Comparison

Item	*Desktop*	*Notebook*
Model	Axis	Dell Latitude C-400
Processor	550 MHz Athlon	866 MHz Pentium III M
MS Windows	98SE	XP Pro
Memory (RAM)	384 MB	256 MB
Hard drive	13 GB	20 GB
CD/DVD drive	Internal	Plug-in
CD-RW drive	Internal	none
Ethernet	Internal board	Built-in
Wireless	None	Built-in
Monitor	17 inch Panasonic	12 inch
Printer	Epson Stylus 1520	Same
Scanner	Epson Perfection 1200S	None
Power draw	180–190 W	15 W; 18 W w/ DVD drive on; 24 W w/ DVD movie
Sleep mode power draw	105 W	N/A
Standby & hibernation	N/A	1 W

Over a typical day of turning the system on first thing in the morning, using it for about 5 hours off and on, with it in standby or hibernation the rest of the time (about 7 to 8 hours), the total watt-hours used is 84. That's equivalent to about 25 minutes use of the desktop system! If it is on standby, the C-400 comes back to full use in a few seconds. From hibernation, it takes all of about 15 seconds. That's very tolerable for an appliance.

Other Considerations

As a selling feature, notebook manufacturers try to maximize battery life, that is, the amount of time their computers will run on a single charge. Since we keep the unit plugged in so much, battery life is not critical, but it's still a good indicator of system efficiency.

Within groups of similar computers, the longer the battery life, the more efficient the computer is. This comparison works best if independently measured, but manufacturers' estimated time is usually a good rough estimate. Just remember that this measurement applies within a given category of processor, screen size, battery size, and peripherals.

While it may seem good to keep the battery charged up, it is also good to let it cycle some. So don't leave it plugged in all the time. Unplug it every once in a while, and let it discharge fully before charging again. If NiCd is used, the battery should be fully discharged routinely (several times a month) and then refilled. If the battery is NiMH or lithium technology, it isn't as important to fully discharge the battery routinely, but it should be fully discharged once every month or two. Most modern notebooks use the NiMH or lithium ion batteries.

Keyboards are also a concern with notebooks. The great portability of a 3+ pound (1.4+ kg) unit is somewhat offset by a slightly smaller keyboard, not to mention a few keys in somewhat different places. I find the tradeoff to be acceptable. You may not. The larger notebooks do have equivalent keyboards, but not exactly ergonomically correct ones.

Another alternative is to buy a notebook with an auxiliary keyboard port. Then you can use a standard keyboard ordinarily used with a desktop unit. Most larger notebooks have similar ports for a mouse and monitor. Others have auxiliary ports in docking stations so a notebook can emulate a desktop computer.

Of course, not everyone is in a position to part with more than US$2,000 to save some watt-hours. But it was worth it for us. The cost of adding more PVs and related equipment to have our desktop unit available full time would have exceeded what we spent. Almost any notebook computer, with the ability to handle similar tasks, is far preferable to a desktop system for energy conservation.

As time goes on, more models will use the new energy-saving chip sets. Even the model we bought is now available as refurbished. (Usually they are returned within 30 days after purchase and like new.) I just saw one similar to ours for less than US$1,600.

Although I was researching PCs, Apple's latest notebooks are also quite frugal. I managed to get permission (not without a questioning look from the store manager) to measure one of the 600 MHz G3 iBooks, and it came in at around 20 watts.

Dessert

The rest of the changes to our computing scene may seem frivolous. Still, if we see the computer as an appliance, the handier the better. We added a D-Link wireless router (Model DI 713P, US$140, 7 watts) that gives us the ability to use the laptop almost anywhere in the house. It also connects the two computers together and provides good Internet security from hackers. (Incidentally, software can provide good protection also, but it's not as good as the hardware solution in a router.)

John's wife, Linda Cavis, works on their notebook computer that only draws about 15 watts.

The setup of the router was very time consuming. I have read of others who have had an easier setup, and still others who have given up and returned the unit. So I have mixed feelings about it. Setting up a single computer would be easier, as would setting up with only a newer operating system.

The manufacturers need to provide more information than we received. Usually I like to exhaust my own resources before calling tech support, but I still spent quite a few hours sorting things out with both the router tech support and my Internet service provider tech support.

Energy-Sipping Computing

Everything needs to be on switched outlets for efficiency, preferably surge protected outlets. On one switch, we have the fixed wireless radio and the router, which have no internal switches, and the printer, which does have an internal switch (usually turned off). The notebook computer is on another, and the desktop computer and scanner (usually turned off) on another. So we can handle almost any combination of computing needs without having unnecessary equipment sucking electricity.

In spite of the less-than-satisfactory router experience, our new computer system has been a great convenience. After half a year of no computer availability in our off-grid home, we learned that our desktop computer was just too much of an energy hog to work for us in our limited-energy environment. Having cast about for a solution, I believe we found a good one with our 3 pound (1.4 kg) notebook computer. It draws only 15 to 18 watts when being used, and practically none when in standby.

We no longer have to feel guilty when using a very important appliance. It is handy anywhere we are in the house, anytime we need it. And so far, we have run the generator hardly at all. *Aloha.*

Access

John Bertrand, PO Box 811, Holualoa, HI 96725
caber@kona.net

Dell Computer Corporation, One Dell Way, Round Rock, TX 78682 • 800-915-3355 or 512-338-4400 csd@dell.com • www.dell.com • Dell Latitude C-400 notebook computer

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www.zonelabs.com • Zonelabs' Zone Alarm is a free download; the Pro version costs US$40. The free version has been highly recommended and has been used by the author. The Pro version has more bells & whistles.

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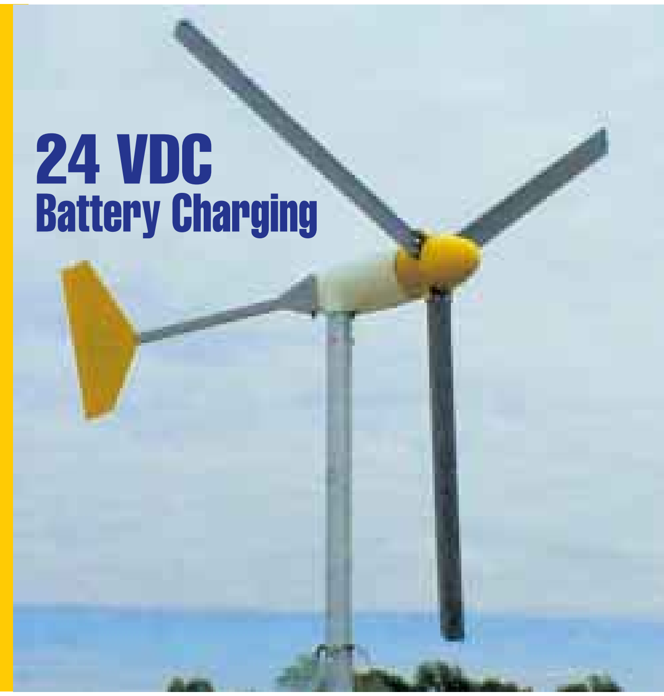

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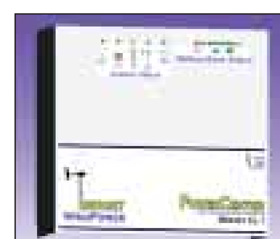

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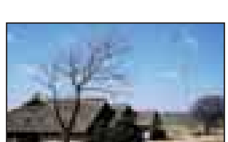

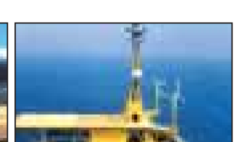

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Solar Powered Portable Workshop

Philip Angell

Philip Angell's PV powered trailer provides electricity, no matter where a job takes him.

My home repair and remodeling business had grown to the point that a cargo van just wasn't practical any more. I knew that a pickup and trailer combination would give me some freedom and reduce my fuel consumption. Getting a trailer, after years of driving a van, was the long-awaited opportunity to install a PV system.

Since this was my first renewable energy (RE) installation, I wanted to get it right. I was referred to Rocky Mountain Solar (RMS) Electric in Boulder, Colorado. Matt Lafond of RMS put together a system that works to my expectations and was within my budget. They supplied good tech support and all the components for this system, down to the wire. The only exception was the batteries.

Trailer Design

With many choices available, I decided on a 5 by 10 foot (1.5 x 3 m), single-axle, cargo trailer for its capacity, economy, and tow weight. The inside was painted, but otherwise unfinished, which was a plus because I wanted to insulate it with rigid insulation. I chose 4 foot by 8 foot by $^3/_4$ inch (1.2 x 2.4 m x 19 mm) R-Matte Plus panels, with an R-value of 5.4. These are easily cut to fit with a utility knife and straightedge. I installed them using construction adhesive, with the foil side facing inside the trailer.

To fit the curves, I made parallel cuts an inch apart, through the facing of the panel, into the foam insulation, but not through the backing. This allowed the panels to bend. The insulation is very effective at keeping the trailer cool in the summer, a big issue in Texas.

As luck would have it, Sears was having a sale on tool chests. Craftsman steel-case tool chests come in stackable modules. I bought two complete sets of these, one for each side. These were securely bolted to the floor and walls of the trailer.

Weight distribution was an important consideration. I estimated the weight of the tools and the PV system, and placed the tool chests accordingly before bolting them in. The PV system had a total weight of approximately 300 pounds (136 kg), and was placed in the very front of the trailer. The tool chests are installed approximately over the axles to balance the load. A section in the back of the trailer is left for smaller toolboxes, supplies, and materials.

The RE equipment: inverter (center, top shelf), AC battery charger (upper right), and PV charge controller (left, bottom shelf).

The trailer is insulated, and the weight has been evenly distributed. Note the recessed receptacle and cord for charging the batteries from 120 VAC.

After reading *EV Tech Talk* in *HP59,* and *EV Tire Fitness* in *HP71,* I knew that quality tires make a significant difference to efficient energy use. I replaced the tires that came on the trailer with Goodyear Marathon low rolling-resistance tires, specifically designed for use on trailers. These tires are not intended for use on passenger cars. Specifications on these tires are available from your Goodyear dealer.

I installed a roof vent and two side vents for ventilation and natural light. Ventilation is necessary to eliminate the possibility of hydrogen buildup while the batteries are charging. The roof vent is translucent plastic with a crank to open and close. The side vents are metal, and can be adjusted to open and close for intake or exhaust. The side vents were difficult for me to find. I found them at a trailer repair center; they are generally used on horse trailers.

The trailer is equipped with brakes that are electrically controlled by the brake pedal of the tow vehicle. It also has a break-away emergency brake system, powered by a small, 12 volt battery, which activates the brake if the trailer should break away from the truck. The charge controller provides a trickle charge to this battery.

PV System

When I was ready to install the PV system for the trailer, I followed Matt's advice. I needed a system that could power my tools and not take up too much space or add too much weight. My tools span a wide range of power needs, from the battery chargers for cordless tools to a 12 inch (30 cm) miter saw that surges to 13 amps. Although some of these tools draw a lot, they are only used for a short duration, so we decided that a small system would be adequate.

Angell Portable System Loads

Tool	Rated Amps	Surge Amps	Average Running Amps
Craftsman 2 hp portable compressor	10	15	10
DeWalt miter saw	10	13	7
Porter-Cable circular saw	13	17	10
Makita portable table saw	12	15	7

The system we came up with consists of a 120 watt Kyocera KC120 solar-electric module, a U-RV series UniRac PV mount, a Kyocera FM16D Solar Commander charge controller, a Statpower PROsine 1,800 watt sine wave inverter, two Trojan T-105 batteries, and an Iota 15 amp charger.

The 120 watt solar-electric module is secured to the roof of the trailer on the UniRac mount. It is adjustable for proper angle to the sun, or to be flat when the trailer is moving. I ran #10 (5 mm^2) stranded wire in flexible conduit from the module through the roof to the controller.

The Kyocera Solar Commander FM16D model is generally used for RVs because it has a separate circuit to trickle charge an accessory battery. This circuit charges the battery for the trailer's emergency braking system. The primary circuit charges the main battery using pulse width modulation (PWM).

Weight is an issue, so I decided to use two Trojan T-105, 6 V batteries, connected in series for 12 volts at 225 AH. Because most tools are used for a very short duration, the small storage capacity has not been a problem. I pay careful attention to the battery state of charge (SOC), though I don't have an amp-hour meter. I use the digital readout of the controller, which shows me battery voltage, as well as PV charging current.

We considered a modified square wave inverter, until I told Matt that I would be using battery chargers for cordless tools. Some of these chargers require a sine wave, so we chose the PROsine 1800. This inverter not only provides the proper waveform for the chargers, it also has a 2,900 watt surge rating, a requirement for many power tools. This inverter has worked very well—beyond my expectations. It's powering my computer right now, and will power my circular saw tomorrow.

I recently did a comparison between my new sine wave inverter, and a PowerStar UPG1300 modified square wave inverter. The difference is very noticeable. I ran the same vacuum cleaner off each of these two inverters. On modified square wave, it ran like it was struggling to get power, with lower rpms. I'm glad I went with a sine wave inverter!

Because of the limited charging capacity of a single module, and the possible high demand on the system, we decided to include an AC battery charger that can plug into the grid and charge the batteries overnight if necessary. The Iota DLS15 charger has an output of 15 amps at 12 VDC nominal. I don't mind accessing the grid if I have to. My electricity provider is Green Mountain Energy, so my grid electricity is coming from a wind farm in west Texas.

Wiring—12 VDC & 120 VAC

A ground fault interrupt receptacle is recessed into the front of the inverter. I mounted my cordless battery chargers on a shelf below the inverter, so I can directly plug them in. I also ran a #12 (3 mm^2) cable to another receptacle that I installed in the back door of the trailer.

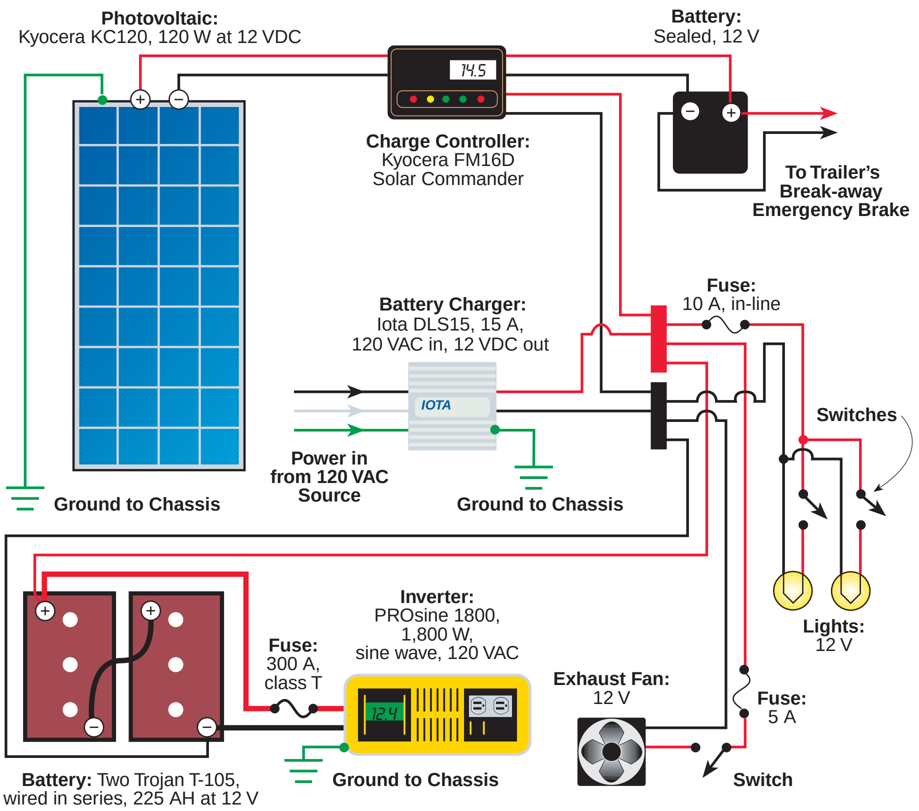
There is also an outdoor receptacle with a recessed male plug, purchased at an RV store. This is a standard

Angell Trailer Power System Costs

Item	Cost (US$)
PROsine 1800 inverter	$1,250
Kyocera KC120 120 W module & mount	639
Wire & cables	222
2 Trojan T-105 batteries	140
Kyocera FM16D Solar Commander charge controller	123
Iota DLS15 charger, 15 A	119
UniRac PV mount, U-RV series	90
Fuse package, 300 A	75
Total	$2,658

The system's two lead-acid batteries are vented and safely secured for travel.

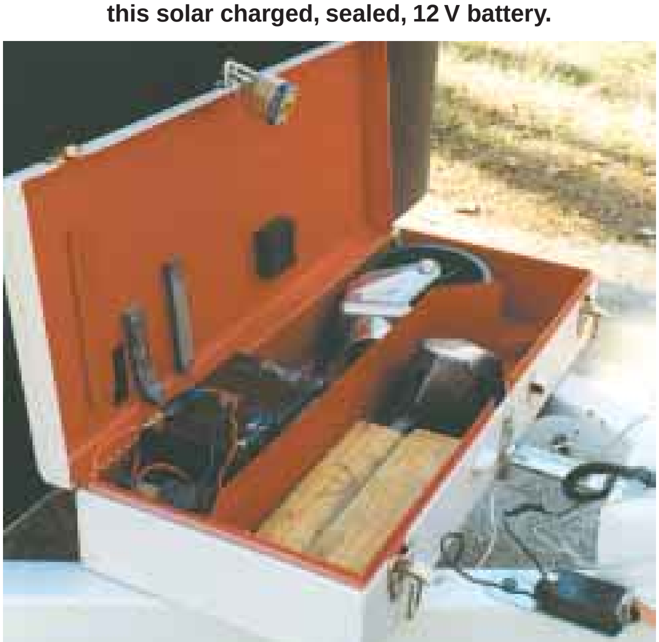
Philip Angell's Portable PV System



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

arrangement used for plugging an RV in at an RV park. I use this male plug for charging the trailer batteries, if necessary. I plug a regular extension cord into a house receptacle and into the door receptacle, and use the Iota charger.

The trailer's emergency braking system is powered by this solar charged, sealed, 12 V battery.



While I was at the RV store, I picked up two, 12 V interior dome lights, which have integral switches. I installed these lights on the ceiling of the trailer, and wired them directly to the 12 V circuitry with a 10 amp, in-line fuse. I installed a 12 V, 1.2 W Sunon muffin fan to exhaust hydrogen gas from the battery box. This is also on a fused connection to the 12 V system.

All the 12 V circuits connect to a bus bar mounted in the shelf below the inverter. I salvaged a neutral bus bar from a residential service panel. I cut it in half, mounted it to the side of the shelf, and use one side for positive and the other for negative. I ran #10 (5 mm^2) stranded wire from the batteries to each side.

Practical Renewable Energy

On weekends, I park the trailer so the PV panel faces south. I run a cable to the house from the receptacle in the back door of the trailer. The cable runs through a foundation vent to a stand-alone wall receptacle in the house. This receptacle is in no way connected to house current or the grid. On sunny weekends, I use this for vacuuming the house, washing clothes with my Staber washing machine, and occasionally running the blower for the furnace. It's also a great backup system in case of a power outage.

Having used the system for a while, I can see room for improvement. I have more total weight in the trailer than I planned for. The large tool chests are a bit too far forward, making the trailer slightly tongue-heavy. However, this is preferable to having a trailer that is too light in front. Also, another module on the roof would give me more charging capability. I plan to add one as soon as I can afford it.

My portable workshop is an excellent way to demonstrate a practical use for renewable energy. My customers have shown an interest in what I have done, and I hope this will spark their enthusiasm for renewables. In September, I took the trailer to the Texas Renewable Energy Roundup in Fredericksburg, Texas. The weather, the food, and the people were great; and a lot of people asked questions about my PV powered trailer.

Having this system has been a great introduction to using renewable energy. I can expand this system, and I can put this knowledge to use on other projects. I may not be putting electricity onto the grid with this system, but when I'm connected to the trailer, I'm getting 100 percent pollution-free electricity from the sun, instead of electricity from the utilities.

Access

Philip Angell, PO Box 224, Rodeo, NM 88056
505-557-2318 • angephil@vtc.net

Susan Carson, Carson TechWriting Consultants, 7401 Alma Dr., #711, Plano, TX 75025 • 972-517-5405
s.d.carson@att.net

Harrison Evans, Photographer • 214-522-1754
harrican@sbcglobal.net

RMS Electric, 1844 55th St., Boulder, CO 80301
800-767-5909 or 303-444-5909 • Fax: 303-444-1615
info@rmse.com • www.rmse.com

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800-297-4777 or 972-276-3323 • Fax: 972-276-3368
campercapitol@att.net • www.campercapitol.com
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Fax: 480-483-6431 • info@kyocerasolar.com
www.kyocerasolar.com

Xantrex Technology, Inc. (now owns Statpower), 5916 - 195th St. NE, Arlington, WA 98223 • 360-435-8826
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inverters@traceengineering.com • PROsine inverter

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Fax: 505-242-6412 • info@unirac.com
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iotaeng@iotaengineering.com
www.iotaengineering.com

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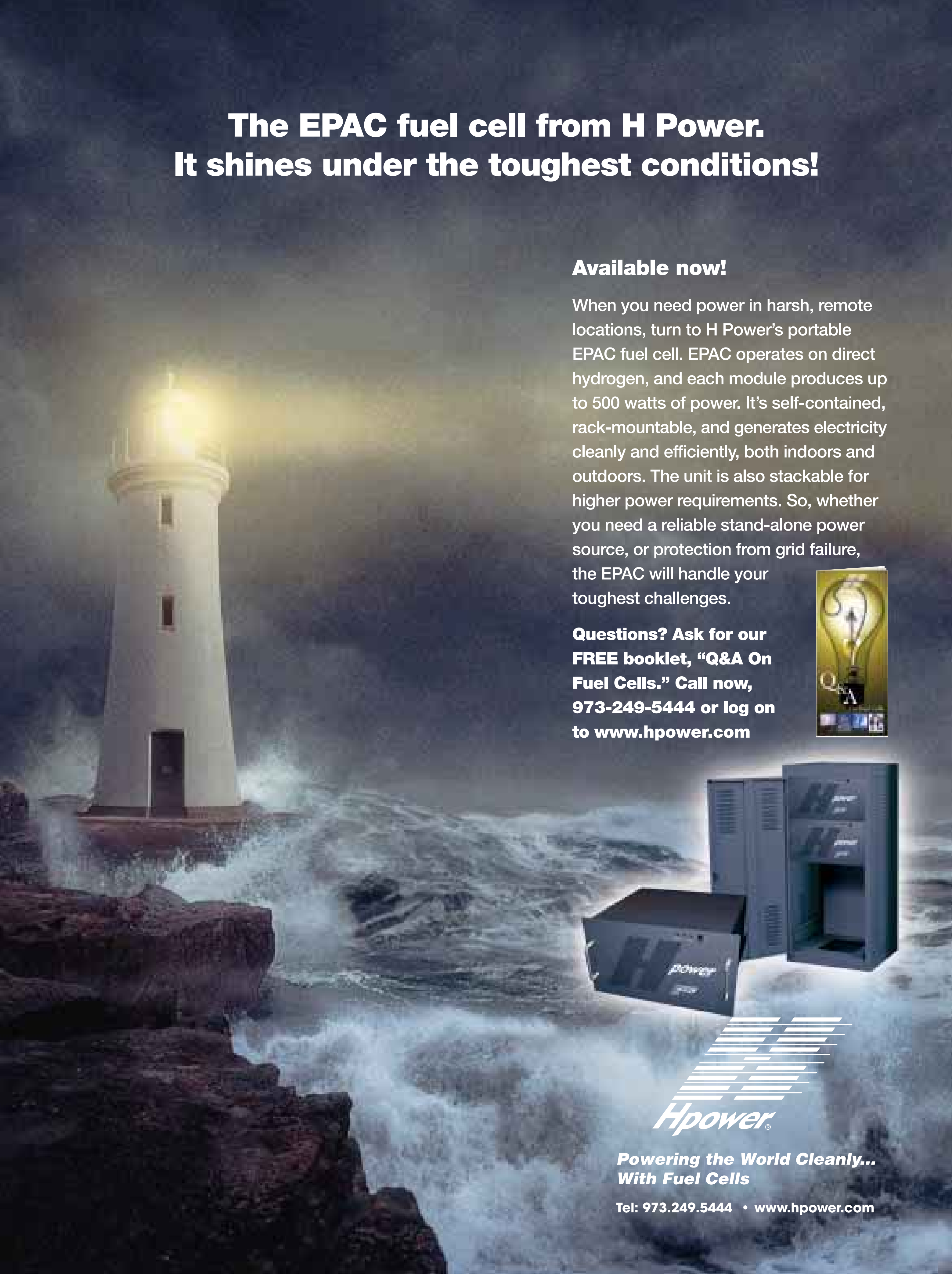
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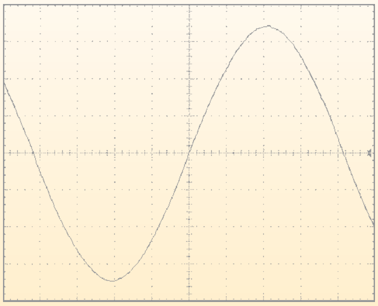

Actual inverter output waveform

Mini Flashlight LED Conversion

John F. Gislason III

An LED conversion makes a flashlight more stout and radically improves battery and bulb life.

After using up countless flashlight batteries and replacing way too many bulbs, I decided that something had to be done. I read about the flashlight conversion in *HP84,* and decided to do some research into LEDs myself.

I was using Maglite brand Mini Maglite flashlights with two AA batteries in stock configuration. The standard bulbs are not shock resistant, which meant frequent replacements at about US$4 each. And they used a lot of energy, which led to short battery life.

Selection & Testing

My first problem was to identify and then locate a suitable white LED. After removing the miniature bulbs from all of the Maglite-type flashlights that I owned, I carefully checked their size against the LEDs available through Radio Shack. I soon discovered that a 3 mm white LED would be ideal, but none could be found that had enough light output for me. I opted for the somewhat larger 5 mm LED. It is Radio Shack #273-320, and is rated at 3.6 V, 20 mA at 1,100 mcd output.

I devised a crude light meter using my Micronta 22-175 multimeter connected to an old photo resistor. The resistor changes resistance with changes in light intensity—the higher the light intensity, the lower the resistance in the photo resistor. I measured the resistance of the photo resistor using the various bulbs and voltages to compare factory bulb output with the LED bulbs. In this way, I could crudely quantify changes in light output.

I determined that the best value with a new conventional bulb and two fresh AA batteries was about 130 ohms on my light meter. To determine if the LED could just replace the standard lamp, I trimmed the leads off to about 3/8 inch (10 mm) long, and carefully inserted them into the lamp holder. Using the same batteries, the LED produced a value of 192 ohms, and it was not very bright.

I decided to see if it could handle 4.5 V. I turned my variable power supply up until the no-load output was 4.7 V, and placed my new LED's terminals across the supply lugs. *It worked!* After being left on continuously for more than an hour, the output value on my light meter had not changed—it was about 98 ohms.

The LED registered fewer ohms on the photo resistor, indicating a higher light output, than in the original bulb configuration, but the light output was range sensitive to a higher degree. It dropped off more rapidly for the LED versions with increasing distance from the photo resistor. I discovered, after sacrificing a couple of LEDs, that the voltage threshold was about 5.5 VDC. Above that voltage, the LED died quickly.

I am admittedly pushing the voltage higher than other LED applications. But in my tests, the LEDs lasted for more than an hour at 5.5 VDC, so operating at 4.5 VDC should not cause any significant problems. The high voltage condition only occurs with fresh batteries. After

An exploded view: barrel padding, flashlight, LED, bulb holder, base, batteries, screw, and spring.

some use, the voltage begins to drop into a more normal range for the LED.

My LED now has hundreds of hours on it with no signs of output reduction or color shift, so I would guestimate bulb life of at least 500 hours, and possibly as many as 20,000 hours (an 80% reduction in life expectancy compared to an operating voltage of 3.5 VDC).

The *real* issue for me is reliability. The stock lamps in these lights last only tens of hours, while my LED conversion has already lasted hundreds of hours. So even if it were to fail "prematurely" compared to other LEDs operating at lower voltages, it would still have outlived the factory counterpart by an order of magnitude.

Assembly & Batteries

When I attempted to screw the lens assembly back onto the body of the flashlight, I quickly discovered that I had overlooked a very important item—the hole in the reflector was way too small. I decided to enlarge the diameter of the existing hole using a drill bit. I needed to make the hole large enough not only to pass the narrow part of the LED, but also the larger collar that is at its base. After some trial and error on a small sample of 1.5 mm styrene plastic sheet, I determined that a $^{1}/_{4}$ inch (6 mm) hole would work.

After the hole in the reflector was enlarged to $^{1}/_{4}$ inch, and the reflector replaced on the light body, it was time for the battery question. It just so happens that common 1.5 V calculator batteries (N cells) are slightly smaller in diameter, but significantly shorter than the standard AA batteries my flashlight was designed for. This allowed me to use three, 1.5 V batteries to achieve 4.5 VDC total.

I separated the clear plastic product covering from the LED packaging, and used the paper backer to form a tube to place in the barrel of the flashlight. This made up the difference in diameter between the smaller calculator batteries and the flashlight barrel designed for larger AA batteries. I cut the tube short so it would not make contact with the threaded end of the flashlight body when installed.

I carefully inserted the three new batteries into the flashlight and discovered that I was about $^{3}/_{4}$ inch (19 mm) short of the grounding spring in the end cap. I quickly determined that a small wood screw would be an excellent "low buck" solution, and it was. Later it became apparent that a single $^{3}/_{8}$ inch (10 mm) diameter spring about 2 inches (5 cm) long would be a better solution, and that is what I use now.

A closer look at the LED, bulb holder, and base.

LED Flashlight Conversion Parts List

Item	*Distributor*	*Cost (US$)*
1 LED, 5 mm	Radio Shack #276-320	$4.99
3 N cells, 1.5 V	Radio Shack #23-023	4.79
1 Mini Maglite flashlight	used	0.00
Sheet metal screw, #10 x 3/4 inch	used	0.00
Packaging material	used	0.00
Spring, 1/4 x 1 inch	used	0.00
	Total	$9.78

To attach the LED bulb to the flashlight, I was able to simply trim the terminals on the LED to about 1/2 inch (13 mm), and insert them into the holes in the factory bulb receptacle. I quickly discovered that unlike incandescent bulbs, there is a polarity to LEDs. I installed it backwards the first time, and had to switch the LED around 180 degrees and reinsert it into the holder.

Real World Use

The placement of the LED higher or lower in the reflector has a dramatic influence on light performance and focus. Setting the LED too deeply causes a very diffuse light, and setting it too high causes a halo effect. With a two AA Mini Maglite, a separation of about 1/8 inch (3 mm) between the LED base and bulb holder seems to work best. But any changes to bulb size or location of the light element inside the LED have dramatic effects.

The converted flashlight is used extensively in my job as a truck mechanic for inspection of various components. The light's output is excellent for nighttime outdoor use and other low ambient light situations, even at distances of about 3 feet (0.9 m). In high ambient lighting conditions, its effective range is limited to about 6 inches (15 cm).

The light is used about two hours per day at work, and the output is very stable. The light appears to have a blue hue to it, compared to other lights, which cast a warmer, more yellow light.

I've been using the flashlight for seven months now without battery or bulb replacements, and it has proven very reliable. I'll never buy mini bulbs again! The LED bulb is very robust, and nearly shockproof—it will tolerate a 12 foot (3.7 m) drop without failing. The light output has remained constant over these months, and the wider beam is very handy. These lamps could also be used in AAA sized flashlights, with dramatically increased battery life using three batteries.

Because I'm no longer concerned with battery or bulb life, I use my flashlight longer and more often. I have also sold all my factory spare bulbs for the flashlight to my coworkers, which has more than covered the cost of conversion.

Access

John F. Gislason III, 426 Felix Ln., Saint Paul, MN 55118 • gislasonzoo@earthlink.net

Mag Instruments, Inc., 1950 S. Sterling Ave., Ontario, CA 91761 • 800-289-6241 or 909-947-1006
Fax: 909-947-3116 • salesdesk@magmail.com
www.maglite.com

Radio Shack, 100 Throckmorton St., Fort Worth, TX 76102 • 800-843-7422 or 817-415-3011
Fax: 817-415-3240 • support@tandy.com
www.radioshack.com

The converted flashlight is super bright and it's considerably more durable than the original.

SUV vs. PV

Jeremy Smithson

IS SOLAR ENERGY TOO EXPENSIVE?...YOU DO THE MATH!

JEEP GRAND CHEROKEE LAREDO

Age	Value[1]	Emissions[2]	Cost[3]
New	$29,499	0.5 tons	$29,499
1 year	$21,710	12.5 tons	$33,099
5 years	$10,445	62.5 tons	$51,099
10 years	$4,075	125.0 tons	$65,500
20 years	$550	250.0 tons	$101,500

[1] Blue Book [2] 10 K Miles per year [3] Operating cost

5 KILOWATT GRID-TIED PV SYSTEM

Age	Value[4]	Emissions[5]	Cost[6]
New	$29,499	0.5 tons	$29,499
1 year	$29,351	-2.7 tons	$28,959
5 years	$28,759	-13.5 tons	$26,571
10 years	$28,019	-27.0 tons	$23,009
20 years	$26,539	-54.0 tons	$13,401

[4] 5% per year [5] Vs. gas turbine [6] Avoided cost

When I put this sign together for my booth in a local fair, it was an attempt to rebut the time-worn argument that we've all heard—solar electricity is too expensive.

As a newbie solar contractor, I was appalled at the negative attitude of my more experienced peers regarding cost. As an experienced remodeling contractor, I knew that cost was not necessarily a factor. For example, my clients would spend US$1,500 on a bathroom faucet, or US$20 per square foot on tile.

The products of the auto industry are *never* subjected to the kind of scrutiny regarding cost effectiveness to the purchaser that renewable energy products must endure constantly. Let's get over it! PV gives a tax-free return on investment (ROI) of 4 percent over the life of the system (50 years) in Seattle, Washington, right now. Compare that to a passbook savings account that presently yields around 1 percent.

If you don't remember anything else about my sign, remember that *if you can afford a car, you can afford a solar-electric system.* Perhaps PV module manufacturers could take a hint from the auto industry and offer zero percent financing.

What if we selected our mode of transportation the way we are told that we must select our source of electricity? Those of us who live in cities would all be using public transportation or bicycles, unless we were hauling loads. (How often do you see an SUV on the road with more than one or two occupants?)

In the comparison chart, the Jeep values are Blue Book prices, Jeep emissions were based on 10,000 miles per year, and Jeep cost is incremented by the cost per mile allowed by the IRS. The PV is devalued 0.5 percent per year. RETScreen (from Natural Resources Canada) was used to compute ROI and emissions saved compared to a modern gas turbine generator, and to decrement the PV cost based on a current utility rate of 8.7 cents per KWH. The installed cost of the PV system is US$6 per watt. We do 'em for as low as US$5.75, give the purchaser a 50 year product, and still make money, all without rebates.

So where is *your* money going—down the road or back in your pocket?

Access

Jeremy Smithson, Puget Sound Solar, 5308 Baker Ave. NW, Seattle, WA 98107 • 206-706-1931
Fax: 206-297-1814 • jeremy@pugetsoundsolar.com
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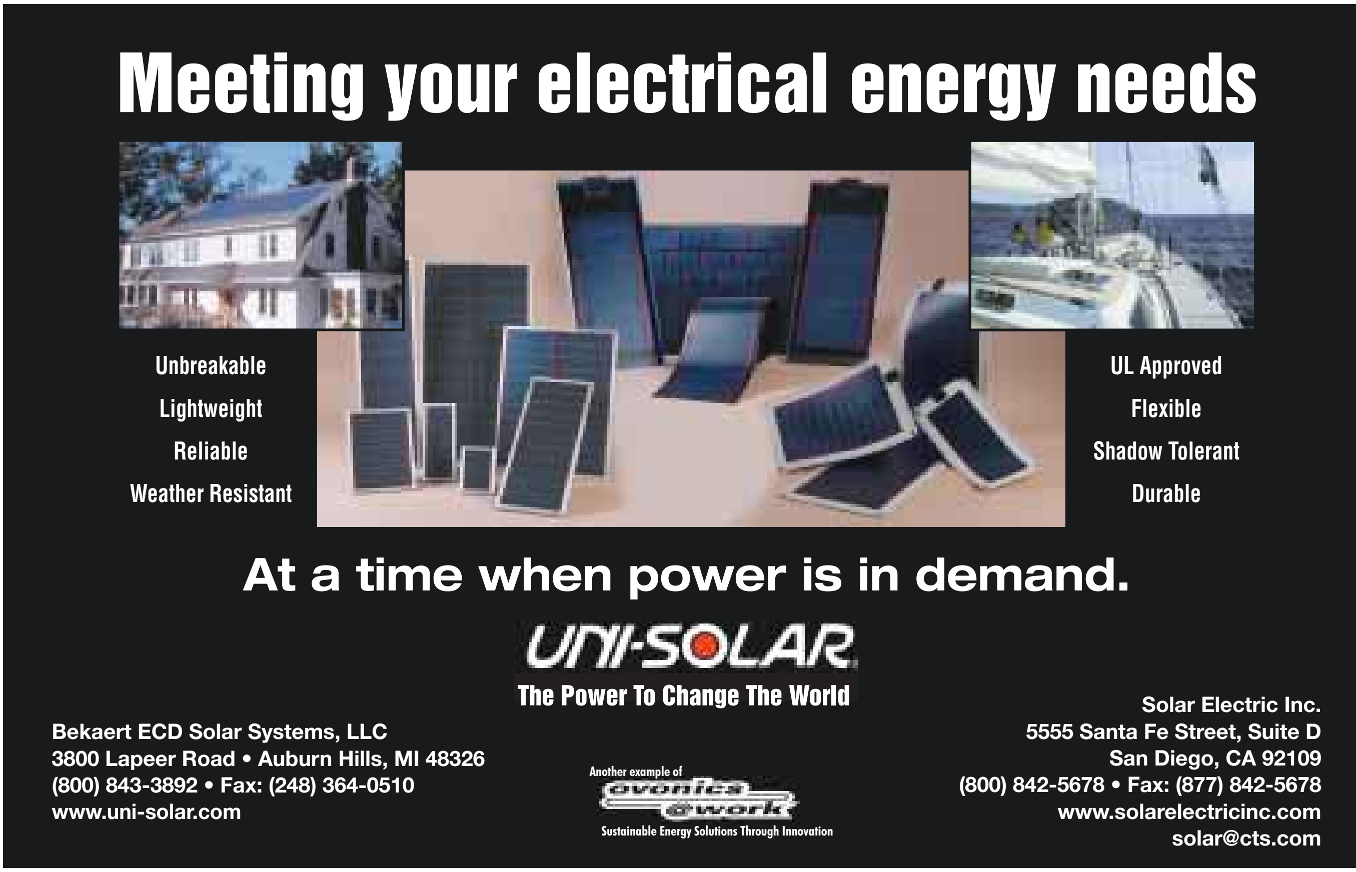

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Apples & Oranges 2002

Choosing a Home-Sized Wind Generator

Mick Sagrillo

You're about to make the big decision: should a wind generator be in your future? You've analyzed your resources, both environmental and monetary, and weighed the pros and cons of having a wind generator. The only question left is: which system should you choose?

I can't answer that question for you. However, I can give you the tools to help you make that big decision. Those tools are the detailed information and specifications for a variety of wind-electric systems, along with some personal observations based on 22 years of working with home-sized wind-electric systems. An appendix with additional discussion and technical commentary can be downloaded from *Home Power's* Web site.

Apples and Oranges (A&O) was originally published in 1993 and updated in 1995 and 1998. Meanwhile, a lot has happened in the small wind turbine industry. One company went out of business, two more entered the field, and one manufacturer bought out a competitor. A number of wind generator models went out of production, and some new models were introduced. While it's been a tumultuous four years since A&O was last published, perhaps the shakeout in the marketplace has at last ended, and things have settled down for the U.S., small wind turbine consumer.

Background

This article will review most of the wind generators that are sold and supported in the United States. One European manufacturer and one African manufacturer are represented by U.S. distributors. A number of new turbines are on the drawing boards, but they are not included here. In addition, at least six non-U.S. manufacturers are considering exporting their wares to the U.S., but have not yet done so.

Several wind turbines currently available on the Internet are not covered by this article. The reason for their exclusion is the outlandish claims made like, "Get a kilowatt for only $250." When compared to other commercially available wind generators, this sounds too good to be true. As the old adage leads us to conclude, it probably is.

As another example, I ordered and paid for a new turbine back on November 1, 2001 from a manufacturer trying to enter the business. As of June 2002, that turbine has not been delivered, and the manufacturer is impossible to get ahold of by phone or e-mail. While their turbine is a promising design, some companies just aren't ready for prime time yet. So, if it's not covered in this article, you'll have to draw your own conclusions.

This article diverges from past articles in covering only "home-sized" wind generators. In the past, A&O has included a large number of microturbines, those wind generators whose primary niche is sailboats, RVs, remote telecommunication sites, and other specialty markets.

While microturbines certainly provide valuable electricity to many remote applications, the intended user of this version of A&O is the homeowner who wants to install a wind-electric system on an adequate tower for either on-grid or off-grid production of substantial amounts of electricity for a home.

A word on failures is in order. You may know someone who has owned one of the wind generators reviewed here, and has experienced a failure of some sort, maybe even a catastrophic failure. Don't prejudge all wind generators based on a few isolated instances. Sure, there have been failures, even with the best of wind-electric systems. Paul Gipe, author of *Wind Power for Home & Business,* reminds us to look only as far as the automotive industry for a comparison. The auto industry is a multibillion dollar industry, spanning more than ten decades. Yet they still don't always get it right, as evidenced by the numerous annual recalls of their products.

What you should be interested in is trends—not the occasional failure. Problems with a wind generator usually occur early in the system's life. All wind generator manufacturers have experienced some failures, as have all other RE equipment manufacturers. Numerous reports of problems with a particular manufacturer should raise a red flag in your mind.

In addition, Joe Schwartz of *Home Power* magazine suggests checking out the customer service reputations of the manufacturers or distributors before buying. Your best bet is to discuss the wind generator you plan to purchase with as many owners as you can, not just your dealer or the manufacturer. Remember that manufacturers and dealers have something to sell. A pleased or disgruntled user doesn't.

The comparison table summarizes all of the various features that you should seriously consider when shopping for your wind-electric system. This article explains how to interpret the information in each row of the table. All of the information in the table (except where noted) has been provided by the manufacturers.

Manufacturer & Model
Contact information for manufacturers and major U.S. distributors listed in the table appears at the end of the article. All of the wind generators presented are new equipment, with the exception of the remanufactured Jacobs Wind Electric generators (short case and long case Jakes). The Jacobs 31-20 is a new machine, based on another Jacobs design.

Even though the old Jacobs has not been made for 50 years, they are still considered by many to be top-of-the-line technology. As such, they have been remanufactured (that is, completely rebuilt with many new components and put back onto the streets with a warranty) by various companies for at least the last 28 years. The Jacobs wind generator is the yardstick by which many judge today's wind equipment.

Swept Area & Rotor Diameter
To help with comparisons, the various wind generator models are listed in ascending order of swept area and rotor diameter. This is a radical departure from the way most manufacturers rate their various turbine models, as well as from previous versions of A&O. You'll see why when you read my comments on cost.

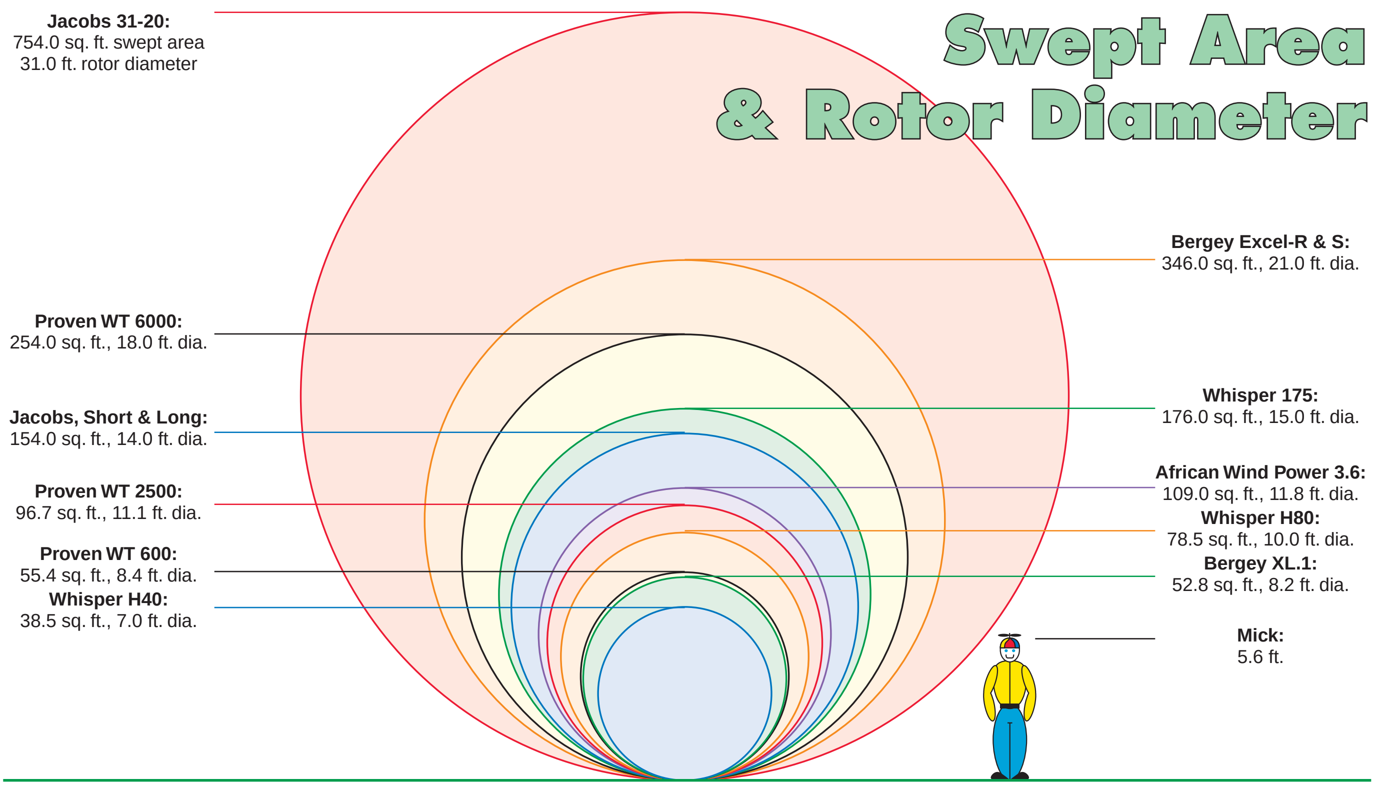
The "rotor" is defined as the entire spinning blade assembly, including the hub to which the blades are attached. The rotor is essentially the collector of the wind generator—gathering fuel in the form of wind, and converting it into electricity by driving the generator.

Think of the rotor in the same terms as we describe a solar water heater. One 4 by 8 solar hot water panel (32 square feet) will collect a certain amount of sunlight and produce a proportional amount of hot water. If you double the number of panels, you double the collector area (now 64 square feet), thereby doubling the amount of sunlight you can collect and the amount of hot water you can produce. Swept area works much the same way.

The rotor converts the movement of air passing through the two or three blades into the rotational momentum that turns the generator, thereby generating electricity. Just like a solar water heater's area, a wind generator's rotor size is a pretty good measure of how much electricity the wind generator can produce. The larger the swept area of the wind generator's rotor, the more electricity it can produce.

While manufacturers rate their products at different peak wattages, the output of a wind generator is primarily a function of its swept area. Other features will influence output, such as high-tech airfoils and more efficient generators. However, they pale when compared to the overall influence of the size of the rotor.

Mike Klemen, a seasoned wind generator user and tester in North Dakota says, "Ultimately, we must realize that energy production comes from square feet." Hugh Piggott of Scoraig Wind Electric in Scotland contends, "Swept area is easier to measure and harder to lie about than performance. What we'd like to know is KWH per month, but until we get more independent testing done, swept area is a good guide." Swept area is *the most* critical feature that will help you compare the output of one wind generator with another.



Cut-in Wind Speed
This is the wind speed at which the wind generator begins producing. For all practical purposes, wind speeds below about 6 to 7 mph (3 m/s) provide little or no usable energy, even though the blades may be spinning. From my perspective, a few watts does not result in usable energy. At best, this minimal output only overcomes the power losses caused by a long wire run or the voltage drop due to diodes.

We are beginning to see high-tech controllers that are able to “store” the small amount of energy available at low wind speeds in the alternator windings. This energy is then pulsed to the batteries in a manner similar to a pulse width modulated charge controller. The new Bergey XL.1 uses such a controller.

Rated Wind Speed
This is the wind speed at which the wind generator reaches its rated output. Note that not all wind generators are created equal, even if they have comparable rated outputs.

There is no industry standard for rated wind speed. “So what?” you ask. The listed wind generator companies rate their turbine output at anywhere from 18 to 31 mph (8–14 m/s). This may not sound like such a big deal until you understand that there is potentially 511 percent more power in a 31 mph wind than in an 18 mph wind.

To drive home the example, let’s use 16 and 32 mph instead of 18 and 31. The power in the wind available to a wind generator is defined by the equation:

$P = \frac{1}{2} d \times A \times V^3$

Where P is power, d is density of the air, A is the swept area of the rotor, and V is wind speed. Notice that wind speed is cubed. In other words, the equation really reads $P = \frac{1}{2} d \times A \times V \times V \times V$.

We can simplify the relationship by stating that $P \sim V^3$, that is, P is directly proportional to the cube of the wind speed. If we double the wind speed (V), the power (P) increases by 800 percent. So there is 800 percent more power available to the rotor at 32 mph than at 16 mph. Viewed in reverse, there is $\frac{1}{8}$ the power in a 16 mph wind compared to a 32 mph wind.

Let’s say we have two wind generators, both rated at 1,000 watts. Lots-o-Watts is rated at 16 mph and Mighty-Watts at 32 mph. At 32 mph, they’re both producing 1,000 watts, right? But at 16 mph, Lots-o-Watts is still producing 1,000 watts, whereas Mighty-Watts is only producing $\frac{1}{8}$ that amount, or a paltry 125 watts!

All of this means that the lower the rated wind speed, the more energy a wind generator will produce, given its rated output. As a consumer, therefore, you should be particularly interested in machines with low rated wind speeds.

Rated Output
This measurement is taken at an arbitrary wind speed that the manufacturer designs for. It tends to be at or just below the governing wind speed of the wind generator. Any wind generator may peak at a higher output than the rated output. The faster you spin a wind generator, the more it will produce, until it overproduces to the point that it burns out. Manufacturers rate their generators at a safe level, well below the point of self-destruction.

You are not necessarily interested in the rated output of a wind generator. A turbine with a high rated wind speed will invariably cost less than one with a lower rated wind speed, for the same rated output. How can this be? Refer back to the power equation mentioned above. A higher wind speed gives a certain wattage to the manufacturer at a smaller rotor diameter, smaller physical size of the generator, and subsequently less weight. All of this means less cost for the manufacturer, and less cost to you.

But remember, it takes a higher wind speed to achieve that rating. In a 12 mph (5 m/s) average wind speed site, you will see 18 mph (8 m/s) winds a mere 3 percent of the time. Not much, you say. But you will see 31 mph (14 m/s) winds for less than 0.2 percent of the time.

Rated output comes to us from the photovoltaic industry, where panels are tested for output at a fixed light intensity and a fixed temperature. The wind industry has no such fixed standards. So, while comparing PVs based on rated wattage makes for great cost comparisons, comparing rated outputs is a poor way to compare wind generators. You are far better off comparing swept areas, or the KWH per month of electricity the different systems will produce at different average wind speeds.

Peak Output
This figure may be the same as rated output, or it may be higher. Wind generators reach their peak output while governing, which occurs over a range of wind speeds above their rated wind speed. Although widely touted by some marketers, it has limited relevance to the buyer. To quote Hugh Piggott, “Peak or rated output specifications for small wind turbines can be red herrings unless you take the rated wind speed into account, and yet these specs are all the customers seem to want to know about.”

Wind turbines are not PVs, don’t operate in the same manner, and should not be rated in the same way. What you should be asking is what wind energy engineer Eric Eggleston asked, “What will this wind generator do at my site in my average wind speed?”

Maximum Design Wind Speed
Bandied about by marketing departments, this term has little bearing on the expected life of a wind generator. Wind generators are designed by engineers, on paper, to survive wind speeds of 120 mph (54 m/s) or more. Unfortunately, wind turbines are not tested for these survival speeds because, quite frankly, it’s a very difficult thing to test for, or to test repeatedly.

Much of the survival speed documentation we have is not from actually testing turbines at those speeds, but from anecdotal situations. Bergey Windpower might boast that their machine survived a hurricane in Kansas that blew Toto away from Dorothy. Great, but what have we learned?

I don’t mean to demean claims like this, but again, they are difficult to test, and everybody supposedly designs their turbines for extreme winds. In fact, Bergey Windpower has actually had very good success designing their turbines to survive such high winds. How? By making their wind generators very robust, very heavy duty.

Does that mean that any turbine will survive a 100 mph (45 m/s) storm? Maybe, maybe not. A 100 mph wind that is coming straight on is fierce, I’ll grant that. But have you ever watched a wind generator sited on a short tower near trees and buildings? The poor thing hunts around continuously, all the while buffeted by the turbulence caused by the short installation height, along with the nearby ground clutter. I have seen more wind turbines destroyed by turbulence than I have seen destroyed in survival-rated high winds.

Furthermore, a 100 mph wind packs an awesome wallop, and while wind generators and their towers can be designed to withstand those winds, there's no guarantee that they will. I live in dairy country in northeast Wisconsin. During our last 100 mph wind, cows were flying through the air! If a cow, or a 2 by 4, or a sheet of plywood hits the wind generator or tower, it will probably crumble, regardless of what wind speed the system was designed for. Flying debris is what takes out many turbines in high winds. You can’t design for flying lumber or livestock.

So what should you look for if not maximum design wind speed? I look for tower top weight, which is a pretty good indicator of reliability. My experience is that heavy duty wind generators survive, and light duty turbines do not. While all of the units listed are rated for 120+ mph (54+ m/s) winds, in-field experience indicates that many of the lighter turbines cannot handle sites with heavier winds or turbulence. Be forewarned! Weight, by the way, will be reflected in the price. You’ll only get what you pay for.




Model	Whisper H40	BWC XL.1	WT 600
Manufacturer	Southwest Windpower	Bergey Windpower	Proven Engineering
Swept area, square feet	38.5	52.8	55.4
Rotor diameter, feet	7.0	8.2	8.4
Cut-in wind speed, mph	7.5	5.6	6.0
Rated wind speed, mph	28.0	24.6	22.5
Rated output, watts	900	1,000	600
Peak output, watts	900	1,800	700
Maximum design wind speed, mph	120	120	145
Rpm at rated output	1,150	490	500
Blade material	Injection molded plastic	Pultruded fiberglass	Polypropylene
Tip speed ratio (TSR)	10.3	5.8	6.7
Generator type	PM 3 AC	PM 3 AC to DC	PM 3 AC
Governing system	Angle governor	Side facing	Hinged blades
Governing wind speed, mph	28.0	29.0	22.5
Shut-down mechanism	Dynamic brake	Dynamic brake	Disc brake optional
Tower top weight, pounds	47	75	154
Lateral thrust, pounds	150	200	450
Battery system voltages	12 to 48	24	12, 24, or 48
Controls included in cost	Controller & dump load	Battery controller	Battery controller
Utility intertie	With batteries	With batteries	With batteries
KWH / month @ 8 mph	30	55	42*
KWH / month @ 9 mph	45	85	66*
KWH / month @ 10 mph	65	115	83*
KWH / month @ 11 mph	80	150	113*
KWH / month @ 12 mph	105	188	124*
KWH / month @ 13 mph	125	220	146*
KWH / month @ 14 mph	155	250	167*
Cost, US$	$1,495.00	$1,695.00	$3,338.00
Cost per sq. ft. swept area, US$	$38.83	$32.10	$60.25
Cost per pound, US$	$31.81	$22.60	$21.68
Weight per swept area, pounds	1.22	1.42	2.78
Weight per TSR, pounds	5	13	23
Years in production	3	1	5
Warranty, years	2	5	2
Routine maintenance	Annual inspection	Annual inspection	Annual inspect & grease
Notes			Downwind

* Estimated by author

Whisper H80	WT 2500	AWP 3.6	Jake, Short Case
Southwest Windpower	Proven Engineering	African Windpower	Abundant Renewable Energy
78.5	96.7	109.0	154.0
10.0	11.1	11.8	14.0
7.0	6.0	6.0	6.0
26.0	26.0	25.0	18.0
1,000	2,500	1,000	2,400
1,000	2,900	950@24 V; 1,050@48 V	2,400 @ 48 V
120	145	100 Experienced	80 Operating; 100 furled
900	300	350	225
Injection molded plastic	Polypropylene	Fiberglass	Sitka spruce
13.4	4.6	5.5	5.0
PM 3 AC	PM 3 AC	PM 3 AC	DC
Angle governor	Hinged blades	Side facing	Blade pitch governor
26.0	26.0	25.0	23.5
Dynamic brake	Disc brake	Dynamic brake	Folding tail
65	440	250	500
250	1,124	250	750
12 to 48, or 220	24, 48, 120, or 240	12, 24, 48, or 220	24 to 48
Controller & dump load	Battery controller	Battery controller	
With batteries	With batteries	With batteries	With batteries
60	167*	75	240*
90	206*	105	300*
125	292*	130	340*
160	333*	168	410*
190	417*	192	460*
215	465*	226	500*
265	542* (* Estimated by author)	246	550* (* Estimated by author)
$1,995.00	$6,900.00	$2,214.00	$8,700.00
$25.41	$71.35	$20.31	$56.49
$30.69	$15.68	$8.86	$17.40
0.83	4.55	2.29	3.25
5	96	45	100
3	9	3	20
2	2	2	2
Annual inspection	Annual inspect & grease	Annual inspect & grease	Annual inspect & grease
HVLV available	Downwind	HVLV available	Includes stub tower

Model	Jake, Long Case	Whisper 175	WT 6000
Manufacturer	Abundant Renewable Energy	Southwest Windpower	Proven Engineering
Swept area, square feet	154.0	176.0	254.0
Rotor diameter, feet	14.0	15.0	18.0
Cut-in wind speed, mph	6.0	7.0	6.0
Rated wind speed, mph	24.0	27.0	22.0
Rated output, watts	3,600	3,000	6,000
Peak output, watts	3,600 @ 48 V	3,200	6,500
Maximum design wind speed, mph	80 Operating; 100 furled	120	145
Rpm at rated output	325	500	200
Blade material	Sitka spruce	Fiberglass composite	Wood epoxy composite
Tip speed ratio (TSR)	5.0	10.0	5.8
Generator type	DC	PM 3 AC	PM 3 AC
Governing system	Blade pitch governor	Angle governor	Hinged blades
Governing wind speed, mph	27.0	27.0	26.0
Shut-down mechanism	Folding tail	Dynamic brake	Disc brake
Tower top weight, pounds	600	175	948
Lateral thrust, pounds	800	700	2,248
Battery system voltages	24 to 48, or 120	24 to 48, or 220	48, 120, or 240
Controls included in cost		Controller & dump load	Battery controller
Utility intertie	With batteries	With batteries	With batteries
KWH / month @ 8 mph	240*	170	417*
KWH / month @ 9 mph	300*	230	564*
KWH / month @ 10 mph	340*	330	667*
KWH / month @ 11 mph	440*	410	917*
KWH / month @ 12 mph	520*	540	1,083*
KWH / month @ 13 mph	610*	620	1,250*
KWH / month @ 14 mph	700* * Estimated by author	720	1,417* * Estimated by author
Cost, US$	$9,200.00	$5,455.00	$13,100.00
Cost per sq. ft. swept area, US$	$59.74	$30.99	$51.57
Cost per pound, US$	$15.33	$31.17	$13.82
Weight per swept area, pounds	3.90	0.99	3.73
Weight per TSR, pounds	120	18	163
Years in production	20	4	4
Warranty, years	2	2	2
Routine maintenance	Annual inspect & grease	Annual inspection	Annual inspect & grease
Notes	Includes stub tower	2 Blades; HVLV	Downwind

BWC Excel-R	BWC Excel-S	Jacobs 31-20
Bergey Windpower	Bergey Windpower	Wind Turbine Industries
346.0	346.0	754.0
21.0	21.0	31.0
8.0	8.0	8.0
31.0	31.0	26.0
7,500	10,000	20,000
8,500	12,000	20,000
125	125	120
310	310	175
Pultruded fiberglass	Pultruded fiberglass	Fiberglass over foam
7.5	7.5	7.5
PM 3 AC	PM 3 AC	Brushless 3 AC
Side facing	Side facing	Blade pitch governor
34.0	34.0	26.0
Crank-out tail	Crank-out tail	Disc brake
1,020	1,020	2,500
2,000	2,000	2,500
24, 48, 120, or 240	Grid-tie only	Grid-tie only
Battery controller	Utility-intertie inverter	Utility-intertie inverter
Use Excel-S instead	Inverter included	Inverter included
340	240	819
500	370	1,160
680	520	1,644
880	700	2,142
1,090	900	2,691
1,320	1,130	3,274
1,550	1,370	3,872
$19,400.00	$22,900.00	$23,500.00
$56.07	$66.18	$31.17
$19.02	$22.45	$9.40
2.95	2.95	3.32
136	136	333
19	19	20
5	5	1
Inspect every 2 years	Inspect every 2 years	Annual oil, grease, & inspect
		Gear box

Rpm at Rated Output
This is the alternator or generator rpm at which rated output occurs. Generally, the smaller the rotor, the faster the blades spin. Generator rpm will have an effect on the amount of noise that the wind generator makes. High rpm wind generators also experience more stress due to centrifugal forces, which are constantly trying to tear the machine apart.

Bearing life is also affected by rpm. Bearing life is dependent on the load on the bearings, plus the speed at which those bearings spin. Light duty, high-speed wind turbines typically have a shorter bearing life than slow-speed, heavier machines—yet another benefit of heavy duty machines.

Blade Material
Within the last eight years, a number of new materials have become available for making wind generator blades.

While more expensive for materials and labor, wood is still considered by some to be the tried and true material of choice for blades. Blades do a lot of flexing. That's what trees did as a side job for most of their lives, as they swayed in the ever-changing breezes. Without question, Sitka spruce is the primo material for wood blades. It has one of the highest strength-to-weight ratios of any material ever used by blade makers, as well as airplane and boat builders.

Wood blades need exceptional paint coatings to protect them, along with a durable leading edge tape to protect the blades from abrasion due to dust and insects in the air. Both paint and leading edges need maintenance. If the paint cracks or the leading edge tape tears away, resulting in wood exposed to the elements, the wood will quickly erode. Moisture entering these areas will cause an unbalanced rotor, stressing the wind generator over time. Wooden blades must be inspected annually, with repairs made as soon as damage is discovered.

Since good wood is ever more difficult to secure, as well as labor intensive to convert into quality blades, most manufacturers have moved away from wood and towards synthetic materials for their blades. A number of synthetics are currently in use.

One good replacement for wood blades is fiberglass over a foam core. The foam gives body to the blade, while the fiberglass covering laid up over the foam results in an extremely durable, smooth blade surface. The leading edge of fiberglass blades is also covered with an abrasion resistant tape to protect it from erosion. This tape needs periodic replacement.

A variation on fiberglass blades is to use a carbon fiber composite for an even tougher blade surface. Yet another variation on fiberglass is to use the material, not on the outside of the blade, but throughout the entire blade. One technique, known as pultrusion, is used by Bergey.

Pultruded fiberglass blades are made in a process that resembles making spaghetti. Spaghetti dough is squeezed through a hole in a die, and then cut to length. Pultruded blades are made by pulling fiberglass through a die along with fiberglass cloth, to make the form of the airfoil. Lengths are cut, the blade butts are fabricated and added to the blades, and, voila—you have Bergey blades.

Plastics are also being used for blades. Southwest Windpower uses injection molded plastic for the blades on their Whisper H40 and H80. Proven Engineering uses a hollow polypropylene blade, another form of plastic. One potential advantage of plastic blades is that they should be relatively inexpensive to replace when that time comes. They're also tough and impervious to water.

Blade color is not included in the table, but should be mentioned. Most blades are white, while a few are colored (blue or gray, for example) to blend in with the sky. Plastic and carbon-fiberglass blades are black. When I first encountered black blades, I thought they would look horrendous on the landscape. Interestingly, a black rotor almost disappears in the sky when spinning.

Tip Speed Ratio (TSR)
The performance of a blade's airfoil (shape) is a function of the ratio of the speed of the tip of a blade to the wind speed. A low-speed blade will have a TSR of 5 or 6 to 1, while a high-speed blade with a TSR of 10 or 11 to 1 will be a less efficient performer.

So why use a high TSR airfoil? Faster spinning blades allow a manufacturer to build a smaller generator (therefore, lighter weight) to get a certain output. However, the faster the blades spin, the more noise they make, especially when governing. A much more detailed discussion of airfoils and tip speed ratio can be found in the A&O '02 Appendix on *HP's* Web site.

"Number of blades" has not been included in this version of A&O, since all of the models listed have three blades except for one, the Whisper 175. While a number of manufacturers have offered two-bladed wind generators in the past, most no longer do. Three-bladed wind generators avoid yaw chatter, which happens when a two-bladed machine yaws. "Yaw" is a term that refers to a wind generator pivoting on its bearings around the tower top to follow the continually changing direction of the wind. See the A&O '02 Appendix on *HP's* Web site for further discussion of this issue.

So, what about the only two-bladed machine on the market, the Whisper 175? In the "Whisper 175 Redesign Status Report" dated February 14, 2002, Southwest Windpower announced that they are redesigning the blade plate for the 175. The blade plate they are considering will be made of heat treated spring steel, like the springs in a car. In theory, the spring plate will flex to absorb some of the yawing vibration to try to mitigate the yawing chatter on the two-bladed Whisper 175.

Regardless of the number of blades on the wind generator, proper blade balancing is critical for a smooth running machine. Severe chattering or a poorly balanced rotor may result in the failure of the wind generator or, in extreme cases, the tower. Look for an unbalanced rotor to show up as tail wagging.

All of the wind generators listed are upwind generators, with the exception of the Proven wind turbines. Upwind generators use a tail to orient the turbine into the wind. Downwind machines have no tails. With a downwind turbine, the wind blowing on the rotor literally pushes it away from the tower, thereby keeping the blades oriented into the wind. While some are biased towards either an upwind or downwind configuration, I think either style works just fine.

Generator Type

Three types of electrical generators are used in wind-electric systems: permanent magnet (PM) alternators, DC generators, and brushless alternators. All three do a fine job of generating electricity.

In general, PM alternators are lighter weight, less complicated, and less expensive to manufacture than either DC generators or brushless alternators. These latter two require more copper and labor to manufacture, but they match the power curve of the rotor more closely.

A more detailed analysis of the pros and cons, plus the various design parameters of the alternators and generators used in wind-electric systems, can be found in the A&O '02 Appendix on *HP's* Web site.

All of the wind generators listed are direct drive units with the exception of the Jacobs 31-20, which uses a 6 to 1 gear box in the design. Direct drive means that the blades directly drive the generator, with no gears. The advantage of gear drive machines is that they can deliver kilowatt-hours at a lower cost than direct drive machines. It's cheaper to add a gearbox than to custom design a large, slow-speed generator. The downside is that gearboxes add lots of moving parts, which translates to more wear and tear, and more maintenance.

Governing System

Governing is necessary for two reasons. The governor protects the generator itself from overproducing and burning out, and it protects the entire system from flying apart in high winds. The governing devices used on all of these wind generators fall into two general categories—those that reduce the area of the rotor facing the wind, and those that change the blade pitch.

Changing the swept area of the rotor is accomplished by tilting the rotor up and out of the wind, side facing the rotor out of the wind by moving it around the tower (Bergey and AWP), or by a combination of the two (Whisper). In all cases, the fixed-pitch rotor is offset either above or to the side of a pivot point. Wind pressure on the offset rotor causes the rotor to pivot out of the wind.

These governing mechanisms are almost a foolproof method of controlling rotor speed. However, they do come at a cost. Once the rotor governs by tilting up or side facing, it often produces very little because it is no longer oriented to the wind. One exception to this is the AWP, which maintains its power curve in the governed position.

Blade-activated governors (all of the Jacobs) work by pitching the blades out of their ideal alignment to the wind. Because these governors operate due to centrifugal forces, the greater the rotor speed, the greater the degree of pitch on the blades. Having more moving parts than either the tilt-up or side-facing mechanisms, they are more complicated governing devices. More moving parts means more parts to maintain or replace sometime in the life of the turbine. However, they offer much better power output in high winds compared to governors that reduce swept area.

Finally, the Proven turbines also govern by pitching the blades, but not only due to centrifugal forces as with the Jacobs. In addition to springs, the Proven blades have a hinge built into the blade butts. In origami fashion, the blades fold and twist in high winds, changing the ideal blade pitch, stalling the blades, and thereby reducing rotor speed. In very high winds, the blades also cone back and away from the tower, cleverly resulting in a reduced swept area.

Governing Wind Speed

The wind velocity at which the governing mechanism is fully operational occurs somewhere between the wind generator's rated power output and its maximum power output.

Wind Generator Noise

Questions often arise about how much noise a particular wind generator makes. For the most part, a well-designed wind generator is relatively quiet. By the time the wind generator is cranking enough to cause some noise, trees are rustling and buildings are rattling as well. But sometimes the wind genny rustles and rattles, too. What can you reasonably expect?

First of all, wind generators are not PVs. PVs just lie on the roof and smile at the sky all day (what a job!). Wind generators are up there hustling in the wind, making lots of motion. Motion is often accompanied by sound emissions, or what some consider noise. From my perspective, wind generators should be seen and not heard.

Two design parameters influence the amount of noise a wind generator makes. The first is tip speed ratio (TSR). Regardless of how they were designed, field observations from numerous owners say that high TSR rotors are noisy. Low TSR rotors, on the other hand, are generally quiet.

Governing also affects the amount of noise a turbine makes, especially when combined with high rotor speed. A high-speed rotor that changes its plane of rotation by side facing or tilting up can create quite a bit of noise. In contrast to side-facing and tilt-back governors, pitching the blades to govern rotor speed is very quiet.

Some permanent magnet (PM) wind turbines seem to reach a breakaway speed, a point where the rpm of the rotor really takes off. This is due to insufficient flux of the permanent magnets relative to the power available at the blades. Once the breakaway speed has been reached and rpm picks up, the rotor can get very noisy, especially when governing. Interestingly, this is not a problem with either the Proven wind turbines, or the AWP wind genny, all of which use PM alternators. The reason? They both use very low-speed alternators and low TSR blades.

So, how quiet are wind generators? The sound can be virtually imperceptible from the surrounding environmental, or ambient, noise. Two turbines fall into this category, the remanufactured Jakes and the AWP. Most people don't even know they are running without looking at them to see if the blades are spinning. Two other turbines operate close to ambient noise level. These are the Jacobs 31-20 and all of the Proven wind turbines.

The two things that all of these quieter turbines have in common is blade-pitch governors (except the AWP) and low operational rpm. While the AWP side faces, it has a very slow-speed rotor. As a result, the AWP is virtually silent when governing.

What about all the rest of the turbines? Bergey has redesigned the blades on their 10 KW Excels, in part to reduce noise. Field reports point to their success in this endeavor. Owners of other turbines listed here have mixed responses about turbine noise. Some report a given model as quiet, while others have less positive things to say about the same genny's noise.

If noise, or rather lack of noise, is as important to you as it is to me, I'd highly recommend that you experience the turbine you plan to buy in operation. Find one, and visit it when a front is approaching, or a thunderstorm is due to arrive. Listen to the turbine when it's running close to governing wind speed, and when it governs. If the noise is acceptable, buy the machine. If not, keep looking and listening.

Shut-down Mechanism

The shut-down mechanism is one of the most important considerations when buying a wind turbine. Stopping the rotor and shutting down the generator is desirable for maintenance or repairs, or whenever else you do not want the rotor to be turning, such as in a storm or when you are away for a period of time—not an unreasonable thing to want.

Shut-down mechanisms fall into two categories, mechanical and electrical. A review of shut-down mechanisms, their failure modes, and the turbines they are on is very revealing in that very few turbines have reliable shut-down mechanisms.

One mechanical shut-down method is to fold the tail so that it is parallel to the blades. All of these systems, except the Proven turbines, have tails. If the tail is parallel to the rotor, the rotor is out of the wind, and it will slow down or stop. Folding the tail involves either cranking or uncranking a cable that will furl or unfurl the tail, depending on the system. The cable winch is at the base of the tower, meaning you must go out to the tower to accomplish the shutdown, which some might consider a drag—like at 3 AM during a thunderstorm.

The Bergey Excel uses a winch and cable to crank the tail out of the wind. Unfortunately, the failure mode, (for example, if the cable breaks), is that the tail goes back into the wind. With the tail back into the wind, the rotor is back in business. By contrast, the remanufactured Jakes use a winch and cable to crank the tail into the wind. The failure mode if the cable breaks is that the tail furls, protecting the machine by taking the rotor out of the wind. Nice! In fact, this the only shut-down mechanism that is foolproof.

Wind Turbine Industries and Proven use a mechanical disc brake that slows the rotor to a stop on their wind turbines. A winch cranks a cable, which engages the brake. In high winds, it can be tough to get the Jacobs 31-20 rotor to stop with the disc brake. Unfortunately, with both the Jacobs 31-20 and Proven, the failure mode (due to a broken cable, for example) is no brake, and the rotor takes off.

The wind generators with mechanical shut-down systems are the remanufactured Jakes, the Jacobs 31-20, the Proven 2500 and 6000, and the 7.5 and 10 KW Bergey Excels. None of the other wind generators listed have mechanical shut-down mechanisms.

Dynamic braking is an electrical brake unique to permanent magnet alternators. If you short out the three phases of a permanent magnet alternator, it is supposed to overpower the ability of the rotor to spin the alternator, and the rotor will come to a stop. This can be done from the comfort of your home by flipping a switch on the control box.

Dynamic braking works in theory, but may or may not work when you most need it, during a thunderstorm with strong winds, for example. Strong winds have been known to overpower a wind generator's dynamically braked rotor. If not caught, this is potentially catastrophic, since all of the wind generator's output must be absorbed by the tower wiring and alternator windings. In fact, all of the small turbines listed with dynamic brakes have failed in 40+ mph (18 m/s) winds while being tested on my or other towers. Some wind turbine owners report dynamic brakes not holding, or not able to stop the blades in wind speeds as low as 20 mph (9 m/s).

Tower Top Weight

This covers everything that goes on top of the tower—generator, governor, rotor, tail, and yaw assembly. You'll notice that there is wide variation in tower top weights. Based on experience, I side with the school of heavy metal, those manufacturers that have proven that the longevity of equipment life is directly related to the beefiness of components.

From my 22 years of experience rebuilding wind generators, I've come to realize that heavy duty, slow-speed wind generators last longer than their lightweight, high-speed cousins. Many people opt for the lighter duty wind turbines because they are invariably cheaper. They generally buy a heavy duty machine the second time around.

Unfortunately, the trend in recent years has been to make everything as cheaply as possible. Performance and reliability of the machine, while important, were overshadowed by initial cost. Why? You, dear consumer. Weight is reflected in cost. So the goal became lightweight, high-speed wind gennys. As failures accrue in the field, some manufacturers are moving back to heavy metal. I welcome that.

Lateral Thrust at the Tower Top

This figure is important for determining tower design specifications and choices. Lateral thrust, a critical horizontal force vector, is a function of swept area of the rotor, the resistance the tower presents to the wind, and wind speed. The greater the lateral thrust, the stronger (and therefore, more expensive) the tower must be, and the larger the concrete footings and guy wires must be.

Battery System Voltages

Available voltages for the battery systems are listed. Remember that line loss is a significant consideration for low voltage systems. Wind generators are rarely sited next to the battery bank. Line loss due to wire run (including the height of the tower) pushes people to choose higher voltages.

Controls Included

Controller, rectifier, brake, and dump load may be standard equipment that is included with the wind generator for interfacing with a battery charging system. Or, if not listed, they may be options available at an additional cost.

Utility Intertie

Currently, only the Bergey Excel-S and Jacobs 31-20 can be directly connected to the utility grid with a synchronous inverter, which is supplied by the manufacturer. Any and all of the other turbines can also be grid tied by using a battery bank in conjunction with a utility-intertie inverter, such as the Advanced Energy's MM series, Trace SW series, and Vanner RE series inverters. Conversion efficiency with these systems varies. Seek opinions from experienced RE dealers so that your expectations are realistic.

At least three of the manufacturers are working with inverter manufacturers to develop batteryless grid-tied inverters. Watch for developments. For example, the Proven WT 2500 and WT 6000 are operating in Europe as grid-tied machines with SMA's WindyBoy inverters. While it is possible to use these inverters in the U.S., I do not know of any batteryless, utility-tied Provens operating here.

Some turbines can also be used for unusual end uses not normally thought of. Direct-coupled water pumping and resistive heating are examples of this. If you have a particular need other than battery charging or a grid-tied application, contact the manufacturers or their distributors.

KWH per Month at Wind Speeds of 8 to 14 Mph

These calculations are included so that you have some idea of what a wind-electric system will produce at your site's average wind speed. This is how you should size your wind-electric system. You will need to do some homework before these numbers are meaningful to you.

To use this part of the table, you must know the wind speed at your site, based on locally available data. From there, you will need to extrapolate that wind speed to determine the wind speed at your proposed tower height. The procedure for determining your tower top wind speed is laid out in "Site Analysis for Wind Generators," parts 1 and 2, in *HP40* and *HP41,* available on the *Home Power* Web site.

If, for example, you are using 600 KWH per month, check the table to find the turbines that will do the job for you. If you want a wind/PV hybrid system, use your area's average winter wind speeds. For a grid-tied net metered system, the annual average wind speed will do.

For comparisons, a very efficient home or small cabin uses 75 to 200 kilowatt-hours (KWH) per month. The average home (whatever that is) in the U.S. uses 900 KWH per month. An all-electric home consumes from 1,500 to 2,500 KWH per month, as might a small business or farm. The output estimates of the various wind generators are mostly the manufacturers' numbers, not mine. Be aware that your mileage may vary, sometimes considerably. Unfortunately, KWH per month outputs are not independently tested.

Also note that the only true outputs are those listed for the utility-tied applications, the Bergey Excel-S and Jacobs 31-20. Efficiency losses due to the grid-tied inverter are built into these numbers, so the values listed are what you will see at your kilowatt-hour meter. All of the rest of the KWH per month numbers represent DC bus bar values—energy delivered to the battery bank by the wind turbine. You will still need to derate the outputs to 75 to 80 percent to reflect battery efficiency and inverter losses, just as you do with a PV system.

Cost

Note that these costs are only for the wind generator and controller or utility-tied inverter. Check under "Controls included" to determine what controllers or utility-intertie inverters are included in that price.

While this may seem obvious, it never ceases to amaze me that people don't realize that a wind-electric system's installation costs also include such miscellaneous items as shipping for the wind turbine, a tower (of all things) and its shipping charges, maybe batteries and inverter, wiring and electrical components, backhoe and crane costs for larger turbines, concrete and rebar for some towers, sales tax, and labor and travel expenses if the job is farmed out to an installer.

Actually, depending on the system you install, the wind turbine cost represents only 12 to 48 percent of the total installed cost of the wind-electric system. In PV systems, the PV panels represent the major portion of the cost of the generating part of the system. Wind generators are mounted on towers to access their fuel, the wind. While a 120 foot freestanding tower is only about half the cost of a Jacobs 31-20 wind generator, an 80 foot tilt-up tower can cost upwards of five times the price of a Whisper H40!

Cost per Square Foot of Swept Area

Remember that the rotor is effectively the collector for a wind generator. Double the collector size and you will likely double the output. It's actually not quite this simple, since we also have differences such as airfoil efficiencies, alternator efficiencies, tower height, and a myriad of other factors that impact the output of a wind generator. But still, as author Paul Gipe states, "Nothing says more about the output of a wind generator than its swept area. Nothing!"

Unfortunately, like dollars per rated watt, dollars per swept area still rewards lightweight turbines, since it doesn't say anything about the *quality* of the swept area or longevity of the machine. In my experience, quality and longevity cost more, not less.

Cost per Pound

In my bias towards heavy metal, the "beasties" look really good on a dollars per pound basis when compared to the high-speed, lightweight turbines. But perhaps this measure says more about the weight of the machine and less about the cost. Robert Preus of Abundant Renewable Energy points out, "Just throwing weight at a machine doesn't necessarily make it more robust. However, there does seem to be a close correlation."

Weight per Swept Area

This provides an indication of machine robustness, which usually translates into longevity. Notice the range in this relationship, from less than 1 pound per square foot (5 kg per m^2) to more than 4 pounds per square foot (20 kg per m^2). I consider any machine with more than a 2:1 ratio as a heavyweight. I'd categorize machines between 1:1 and 2:1 as medium weight, and anything under a 1:1 ratio as a lightweight. Substitute "heavy duty" for "heavyweight," and you will understand my bias.

Weight per Tip Speed Ratio (TSR)

For a really dramatic comparison, compare weight and rotor speed in the machines listed here. As weight increases, rotor speed and, therefore, TSR decreases. In other words, there is an inverse relationship between TSR and weight. The lightweight, high-speed machines have low numbers, while the low-speed, heavyweights end up with high numbers. The beasties with high numbers really stand out, don't they?

Years in Production
The length of time each wind generator model has been in production varies considerably. Note that some of these machines have been through numerous changes over their production life, while others have seen relatively few changes.

Warranty
All the manufacturers warrant their products for parts and labor (that is, in-house repairs at their facility) against defects in materials or workmanship. This means that you must return the defective part, or the entire wind generator, to the factory for evaluation and repair or replacement, at the discretion of the factory. Standard practice is that you will pay shipping both ways, just as with any other consumer good.

Warranties do not cover improper installation, neglect, use of unauthorized components, abuse, or acts of god. (This is why you have homeowners' insurance.) The manufacturer's liability is for the defective part only, and does not include incidental or consequential damages.

Routine Maintenance
What needs to be done to the wind generator to keep it in prime operating condition for a long life? Some manufacturers recommend only a visual inspection as their annual maintenance. Several suggest that after you install one of their units, all you need to do is go out to the base of the tower once a year and look up to see if it's still running. That's it for another year! I'm a little more realistic and conservative than that.

The life of a wind generator is directly related to the owner's involvement with the system and its

Rethinking Cost Comparison

Cost per rated watt has been included in past versions of A&O, but is not included here. Why, you ask? It makes such an easy comparison, you argue.

First of all, there are just too many other expenses involved with installing a quality wind-electric system to just compare one wind generator with another by such a simplistic number as dollars per rated watt. Tower, installation, wire run, and other costs are a significant percentage of the generating system cost. To quote Mike Klemen again, "Dollars per rated watt can be a very misleading way to buy a wind turbine."

PV panels are typically sold by dollars per rated watt. That makes sense, since PV panels all are rated at an industry standard. They are tested at 1,000 watts per square meter at 25°C (77°F). Since one panel is easily comparable to another, based on a set of controlled specifications, it makes sense to compare the cost of one panel to another on a dollars per rated watt basis. However, wind generators don't share any similar specifications, nor are the outputs tested against each other at a standard wind speed.

For example, let's assume we have the two wind generators mentioned previously, Lots-o-Watts, which costs US$1,000, and Mighty-Watts, which costs US$500. Let's also assume that both wind generators are rated at 1,000 watts. Since both turbines have the same rated output, it might appear easy to just divide the cost of the two by their power output to arrive at dollars per rated watt. Right? So, on the surface, Mighty-Watts appears to be the better deal because it only costs US$0.50 per watt compared to the US$1 per watt Lots-o-Watts machine. It's only half the price, you say.

Not so fast. Remember that the Lots-o-Watts manufacturer has rated the wattage of their turbine at a wind speed of 16 mph, while Mighty-Watts rates theirs at 32 mph. What's this mean?

Remember the power equation, $P = \frac{1}{2} d \times A \times V^3$. And remember that we can really simplify the relationship by stating that $P \sim V^3$, that is, power is directly proportional to the cube of the wind speed. When we apply this to our wind generator comparison, we find some startling results.

The Lots-o-Watts 1,000 watt wind genny rated at 16 mph will reach its 1,000 watts at 16 mph. But the Mighty-Watts wind genny needs a 32 mph wind to reach its rated output. That means that the Mighty-Watts wind generator is producing only 125 watts when the Lots-o-Watts is peaking at its 1,000 watts. Now dividing dollars per rated watt doesn't look so good, does it? That's why it's not included here.

No Single Measure
So, if not dollars per rated watt, how do we compare one turbine against another? We can consider some other comparisons, like cost per swept area, cost per pound, weight per swept area, or weight per tip speed ratio, and gain some more meaningful information.

None of these measures is very good by itself. But they all contribute to the big picture. Looking for one perfect measure to compare wind generator cost may be a fool's quest. If we could have one, it would look something like "dollars per KWH per month at X wind speed for X years." But that's a different article.

maintenance. If you don't at least periodically inspect your wind generator, you may be picking it up off the ground someday!

What do routine maintenance and annual inspections entail? It doesn't mean that you will never have to replace parts or do some major repairs. Some blades will need repainting and new tape on the leading edge eventually. Bearings wear out and need replacing. High-speed, lightweight machines will need bearings more frequently than the beasties. Some systems, as noted, need annual greasing or oil changes.

In addition, there's what I call "common sense maintenance." Bolts might loosen and need tightening. Adjustments might be needed here or there. It is unrealistic to expect something as complex as a wind generator, operating continuously in a harsh environment, to work flawlessly with no maintenance. If that's your expectation, *don't buy a wind generator!*

Most of the catastrophic failures that I have seen over the years with various systems were due to something as seemingly inconsequential as a bolt loosening and not being attended to. The prudent wind generator owner should thoroughly inspect the complete system once a year at a minimum. Pick a nice fall day before winter hits or a warm spring day before thunderstorm season. As they say, prevention is the best cure! Preventive maintenance becomes more important to you, the owner, as your investment in the system increases.

The designs for today's wind generators have been around for a long time. For example, the side-facing governing mechanism used by Bergey and Wind Turbine Industries was patented in 1898 and originally used on waterpumpers. The tilt-up style of governing was patented in 1931. And the blade-activated governor used on the old as well as the new Jacobs was patented in 1949. (One new development: Proven's origami-like blade governing is a radically new idea in wind turbine design.)

Most of the great strides in reduced maintenance have come, not from new designs, but from new materials. Things like carbon reinforced fiberglass blades, aliphatic resin leading edge tapes, high-tech paints, and any number of synthetic and metal alloys have reduced wind generator maintenance considerably, while improving reliability.

Continuous upgrades by incorporating modern materials in wind-electric system components have helped greatly in the maintenance and reliability arena. The manufacturer who cuts corners by using cheap materials is courting trouble with customers. And homeowners with wind-electric systems that are never inspected and maintained have a time bomb on their hands.

So how long do these things last? That's hard to say. A decade ago, I took down an old Jacobs that had seen 60 years of nearly continuous duty. While the old Jakes were certainly overdesigned and overbuilt wind generators from an era that valued quality workmanship, there are others in that category. These are the heavyweight machines. Experience and reports from the field indicate that the heavies will last at least their 20 year design life, and then can be completely overhauled and given a new life. The lightweights? They may last half that time, or maybe only one quarter. This assumes, however, diligent maintenance.

Notes

Other than being a miscellaneous catchall, one explanation is necessary. Some of the Whisper wind-electric systems and the AWP are available with a high voltage/low voltage (HVLV) option. This means that the wind generator is wound for 240 VAC, and a step-down transformer is included near the controls to step the voltage down to the 12 to 48 VDC battery voltage. Since high voltage results in low current for a given level of power through the wire run, the HVLV option means that you can site your wind-electric system up to a mile away from the battery bank, something unheard of with low voltage DC generation.

Odds & Ends

Power curves for the wind generators, while included in the past, have not been included in this version of A&O. Unless you really appreciate the value of V^3 in the power equation, power curves tend to be meaningless to most consumers. Unfortunately, the only ones who could decipher them were the tech-weenies. If you need a power curve for any reason, check the manufacturer's Web site or product literature.

Home-sized wind generators are not manufactured on an assembly line like other consumer products. Instead, they are made in batches ranging from a handful to a few dozen at a time. As a customer, you need to be a little understanding about the lead time for the machine you order. In all likelihood, your wind generator will not be instantly available unless you happen to find a dealer who has the particular machine you want in stock, a rare occasion. Lead times can vary from three weeks to as long as eight weeks—or eight months.

A few customers (myself included) have had rather bad experiences with unusually long lead times, not only with new machine orders, but with parts and repairs as well. But the manufacturers are pretty good on the whole. They really are concerned about satisfying their customers. After all, without you, they're out of business.

My Choice?

"So, Mick, what do you recommend?" is the most frequently asked question that I get. The answer—it all depends on your situation. I can honestly say that, properly specified and installed, any one of these machines will do a fine job of producing electricity for you for many years, *in the right location.*

Notice the qualifiers. If you install a light duty machine where the winds are severe, even for part of the year, you are asking for trouble. If you install a light duty machine on a short tower where turbulence will be an issue, you are asking for trouble. If you install a machine with lots of moving parts, knowing full well that you have no intention of climbing the tower to do maintenance and repairs, you are asking for trouble. If you never do routine maintenance on your car or house, what makes you think you'll do it on your wind generator?

All of these wind generators have their own personalities and idiosyncrasies, just like the cars we drive. And, just like the cars we drive, they come in a variety of shapes and prices. Finally, just like the cars we choose, they all will get us from point A to point B.

However, not all cars, nor all wind generators, are created equal. As the saying goes, "You get what you pay for." Quality always comes at a price. To quote long-time wind energy user and *HP* editor Ian Woofenden, "Remember, what you want is value. I put high value on low maintenance, long-term performance. You do not want to buy bragging rights to the highest peak output at the lowest price. Instead you want the most energy put into your battery or the grid *for as many years as possible.* That doesn't come cheap."

What do I fly at home? An old 1946 Jake with original bearings does its magic on an 80 foot (24 m) tower, 37 feet (11 m) from our home, backfeeding to the grid. And as soon as I'm done testing some new-to-the-market turbines, the 84 foot (26 m) tilt-up tower behind the shop will see the return of the AWP 3.6. Both are heavy metal and slow speed, and I can't hear them without seeing them—my idea of what a wind generator should be. After that, my next genny will possibly be a Proven WT 6000 or Bergey Excel-S.

With the exception of a hydro plant in a raging flood, a wind generator probably lives in the most extreme environment that nature has to offer. Where I live in northeast Wisconsin, temperatures range from 100°F (38°C) in the summer to -30°F (-34°C) in the winter. Frequent howling winds bring with them dust and insects that sandblast barns over time. The turbulence associated with thunderstorms tries to wrench my turbines off their towers all summer long. We have very high humidity in the summer, and then it's desert dry in the winter.

Winds here are commonly in the 25+ mph (11+ m/s) category, but can sometimes get fierce. At least a half dozen times a year, we get 60+ mph (27+ m/s) winds. Rain, snow, sleet, and hail...you know the rest. All of nature's forces work continuously towards entropy, reducing the wind generator to its lowest elements. It's a really tough world out there!

My preference is definitely towards the "beasties," the slow-speed, heavy metal brutes that seem to be able to take most all that nature can throw at them. These include the AWP 3.6, the remanufactured Jakes, the Provens, the Bergey Excel, and the Jacobs 31-20.

The dollars per pound and weight per TSR are the categories that I look at. I've learned over the years that the cheapest turbine or least expensive dollars per rated watt may be nice for the pocketbook, upfront, but not in the long run. In my experience, inexpensive turbines do not last long. Period. If you are looking for stopgap electricity for a few years, buy cheap.

If price *is* an issue, light duty machines may be an acceptable option in moderate wind locations. According to *Home Power* tech editor Joe Schwartz, "Swept area aside, Whispers hold up OK in most of the installs I've done in moderate wind sites. The failures I see are typically maintenance related—loose bolts."

But if you're going through the effort of installing a wind generator on a quality tower and are in wind for the long haul, buy heavy duty. Heavy duty translates into reliability, pure and simple, regardless of engineered design life, designed maximum wind speed, or the highly touted dollars-per-rated-watt comparison favored by some manufacturers.

What about the rest of the turbines? Well the jury is still out on some of them, like the Bergey XL.1. I have serial number 00001. I have only had that machine for a year, and have flown it for less than that. While the XL.1 looks like a robust machine, I'd like more data points than just my own.

Others, like the Whispers, are definitely light to medium duty wind turbines. Feedback from the field indicates that they do not do well in gusty sites, sites with a lot of turbulence, or sites that experience seasonally or consistently high winds, like more than 25 mph (11 m/s). But if you really have a medium duty wind site, you may get by with a medium duty wind turbine.

Your Choice?

I've given you some tools to help you make an educated choice. Seek out other wind power users and gain from their experiences, both positive and negative. By all means, discuss owner satisfaction with your wind generator dealer. But realize that, just like the manufacturers, dealers are trying to make a living by selling a product. Does that mean they're out to deceive you? No. Just make sure that you digest the field reports, opinions, facts, and figures, and assess your needs and pocketbook, so that you choose the best wind generator for your site, system, and situation.

Access

Mick Sagrillo fiddles with wind generators for Sagrillo Power & Light, E3971 Bluebird Rd., Forestville, WI 54213 • Phone/Fax: 920-837-7523 • msagrillo@itol.com

Abundant Renewable Energy, 22700 NE Mountain Top Rd., Newberg, OR 97132 • 503-538-8292
Fax: 503-538-8782 • rwpreus@yahoo.com • AWP 3.6 importer, and remanufactures the long case and short case Jakes.

African Windpower, PO Box 4533, Harare, Zimbabwe
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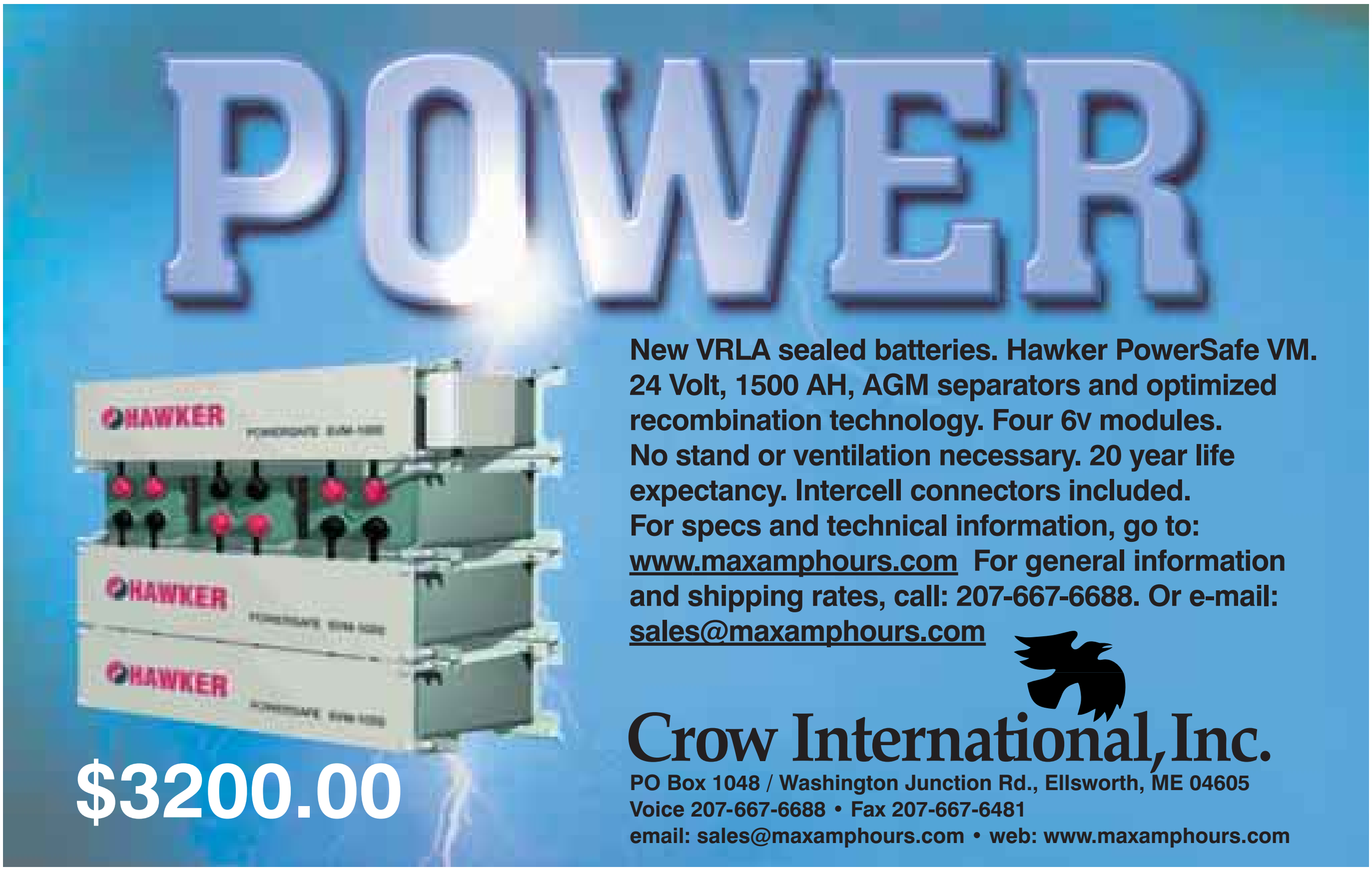
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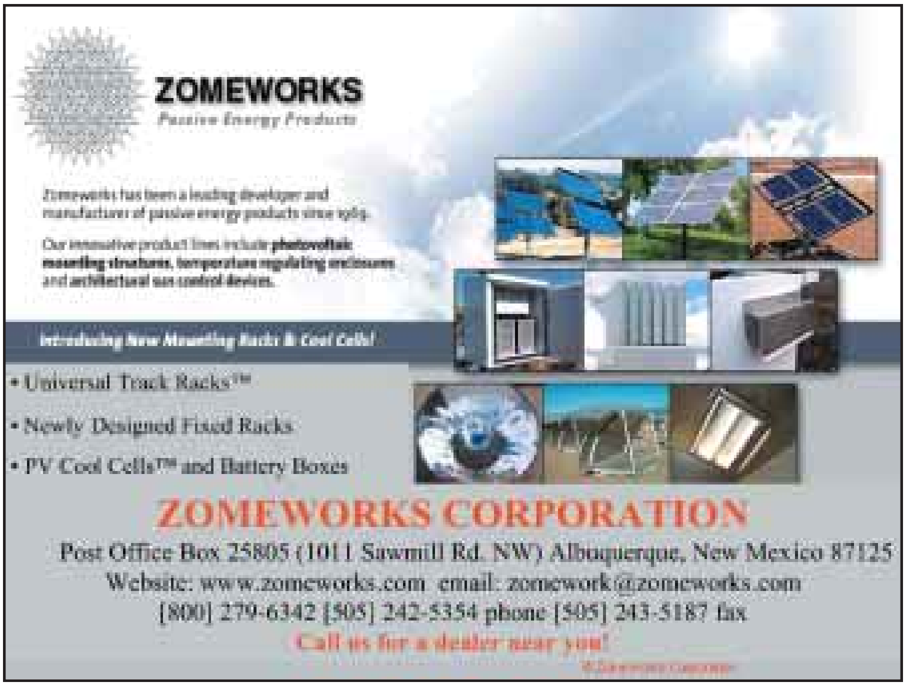
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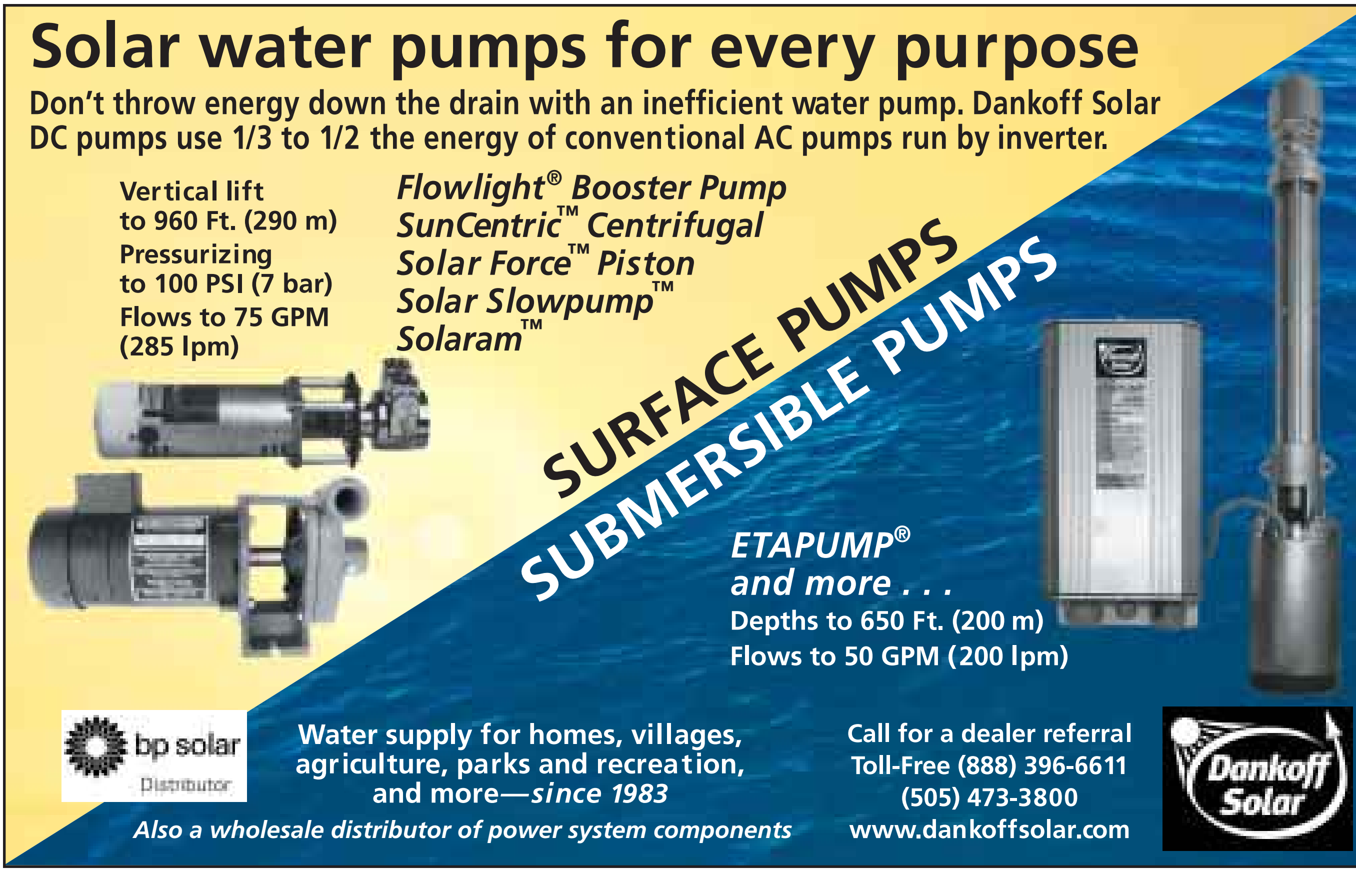
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Cast a thousand beams upon me, like the sun.

They promised me eternal happiness.

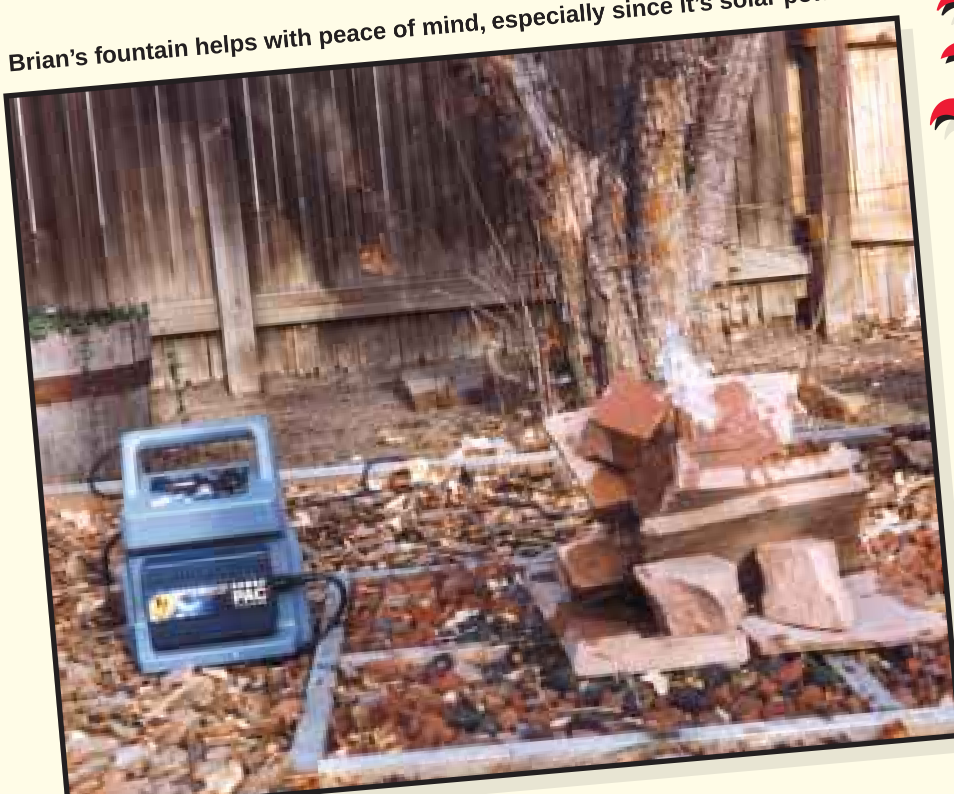
— Henry the Fifth, Act 4, Scene 2

Sun & Shakespeare

Hamlet, a 43 W Solarex module, & Horatio, a 21 W Uni-Solar module

Brian Underwood

Brian's fountain helps with peace of mind, especially since it's solar powered.



I have a small fountain. It is powered by the sun. I enjoy summer days sitting next to it reading Shakespeare. That is why I named my photovoltaic array Horatio, after Hamlet's tried and true friend.

The system uses the Nomad 300 sold by Solarsense.com. I purchased it for my family's forty-acre dream property in Colorado's Huerfano River Valley. The Uni-Solar 21 watt PV panel and Statpower 300 watt inverter, with an 18 amp-hour battery power pack, is perfect to meet the needs for our weekends down on the rancho. Lighting, a radio, and some battery powered hand tools are our only loads.

In between our trips to our place in the valley, I started using the power pack to run my fountain at home. I used to lay the panel on the ground or prop it against a tree. This didn't get it the best sun, so I built a hand-tracking PV rack from some extra fencing material. The 4 foot (1.2 m) high, single panel rack has two axes, which allows me to track the sun as it moves from east to west. With this device, I can also get the best tilt angle throughout the day and seasons. It is light enough to move it into sunny areas as the yard becomes shaded.

I have a regular rhythm of carrying charged power packs into the house for different loads, and carrying discharged ones out to the array for recharging. By keeping an eye on the weather, I know what kind of sun to expect for the coming days. On cloudy days, the array bears a little more hand-tracking. Even on an overcast day, I can get some recharging by following the slightly brighter spot of sun across the gray sky.

Volt Garden

I am using my power packs and panel as a kind of electricity garden. I carry my power pack to Horatio every morning. I clean the panel, connect the battery, and begin to hand-track the sun. I hold a dowel perpendicular to the face of the panel. I then move the panel until the shadow of the dowel is at a minimum. I tend my volt garden throughout the day, making adjustments every hour or so. In the late afternoon, I move it across the yard to get the last of the day's sun.

On days when I am not home, I face the panel towards true south and tilt it at the best angle for the particular time of year. In this fixed position, the PV collects approximately 5.5 peak sun hours each day. A protractor and a directional compass are attached to the panel to help me find the best orientation for my panel.

I am using the power pack to operate loads such as my fountain, a living room light, or a black and white television I use to watch the 10 o'clock news. I collect enough energy each day to use these loads. But I don't have enough battery storage to power these loads for more than a single day.

During dark, dreary days, or on days that I can't tend my volt garden, I don't get a good recharge. Then I don't have the pleasure of my fountain or the television, and I have to use the grid for the living room light.

I purchased a Vector 400 watt inverter and a separate battery pack on sale at Target. With a little rewiring, I created a power pack not too different from the Nomad 300. I added an IPC charge controller to the system because my new power pack did not have a charge controller like the Nomad does. This charge controller also allows me to charge another set of 12 volt batteries, which I use for a reading lamp made from some recycled wood and a 12 volt auto light.

Brian hand-tracks Horatio using a dowel.

At a Sam's Club store, I found the small Vector 50 watt inverter/battery power pack. I use it for my black and white TV. This lightweight battery system, for powering small loads, came in a nylon pack made for carrying on a belt. The case was bright blue and green, which my wife didn't like. I ignored manufacturer warnings and took it apart. I put the battery and inverter into a wooden box. My wife likes this a lot better on the dresser next to the TV. It matches the bedroom set.

I have a teenage son who continually needs small batteries for one electronic device or another. I found two Supersolar chargers and rechargeable batteries at Real Goods. With some scrap plywood and paint, I built a small hand-tracker. I call it Ophelia. This 1 watt device will charge AA and C batteries in about seven hours.

Hamlet's mechanism for adjusting tilt angle
Azimuth is adjusted by moving the whole mount.

Horatio's mechanism adjusts angle and azimuth.
Notice the protractor for determining tilt angle.

My son tends this array by using my dowel method, and turning the panel until the dowel's shadow disappears. This ensures that it is facing the sun. I have been told that it is an attractive and useful piece of yard art. My son uses the AA batteries in a CD player and a hand-held video game.

Amp-Hour Cultivation

I have a free supply of used 7 amp-hour batteries. These batteries have been used in a standby power system, so they are in various states of ability to take and deliver a charge. I bought another Vector 350 watt inverter, and I use it with my new and used batteries to power various tools on my workbench. It's very effective for recharging battery-powered hand tools. I am able to get energy out of these used batteries, but they do die. I always find a recycling center for proper disposal.

At this point, my storage capacity exceeded my generation capability. The batteries did not reach a full state of charge on a regular basis. A 43 watt Solarex Millennia PV panel solved this problem. My original plan was to build a portable array like Horatio, but I found that the panel is too heavy to be easily carried around the yard.

I mounted the panel, called Hamlet, onto a pole, which fits into a foot-long piece of PVC pipe, buried vertically in the ground. This pole socket allows two-axis hand-tracking. A weatherproof container protects my batteries and power packs from Colorado's climatic changes. I can now keep all my batteries charging or in use at all times.

I purchased a 55 amp-hour Guardian AMG battery from Batteries Plus so I can fully use my new panel. I also returned to Real Goods for a Porta-A-Wattz 600 watt inverter and a Morningstar SunGuard charge controller. With these components, wiring from an RV dealership, and a voltmeter from Radio Shack, I put together another power pack. I use it to power my study, which includes a CFL lamp, a 14 inch (36 cm) TV/VCR, and a word processor. I also can use it to run larger loads, such as our 27 inch (69 cm) television. If my higher math skills are sufficient, I believe I'll even be able to run the refrigerator for a short time.

How Much Electricity Do I Have & Use?

What can I operate with my power packs and for how long? When I sit down to do this math, I round down to cover battery and inverter losses. I figure that I have 64 watts of PV generation, and I can get 492 watt-hours per day from my panels. This is based on the 7.7 hours

Underwood Systems Costs

Item	Cost (US$)
Nomad 300 system (21 W PV panel, battery, inverter)	$300
Solarex Millennia MST-43LV PV panel, 43 W	200
Statpower Port-A-Wattz 600 W inverter	111
Vector 400 W inverter with 18 AH power pack	88
Guardian 55 AH battery	86
2 Supersolar chargers, 4 AA & 2 C batteries	80
ICP charge controller	33
Misc. wiring & hardware	30
Vector 50 W inverter power pack	29
Morningstar charge controller	29
Vector 350 W inverter	29
Total	$1,015

of sun a double-axis tracked panel can receive in my region of Colorado. But I take a more conservative approach and round this down to 350 watt-hours.

Adding up my batteries, I have about 111 amp-hours of storage. Multiplying that by 12 volts, I come up with 1,332 watt-hours of stored energy. I round this down to a kilowatt-hour. So on average, I can use a little more than 0.3 KWH per day, and still be able to replace that energy the next day. Or I can use all my storage up, and take three days to replace it.

I use my power packs daily. I have come up with some theories on how to best use my system, hoping to get the most out of it. I divided up the areas of use, and judge the amount of energy I use by the average run time each power pack will give me.

Brian built two boxes for his power packs that run various equipment around the house.

I use my 18 amp-hour power packs for lighting and entertainment. I can either keep the living room light on from after dinner until bedtime or watch a video on my TV/VCR, without discharging the batteries to the point where low battery voltage shuts the inverter down. My workshop loads are powered by using my 350 watt inverter with two, 7 amp-hour batteries. I can recharge the 7.2 volt battery-powered hand tools and use them for several hours of honey-do jobs around the house and yard.

While I could run a lot more with my power pack, these loads are the ones I operate the most. I try to use as much as I can every day. If I really work at it, I can use a kilowatt-hour a week. Before I started generating my own electricity, we averaged about 10 kilowatt-hours a day of grid usage. With the use of the power packs, CFLs, energy-wise products, and sun-dried laundry, we have reduced our usage to 8 kilowatt-hours. I figure that I am replacing about 3.75 percent of my demand with solar electricity.

A New Solar World

It has been very exciting, building my own little power station. I gained much practical experience that I will use as I continue to develop my system. I've been pleased that I have found many of my system components locally—batteries, wiring, and inverters. I hope that PV panels will soon become a common product in hardware outlets.

Power Pack Run Times

Item	Appliance	Run Time (hrs.)
18 A power packs	15 W CF light	7
	Fountain	8
	Hand-held vacuum	1
Workshop with 350 W inverter & two, 7 AH batteries	Battery charger, drill, saw, etc.	24
	Corded drill	2
	Shop radio	2
	Scroll saw	1
	Soldering iron	1 1/2
50 W inverter with 4 AH battery	TV, B&W	1/4
600 W inverter with 55 AH battery	15 W CF light	20
	Word processor	10
	TV/VCR	4

I have a little Web site that I hope will promote interest in solar energy. With the challenges that America faces today, I feel that the best thing I can do is help make myself and my country energy independent. In my own studies of photovoltaics, I have found that there are as many ways of creating and using solar energy as there are different people involved with solar energy. It all makes me think of a quote from Shakespeare's *The Tempest:*

O wonder! How many goodly creatures are there here!
How beauteous mankind is! O brave new world,
That has such people in't.

Access

Brian Underwood • bauwood@juno.com
www.sundogsolar.hothomepages.com

Solar Sense, 321 Shoemaker St., Kitchener, ON, Canada N2E 3B3 • 877-797-6527 or 519-725-2244
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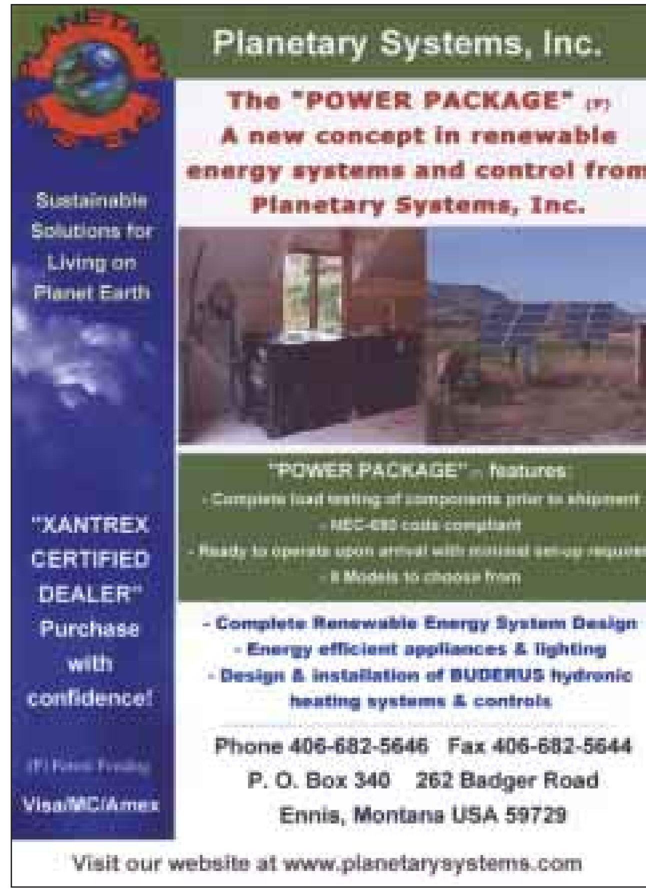
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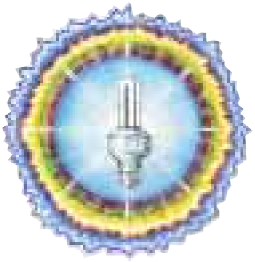
Home Power's Business



"The man who on his trade relies, Must either bust or advertise."
Sir Thomas Lipton — 1870

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TOP SECRET

GUERRILLA SOLAR: The unauthorized placement of renewable energy on a utility grid.

PROFILE: 0021

DATE: June 2002
LOCATION: Spain
INSTALLER NAME: T-Sol/ACYCSA
OWNER NAME: Fundacio Terra
INTERTIED UTILITY: Fecsa-Endesa
SYSTEM SIZE: 2,200 watts of PV
PERCENT OF ANNUAL LOAD: 50%
TIME IN SERVICE: 3-1/2 years

The headquarters of the Fundacio Terra (Terra Foundation, www.ecoterra.org) is situated in the heart of the old town of Barcelona, Spain. It is an NGO working on environmental activism. We co-organize the worldwide annual meeting "Encuentro Solar," in Benicarlo, on the Mediterranean coast. Fundacio Terra also distributes a parabolic solar barbecue for gardens and terraces. This promotes solar cooking as a strategy to reduce carbon dioxide emissions, and to stop global desertification in nonindustrial countries.

The office of the foundation is situated in the top of an old building in Barcelona, where it is supposed that Picasso painted the famous picture "Les Demoiselles d'Avignon." The building was retrofitted for energy efficiency, using recycled materials. It was one of the first ecological building renovations done in Spain, and it incorporates a solar-electric array of 2.2 KW peak (KWp) on the terrace. This is connected to the main utility supply, to offset the energy use of the office.

The PV array was inaugurated by the mayor of Barcelona on January 25, 1999. This was just when the law on binding purchase of solar energy came into force in Spain, with a price of 35 cents per KWH. But when Fundacio Terra tried to legalize our installation, it was impossible because the legislation held private energy suppliers to the same administrative conditions as a nuclear power station. There are strict technical rules, and fiscal treatment is the same as for large energy producing companies. Due to this inequality, the foundation is contesting this law in the courts of Barcelona, and is waiting for a resolution.

As a measure of pressure, Fundacio Terra is still feeding the solar energy to the local utility grid. Since January 25, 1999, we have been producing and giving all the solar-electric production to the electricity supply of the city. On May 5, 2002, our array surpassed 7.5 MWH of production, with an overall savings of 2.1 metric tonnes of carbon dioxide.

At this moment, only a few solar-electric producers with less than 5 KWp are connected to the line who have accepted the burdensome conditions of the law. Fundacio Terra continues with its solitary battle against the administration so that the production of solar energy will be as easy as making coffee in a coffee machine. The solar power plant of Fundacio Terra will continue to be plugged into the sun as a solar guerrilla fighter.

Guerrilla Solar Defined

Energy is freely and democratically provided by Nature. This century's monopolization of energy by utilities both public and private threatens the health of our environment. Solar guerrillas believe that clean renewable energy should be welcomed by utilities. But utilities and governments continue to put up unreasonable barriers to interconnection, pushing common citizens to solar civil disobedience.

Guerrilla systems do not endanger utility line workers (see *HP71*, page 58). They share clean, renewable energy with others on the utility grid, and reduce the need for polluting generation plants. When interconnection for small-scale renewables becomes fair, simple, and easily accessible to all, there will be no more need for guerrilla action.

Home Sweet Solar Home

A Passive Solar Design Primer

Ken Olson & Joe Schwartz

Photo courtesy of www.sunplans.com

A modern passive solar home can compete with the Jones' for style, *and* make them envious of its energy and fiscal efficiency.

Home dwellers in the United States spent US$138 billion on energy for their residences in the year 2000. As an average home dweller, your share of that energy pie was US$1,300. Heating and cooling typically account for more than 40 percent of the energy consumed in a given home, or US$520 worth each year. The good news is that passive solar design can offset the majority of the energy (and money!) you spend heating and cooling your home.

Passive solar design has come a long way from the tilted windows, water walls, and roof ponds of the 1970s. Today's passive solar house has more in common with conventional residential structures than not. Modern designs create living spaces that are bright, attractive, comfortable, and inexpensive to heat and cool.

Passive solar construction may add less than 5 percent to the cost of building a new home. Any additional cost typically yields a 15 to 20 percent tax-free return on investment through energy savings. Most homes built today will likely still be occupied 50 to 100 years from now. Good design results in huge energy and resource savings over the life of the building. So why isn't everyone incorporating passive solar design into new construction? Why isn't it required by local building codes? Good questions!

A passive solar energy system is designed to collect, store, and distribute solar energy without the aid of mechanical or electrical devices. There you go—a definition suitable for any glossary. But passive solar design isn't about a definition. It's about a better life—any way you measure it. Passive solar design uses sunlight to create energy efficient living and work spaces that are a pleasure to be in, and minimizes the use of fossil fuels and associated pollution. To top it all off, the principles of passive solar design are easy to grasp and implement in new construction.

Design Basics

Passive solar design is based on the following five principles that optimize the use of solar energy for heating and cooling your living space:

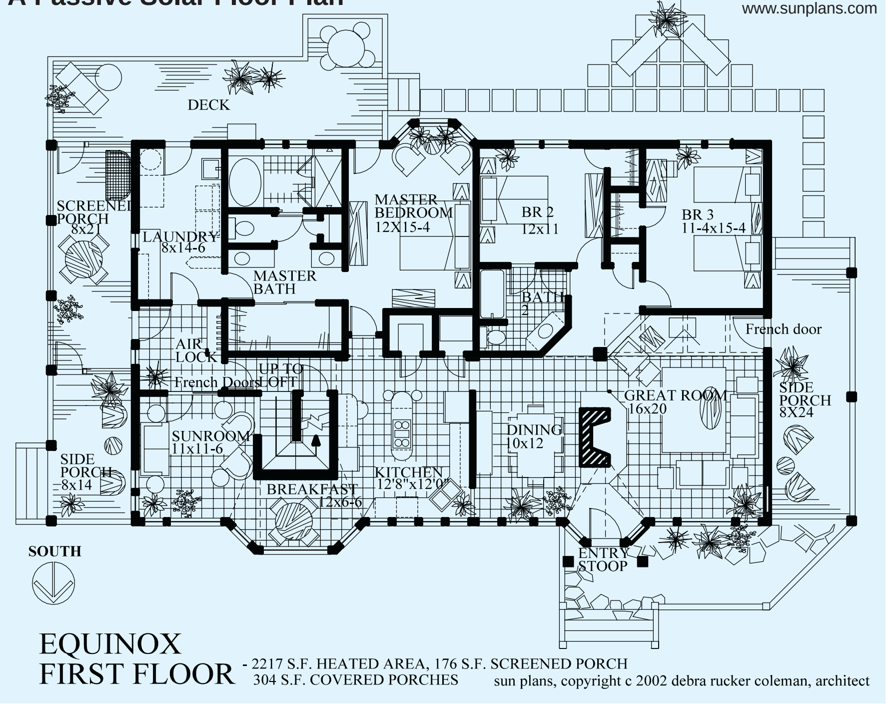
- Building orientation towards true south (in the northern hemisphere)
- Properly placed, energy efficient windows
- Calculated roof overhangs
- Thermal mass for energy storage
- Thermal efficiency and insulation

Passive solar design uses south-facing windows to bring the sun's energy into your home. Thermal mass, such as a tiled, concrete floor, stores the heat and minimizes temperature fluctuations inside the building. Ample insulation conserves energy for both heating and cooling. That's the concept—plain and simple.

In the winter, when the sun's path is lower in the sky, calculated roof overhangs let the sun shine directly into the building and warm the slab. The happy coincidence is that the sun's path is higher overhead in the summer, and these same overhangs shade the windows then, keeping the sun out and your home nice and cool.

Passive solar heating and cooling designs are easy and inexpensive to incorporate into new buildings, but can be difficult to retrofit into existing structures. This is because many passive solar design elements and materials are integral to the home. This article focuses on new home design and construction.

A Passive Solar Floor Plan



Face the Sun—Building Orientation

Step one in passive solar design is to simply orient the building toward the sun. This is a "no added cost" element of passive solar design. Orientation toward true south (magnetic south adjusted for declination) or true north if you live in the southern hemisphere, allows your home to capture as much solar energy as possible. Elongating the building's east-west dimension allows direct solar energy to reach more of the building interior compared to a structure that has a deeper north-south dimension.

Fortunately, we have some room to play with orientation. A building orientation 20 degrees east or west of true south will only lose about 6 percent of the solar gain possible. This minor design penalty gives you some room to accommodate other factors, like the view, into the design of your home. For comparison, orientations 25 degrees off true south will lose about 10 percent—a more significant loss, but still worthwhile if that is the best you can do with your site.

Since you're reading *Home Power,* you may be planning to install solar-electric or thermal panels on the roof of your new home. If this is the case (and we hope it is!) the closer to true south you can orient your house, the more energy these systems will produce, and the more cost effective they will be.

Room layout is important too. Open floor plans passively distribute both warm and cool air throughout the building. Living spaces like kitchens, living rooms, and dining rooms are best located along the south, east, and west sides of the house. Place bedrooms, bathrooms, storage closets, laundry rooms, hallways, and other less used spaces along the north. The west side of the house is a prime location for a covered porch. The porch roof will shade any windows on this side of the house, keeping out unwanted afternoon sun. It will also double as an excellent place to sit and watch the sunset.

Passive solar design creates open, well-lit, and temperate indoor environments that are comfortable to be in. And it's interesting to note that these same open floor plans are now commonly used in conventional home designs. Passive solar homes fit right in with today's architectural styles.

Windows—Location, Location, Location

Windows are the solar collectors of a passive solar building. But windows also have low insulative values, compared to well-insulated walls. In a typical American home, 25 percent of the energy used to heat and cool the house goes—you guessed it—right out the window. Even energy efficient windows are responsible for the majority of heat loss from a well-sealed building envelope. Because of this, passive solar design optimizes the amount of south-facing windows to collect solar energy, and minimizes the use of nonsouth-oriented windows to limit heat loss. Window placement is another "no additional cost" principle of passive solar design. The materials are the same as the ones used in conventional, energy efficient construction.

South-facing windows provide the greatest amount of solar heat over the course of the day. Southeast or limited east-facing windows allow for a quick heat-up, and provide a pleasant light in which to sip coffee or tea during the "up and at 'em" process.

West and southwest-facing windows should be kept to a minimum. They tend to cause overheating since they allow low-angle sunlight to enter the house in the afternoon when the house is already up to temperature. North-facing windows should be kept to the minimum needed for light and ventilation. They're the hands-down energy loser of the four compass directions.

In the 1970s, many passive solar designs specified south-facing windows that were tilted to the latitude of the building site. Solar collectors (PVs, thermal panels, or windows in this case) capture the greatest amount of energy when oriented perpendicular to the sun. Nowadays, tilted glass surfaces are not recommended for living spaces because they make it more difficult to control direct solar gain with the changing seasons.

It's much easier to control seasonal shading on a vertical wall. Properly calculated roof overhangs are built once and don't have to be operated on a daily basis, like window shades. It's a hands-off approach. So keep your windows vertical and let the building do the work!

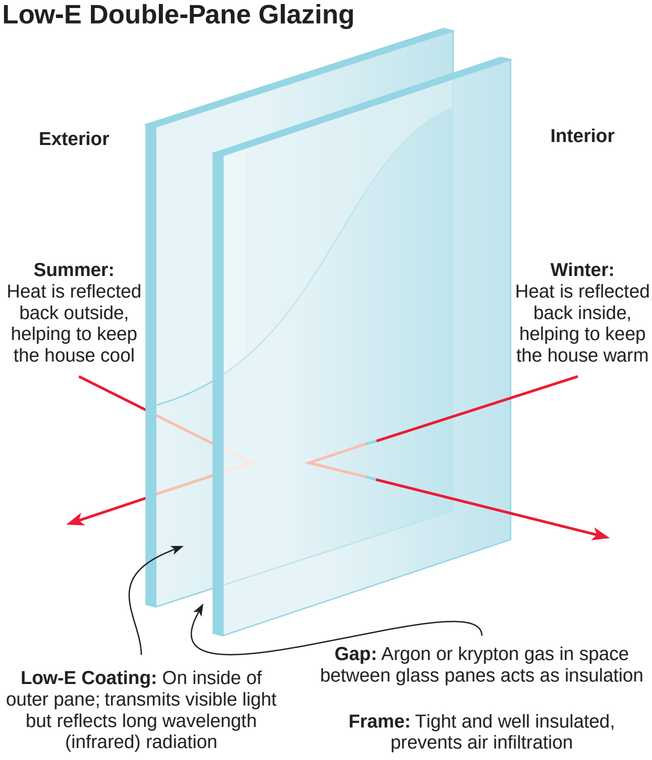
A conventional house has its windows evenly distributed in each of the four compass directions. South-facing windows typically have an area equal to approximately 3 percent of the total floor area of the house. In a passive solar house, south-facing window area is increased to a range of 7 to 12 percent of the floor area depending on the amount of thermal mass that's integrated into the design. Higher percentages than this will likely result in overheating during the day and adds cost to the wall's structural design and construction. Too much glass also results in greater heat loss at night.

Remember, compared to well-insulated walls, even windows with high insulative values are pretty much "big holes in the wall" when it comes to thermal efficiency. In fact, the most common mistake made in passive solar home designs is too much glass. High temperature swings and high heating and cooling bills characterize these designs. It's a real life example of a case where "more is not better."

High Performance Windows

High performance, energy efficient windows also make a big difference. An ideal window maximizes solar heat gain in winter and minimizes solar heat gain in summer.

Low-E Double-Pane Glazing

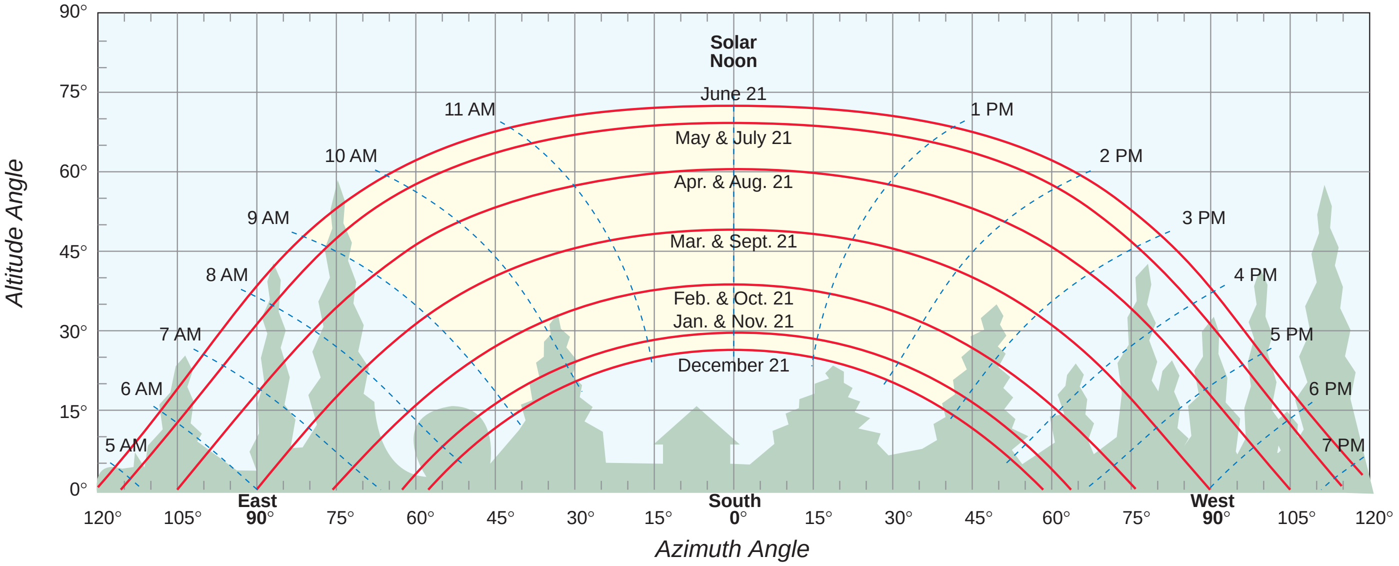


The window may also need to maximize or minimize light transmittance, depending on its use. The good news is that super smart windows are available in the builder's market these days. And compared to standard, double-pane windows, high performance windows only add a small percentage to the total cost of an average-sized home.

Modern window designs demonstrate an understanding of the dynamics of conduction, convection, and radiation well enough to be nearly ten times more efficient than single-pane windows. The rate of heat loss of a given window is referred to as its U-value (BTUs per hour per square foot per degree Fahrenheit). For heating purposes, the lower the U-value, the better. In northern climates, select windows with U-values of 0.35 or below. Some triple-pane windows have U-values as low as 0.15. In southern climates, select windows with U-values 0.60 or less. For comparison, single-pane windows with clear glass have a U-value of about 1.0 depending on the frame material.

Early versions of modern window technology were referred to as transparent insulation, and so they are. Low emittance glass surfaces, often referred to as "low-E," optimize the effects of radiation. Low-E is part of a family of spectrally selective surfaces. This means that they are highly transparent in the visible region of the light spectrum, yet they are nearly opaque to the longer wave, infrared end of the electromagnetic spectrum. We

Sun Path Chart for 40° North Latitude



To use this chart for southern latitudes, reverse horizontal axis (east/west & AM/PM)

can't see the infrared, but we can feel it. Warm interior surfaces of your house emit low temperature, infrared radiation toward every colder surface they see. Low-E glass functions like a mirror to reflect infrared radiation back into the house rather than allowing it to escape.

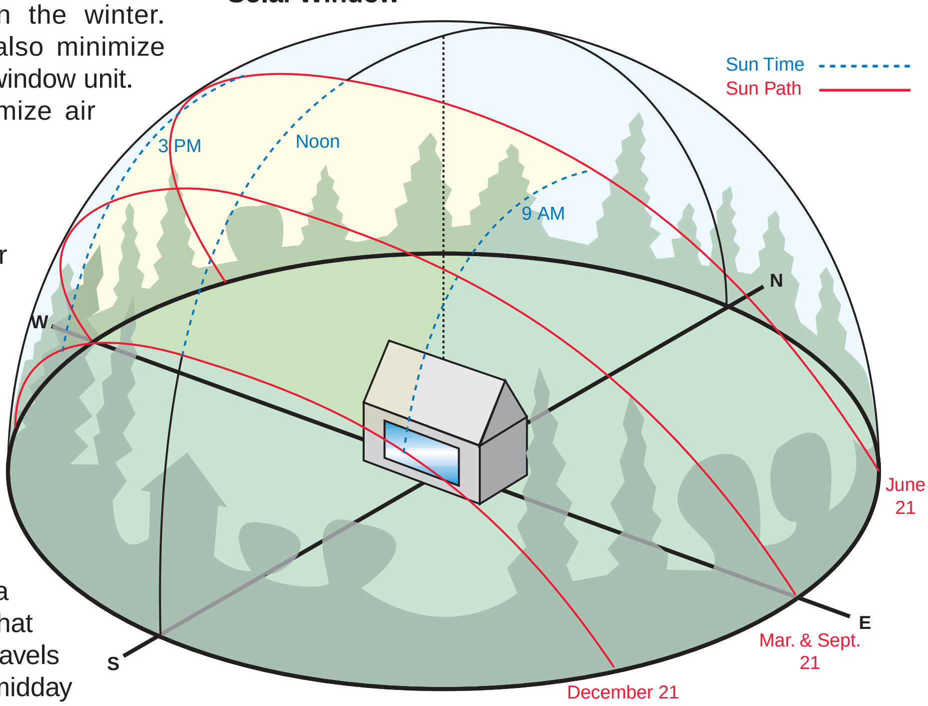
Air spaces between panes of glass reduce summer heat gain as well as winter heat loss. Multiple layers of glass create air spaces that act as insulation. To effectively eliminate the convective air flow within an air space, manufacturers use heavy gases, such as argon or krypton. The result is a window that keeps your home cooler in the summer and warmer in the winter. Insulated frames and thermal breaks also minimize conductive heat loss and gain through a window unit. Tight seals on operable windows minimize air infiltration.

The Solar Window & Calculated Roof Overhangs

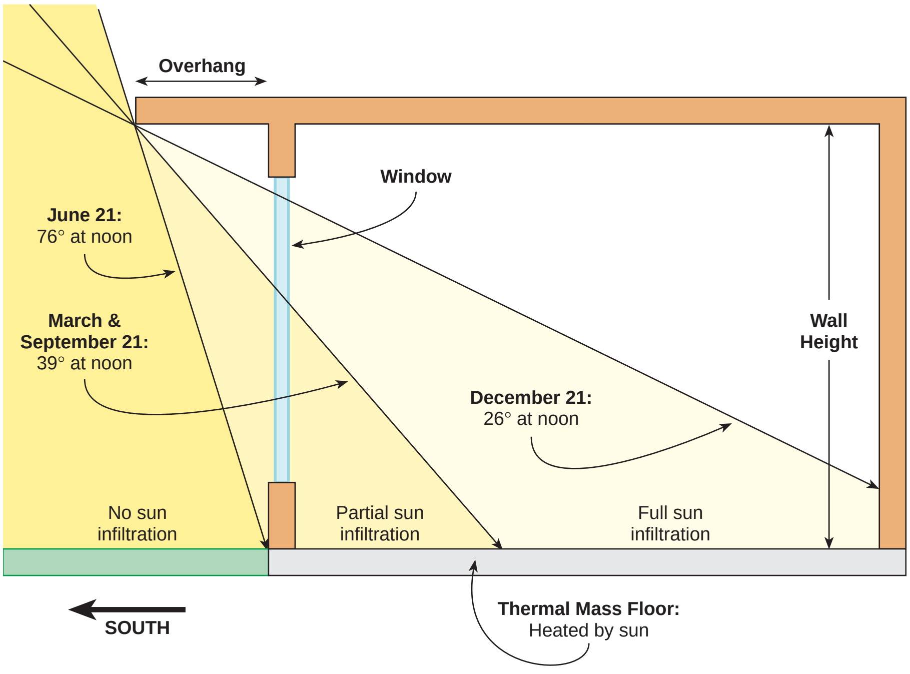
In passive solar design, as well as other solar thermal technologies, the amount of shading you receive during the day results in a corresponding reduction of heating. Midday sun is more intense than early morning or late afternoon sun. So that is your most valuable resource if you are heating, and your enemy if you are cooling.

The concept of a "solar window" identifies the available hours of sun in a location, and any areas or times of day that your home will be shaded. Because it travels through less of the earth's atmosphere, midday sun is more intense than early morning or late afternoon sun. Direct solar gain between 9 AM and 3 PM is your most valuable resource if you are heating, and your enemy if you are cooling. The bottom side of the solar window is defined by the sun's path on December 21st (in the northern hemisphere). The left and right sides of the solar window are defined by 9 AM and 3 PM in each month of the year. The top of the solar window is defined by the sun's path on the longest day of the year—June 21st.

Solar Window



Example Roof Overhang for 40° North Latitude



An effective passive solar home design makes use of the same concept. The notable difference is that, depending on the climate in which you live, you may need to adjust the top side of the solar window downward to block the sun from striking your windows in the months when heating is unwanted, and cooling is the name of the game. In passive solar design, shading windows in summer, late spring, and early fall is taken care of by building appropriately sized roof overhangs.

The optimum size of the roof overhang varies with latitude and window height. A simple approach for calculating roof overhangs is to make a scale drawing of the cross-section of the house (looking east or west), that details the south window height dimension relative to the floor. By adding the noon sun angle at various times of the year, the width of the overhang can be easily determined.

Information on sun angles at different latitudes is provided in the classic, but long out-of-print *Passive Solar Energy Book,* by Ed Mazria. For those of you with Web access, the folks at Sustainable By Design in Seattle, Washington, have a great Web site with calculators for sun angles, sun position, window overhang design, and window heat gain. Check them out at: www.susdesign.com.

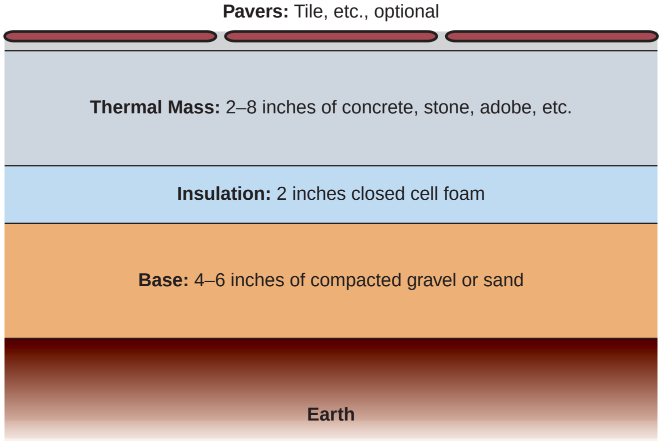
Other helpful resources include two building design software packages that take all aspects of heat gain and heat loss into account. *Guidelines for Home Building* is a great book that comes with a software program called *Builder Guide.* The book and software package present clear concepts and guidelines suitable for owner builders at a cost of US$100. Building design professionals will be interested in a publication and software package entitled, *Designing Low-Energy Buildings with ENERGY-10* at US$250. (See Access.)

Thermal Mass

Thermal mass is a general term for any material that can absorb large amounts heat. Mass within a building acts as a thermal flywheel. It stabilizes indoor temperatures. Heat it up—it stays warm; cool it off—it stays cool. The degree to which a building can be solar heated depends upon its ability to store heat for times when there is no sun. Its mass slowly absorbs heat like a sponge soaks up water, and then releases the heat slowly for winter warmth. The same mass, shaded from the sun, will help keep your home cool during the summer months. The slab will help keep the building cooler if you have a ventilation strategy that cools the slab down overnight.

Although every building already has a minimal amount of thermal mass in its structure, drywall, and furnishings, its ability to store excess heat delivered through south-facing windows is limited. If you want to achieve a higher percentage of heat from the sun, you will have to add substantially more thermal mass. Concrete, brick, tile, adobe, and other masonry materials are the most common choices for thermal mass in a building.

Thermal Mass Floor



How Does Heat Move?

Heat always moves from hot to cold. Conduction, convection, radiation, and evaporation are the four ways heat is gained and lost. The end product of any design will be the combined effect of these four phenomena.

Conduction

Conduction is the transfer of thermal energy between objects in direct contact. If you hold a metal poker in a fire, the heat will pass from the hot end (in the fire) to the cold end (in your hand). The molecules of the metal are in contact with each other and pass heat, always from hot to cold, by virtue of conduction.

Metals are excellent conductors of heat energy because their molecules are so close. Other materials such as wood or plastics are poor conductors because their molecules have spaces between them. Poor conductors are good insulators.

Conduction in a building's structure occurs through walls, windows, roof, floor, etc. If we want to minimize the rate of heat transfer from one side of the wall to the other, we use materials that are good insulators. Insulative properties are rated with what is called an R-value. R stands for resistance. The greater the R-value, the better the insulation.

Convection

Convection is energy transfer between any surface and a fluid medium, such as moving air or water. The movement of air or water across the surface of a solid accelerates the transfer of heat—once again always from hot to cold.

A cold wind will accelerate heat loss because the cold air removes heat from the outside surfaces of your home. A more subtle example occurs within your home, particularly at the surface of windows, which become cold because of their low, conductive R-value.

Put your hand near the glass on a cold day and you will feel a cold draft as the indoor air in contact with the cold glass surface becomes cooler. As the air cools, it becomes more dense and it sinks. This descending draft pulls warm air from near the ceiling toward the window, where it cools at the surface of the window and feeds the draft. If you live in a hot climate, you will experience the very same phenomenon, except that everything will work in reverse.

Radiation

Radiation is energy transported by electromagnetic waves. Unlike conduction and convection, radiation requires neither contact nor the presence of moving air or water. Its only requirement is that surfaces exchanging heat can "see" each other. Once again, the warmer surfaces always radiate to the cooler surfaces. The heating comfort you receive from a fire is 100 percent radiant. Conversely, you don't have to be a rocket scientist to search for shade on a hot, sunny day in Tucson, Arizona. Shade immediately eliminates the radiant heat coming directly from the sun.

Radiation is how the sun's energy is delivered to us every day. At night, the earth's surface is warmer than the deep sky temperature, particularly in arid climates with clear skies, and the radiation serves to cool all surfaces that see the sky. In fact, these surfaces can become colder than the ambient air temperature under clear night skies.

In building design, you may want to maximize or minimize the radiant effect, depending upon the climate and the application. Rooftop surfaces in Phoenix, Miami, or Houston are better off being highly reflective or light in color. Sunbathed floors, walls, and roofs in cooler climates are better off in darker earth tones.

Evaporation

Relative humidity and air movement contribute to comfort, or discomfort. Everyone who lives in a hot climate knows that a fan keeps the comfort level bearable on a hot, humid day. A fan is forced convection that passes air over the surface of your skin to help remove heat and moisture. As moisture evaporates from liquid to vapor, it absorbs heat from your body. It is easier to keep cool in hot, dry climates than it is in hot, humid climates, because the evaporative effect is so much stronger when the air is dry. Evaporative coolers are popular in hot, dry climates, and dehumidifiers are popular in humid climates.

Conversely, maintaining a higher level of relative humidity indoors is wise in a cold climate. As cold, dry air infiltrates your home in winter and your heating system increases the temperature, the relative humidity of the air drops. Relative humidity is a measure of how much moisture is contained in the air relative to how much the air can hold when saturated. The lower the relative humidity of the air, the easier it is to evaporate moisture from your skin. This is why humidifiers are popular in cold winter climates.

Thermal mass can be incorporated into ceilings and walls, but the most cost effective location for thermal mass in a residential structure is a floor that receives direct sun. Mass that is not illuminated by the sun absorbs heat mostly by convection from the warm air in the space, and provides much less benefit in terms of heating.

A slab thickness of 2 inches (5 cm) is sufficient to absorb and release heat on a daily basis. Some passive solar designers are after a rapid response or quick warm-up of the slab on a daily basis. Thin, 2 to 3 inch (5–7.6 cm) slabs lend themselves to this. Compared to thicker slabs, they are less expensive, and can be poured over wood-framed floor systems, designed to handle the added weight of the concrete.

But additional mass provides heat storage that can last through several days of cloudy weather. A 6 to 8 inch (15–20 cm) slab is optimal in most applications, providing it receives direct solar gain over the majority of its surface during the heating season. The increased mass of a thicker slab raises the average minimum room temperature, compared to a thinner slab. It also lowers the average maximum room temperature. This limits daytime overheating and reduces the need for nighttime cooling. Thicker slabs also help keep the building cool during the summer. Slabs thicker than 8 inches provide little additional benefit in most applications.

Two inches (5 cm) of high density, closed cell, rigid foam should be laid under the slab and around the perimeter. This approach thermally isolates the slab from outdoor and ground temperature swings.

The color of thermal mass is another important aspect of passive solar design. When exposed to sunlight, earth tones and dark-colored objects absorb heat more easily than light-colored objects. Extremely dark surfaces, however, may become too hot for bare feet. Also, carpets covering the mass floor should be kept to a minimum. A small throw rug here or there is not a problem. But covering the floor with carpet will insulate the slab and radically decrease its ability to absorb and release heat.

Thermal Efficiency—A Mantra

Just as energy efficiency is the most important step for solar-electric systems, it should not be any surprise that energy efficiency is also vital to any successful passive solar building project. This mantra is to be repeated over and over—the less energy you consume or waste, the less you need to produce. Remember that efficiency is the only energy resource that is 100 percent efficient, and it is almost always the most economical investment. Thermal efficiency has three main applications in passive solar design: windows (discussed earlier), insulation, and a tight building envelope.

The most cost effective investment you can make to improve the thermal efficiency of your home is insulation. It not only helps keep your house warm in the winter; it helps keep it cool in the summer. And when it comes to insulation, more is almost always better. General insulation guidelines for efficient passive solar homes are R-30 walls and R-60 roofs in temperate climates, and R-40 walls and R-80 roofs in extremely cold or hot climates.

Air leakage causes the single greatest loss of energy in most homes. You want to minimize air leakage in the building envelope that surrounds your indoor space. Caulk the trim around windows and doors on the inside and outside, install and adjust the weatherstripping around the operable surfaces of doors and windows, use expanding foam to seal all the penetrations the plumbers and electricians made, and use sill seal between the wall's bottom plate and the foundation. As you build, make sure you take care of those air leaks all the way through the construction process. It will never be easier or more effective.

Note that airtight building envelopes can be a potential hazard to your health. Fresh air—free of dust, spores, bacteria, and any chemicals that may off-gas from

Common Mistakes

- Trying to heat too large or inefficient spaces. Passive solar works better in smaller buildings, such as residences, and where the building envelope design controls the energy demand.
- Overheating as a result of excessive glazing. In hot climates, buildings having large glass areas with direct solar gain may overheat.
- Failing to minimize southwest and west-facing windows, and not sizing shading devices properly.
- Providing inadequate quantities of thermal mass for the amount of direct gain glazing. In passive solar heated buildings with high solar contributions, it can be difficult to provide adequate quantities of effective thermal mass.
- Having too much sun glare. Room and furniture layout needs to be planned to avoid glare from the sun on equipment, such as computers and televisions.

paints, petroleum-based carpets, and furniture upholstery—is important to human well-being.

Mechanical ventilation may be desirable or even necessary to ensure adequate indoor air quality. Ventilation systems bring fresh air into living spaces and exhaust it from bathrooms, kitchens, and laundry rooms where moisture and less desirable air are more concentrated. Super-insulated homes can also use an air-to-air heat exchanger to retrieve the heat content of exhaust air.

Other Design Considerations
In addition to cutting your energy costs for heating and cooling, passive solar home design may integrate daylighting and passive ventilation. Daylighting design uses natural sunlight to supplement and minimize the use of electric lights during the day. When designing your home, pay attention to window location in relation to where light is needed—a window over the kitchen sink, a desk, your favorite reading chair, and in the bathroom can be helpful. Properly positioned skylights or light tubes can be a great source of daylighting as well. Light-colored walls help to distribute light throughout the house.

Passive ventilation optimizes natural air flow by convection and can be used to distribute warm, cool, or fresh air throughout the house. Doors and operable windows and skylights can provide the majority of air transfer in a passive solar house with a tight building envelope. Windows located on opposite walls will create cross-ventilation and maximize air movement.

During warm months, the common practice of shutting windows and doors during the daytime keeps unwanted heat out. In the evening, opening the windows and doors brings in cool, nighttime air that helps cool the thermal mass. In the morning, the windows and doors are shut again and the chilled out mass helps to keep the building cool during the day.

In a home with a tight building envelope, it's amazing how few windows or doors need to be opened to create a whole house draft that cools the house overnight. Open floor plans help this process, as well. This draft effect can be increased by the inclusion of skylights or second stories with an open stairway between floors. Hot air rises. So opening a first floor window and a second floor window or skylight creates a chimney effect that pushes and pulls the warm air out of the building.

Reaping the Harvest
By now you have grasped the fundamental concepts of passive solar design for heating and cooling. The five principles are: building orientation towards true south, properly placed energy efficient windows, calculated roof overhangs, thermal energy storage, and thermal efficiency. Future issues of *Home Power* magazine will detail some successful passive designs, and delve deeper into the concepts introduced in this article.

Conventional home building is responsible for a large percentage of our culture's energy excesses. But it has been undergoing a quiet revolution. Not everywhere or fast enough of course—but you can claim another victory for the revolution just by letting the sun into your home. Thanks to the passive solar pioneers of the 1960s, '70s and '80s, the mistakes have already been made for us, and the successful strategies have been refined. The guidelines presented in this article were generated over the course of several decades of bold front yard experiments, common sense technology, passionate professionalism, and lessons learned and freely shared. Considering that a building built today will last 50 to 100 years, you can be sure that your investment in passive solar will continue to pay off well beyond your mortgage—and your lifetime.

Access
Ken Olson, SoL Energy, PO Box 217, Carbondale, CO 81623 • Phone/Fax: 720-489-3798
info@SoLenergy.org • www.solenergy.org

Joe Schwartz, *Home Power,* PO Box 520, Ashland, OR 97520 • 541-512-0201 • joe.schwartz@homepower.com

Christopher Gronbeck, Sustainable By Design, 3631 Bagley Ave. N, Seattle, WA 98103 • 206-925-9290
Fax: 877-684-0797 or 605-253-1466
christopher@susdesign.com • susdesign.com
Design tools and consulting

Guidelines for Home Building and *Designing Low-Energy Buildings With ENERGY-10,* book and software packages, US$100 and US$250 respectively, available from Sustainable Buildings Industry Council (SBIC), 1331 H St. NW, Ste. 1000, Washington, DC 20005
202-628-7400 • Fax: 202-393-5043
SBIC@SBICouncil.org • www.sbicouncil.org
"Build Better Buildings" PDF available at:
www.sbicouncil.org/resource/4aBldBet.pdf

Solar Today magazine and *Affordable Passive Solar Homes: Low-Cost, Compact Designs,* by Richard L Crowther, SciTech Publishing Co., 1984, US$20 (members US$15), ISBN 0-916653-00-5 and *Sun-Earth: Sustainable Design* by Richard Crowther, reprinted 1994 from 1983 classic edition, US$17.95 (members US$16), available from American Solar Energy Society (ASES), 2400 Central Ave., Suite G-1, Boulder, CO 80301 • 303-443-3130
Fax: 303-443-3212 • info@ases.org • www.ases.org

Energetic Design, Debra Rucker Coleman, Architect, 18250 Tanner Rd., Citronelle, AL 36522
334-866-2574 • sunplans@earthlink.net
www.sunplans.com • Passive solar house plans

Alliance to Save Energy, Kate Offringa, EWC Program Manager, 1200 18th Street N.W., Suite 900, Washington, D.C. 20036 • 202-530-2245
Fax: 202-331-9588 • ewc@ase.org
www.efficientwindows.org • Energy efficient window info

Successful Solar Businesses—2003

A three-day seminar in Ashland, Oregon, taught by Richard Perez of *Home Power*, Bob-O Schultze of Electron Connection, and Bob Maynard of Energy Outfitters on how to start and operate a successful renewable energy business.

Installing dealers will receive specific strategies on how to build their existing businesses. Would-be entrepreneurs will get a jump-start from the "lessons learned" by those who have "been there and done that." Gain instant contacts with major solar energy manufacturers and distributors right at the workshop!

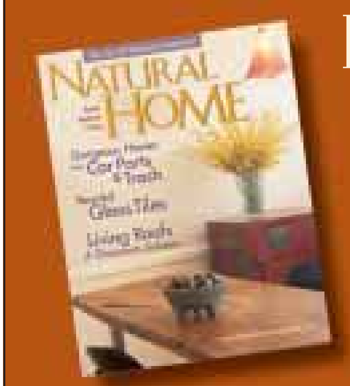
Topics include: how to start a small business, renewable energy career choices, managing a small business, managing employees, marketing renewable energy, legal and tax issues, and using computers. A detailed seminar outline is available at: www.homepower.com/files/ssb00net.pdf

The dates are February 21–23, 2003. The cost is $350 and includes three lunches and a Saturday night banquet.

Seminar size is limited, so contact Rue Wright at 800-707-6585, 541-512-0201, or richard.perez@homepower.com to reserve your place. Reservations accepted for a nonrefundable $100 deposit, with the $250 balance due by 2/1/03. Interest is very high in this seminar, so reserve early if you wish to be sure of a place.

Lodging is available at discounted rates for seminar participants. The location is the Windmill Inn and Suites in Ashland, Oregon, www.windmillinns.com/ie40/ash/ash.htm or call 800-547-4747 or 541-482-8310. The nearest airport is in Medford, Oregon (MFR) and Windmill Inn offers free airport shuttle service.

We hope to see you there, and look forward to helping your solar business prosper.



Our Remote Home Radio Antennas

Bill Layman

Author Bill Layman assembles a custom-tuned, five-element Yagi, FM antenna from salvaged parts.

So you want good radio reception at your remote home, and need to "lock on" to a particular AM or FM signal? Here's how we did it.

First, you have to realize that there are many advantages and disadvantages to both FM and AM radio signals. Without getting into a long diatribe about frequency modulation versus amplitude modulation...wake up! Don't go to sleep on me! AM signals will travel farther, but are more prone to noisy reception (static and the like). FM has a limited area of reception, but is virtually noise free and has better fidelity (sound quality).

Lynda and I lived quite comfortably with our AM antenna, and were happy with the reception of our favourite station for many years. On those days when the signal waxed and waned, and on others when summer storm clouds produced huge bursts of static every ten seconds or so, we just lived with it. After all, our favourite station is more than 400 hundred miles (640 km) away.

We live in northern Saskatchewan, about 340 miles (550 km) south of the boundary with the Northwest Territories, 430 miles (690 km) north from the border with Montana, and about equidistant from the provinces of Alberta and Manitoba. We have a seasonal home on Bob Lake, 30 air miles (48 km) away from the town of La Ronge. We spend four to six months of the year there, and without television, radio is a big part of our life. See *HP68,* page 58 for a story on our cabin's PV system.

AM Antenna

The drawing at right shows you how we built our AM antenna. This antenna is nothing more than a bare, braided copper wire, 75 feet (23 m) long, that is strung out between two trees at right angles to the signal we wanted to receive. The antenna is insulated from the guy lines (clothes line wire works well). A run of #18 (0.8 mm^2) insulated wire feeds into an amplifier coil (about 100 turns of insulated #18 wire) and runs to a ground rod outside.

This gives you a very functional and extremely cheap antenna. Just move the coil around on the top of the radio until you get the best signal. Radio Shack has everything you'll need to build one of these, or you can do as I do and scrounge for all the parts.

Murdering Radio Reception

What really wrecked it for us was the addition of a solar-electric system with a modified square wave inverter (to invert 12 VDC from batteries to 120 VAC household electricity) and fluorescent lights. Both the inverter and the lights interfered with the radio reception.

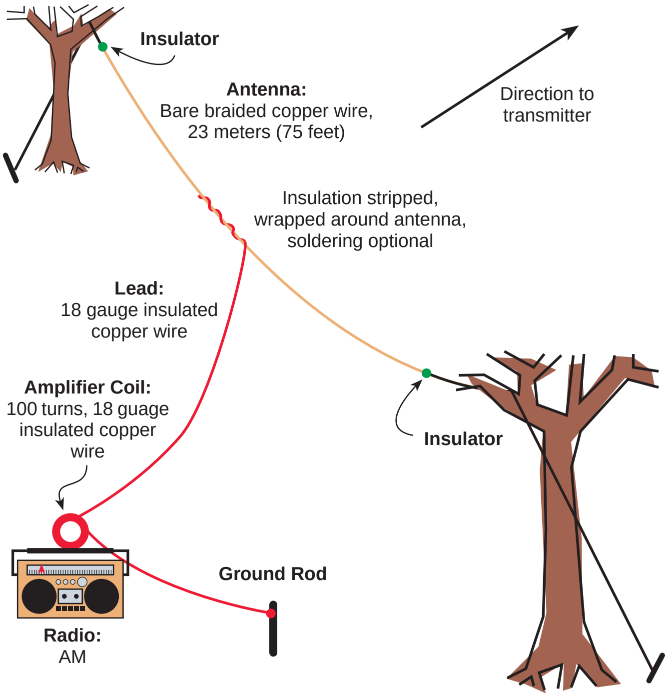
Our Trace SB 2012 inverter produced a steady clicking, hissing noise on our radio. The fluorescent lights—well this is how Lynda described it one particularly bad night: “It’s sort of like a sea mammal being killed with a pointy stick don’t you think?...a sound that starts really slowly and builds into a wild high-pitched death screech...and then quits suddenly...and just when you think the poor creature has finally been put out of its misery...it starts all over again...please, please, please, kill it, Bill!”

When I heard Lynda deliver this description with tears streaming down her cheeks, I thought I’d best fix the situation before *I* was killed in my sleep. I tried a million experiments—a better, higher AM antenna with much improved grounding system, capacitors wired into the lines leading to the offending lights, braiding the battery leads to the inverter, better radios designed for fringe reception areas, and all manner of noise filters.

All that happened was that we ended up with smaller, slightly quieter, dying, wounded sea mammals. For a while, we actually wouldn’t listen to the radio when the lights were on at night, which was not a good plan in the short days of winter!

Bill’s homebuilt FM antenna mounted on a recycled TV antenna mast.

AM Long-Wire Antenna



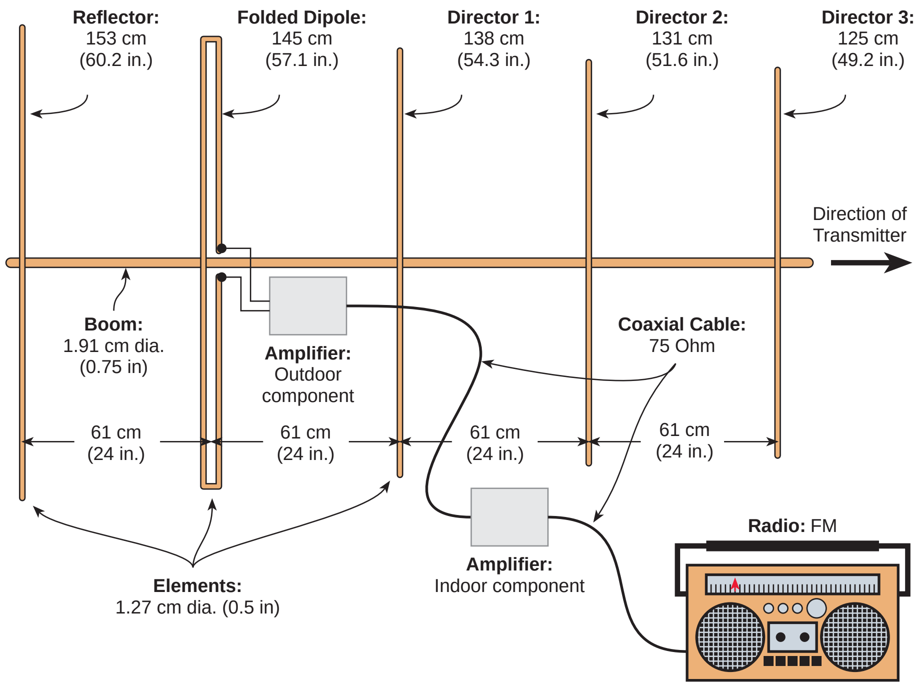
Radio Frequency Interference

Without boring you to death, suffice it to say that we were dealing with what the techno-weenies call radio frequency interference (RFI). RFI drastically interferes with AM radio signals. It is almost impossible to completely beat because it is delivered to your radio both by the power wires leading to it, and also by RF energy that is radiated through the air. Your inverter does both, and your fluorescent lights do the latter in spades.

If you can live with your inverter being turned off while the radio is powered by batteries, you can kill the noise on AM stations by using nonfluorescent lights. Halogen lights (expensive and not as efficient as fluorescents) are a good choice, as are the newer light emitting diode (LED) lights (very expensive, but more efficient). If you can’t live without the inverter being on, make sure you have a sine wave inverter, since they produce less RFI—the purer the sine wave the better!

The field strength of all radiated RF noise is inversely proportional to the square of the distance between the offending source and the receptor. I can just hear you gasping in disbelief, "Honey come quick—read this—how on earth have we lived so long without knowing more about RF noise?" Of course, all I am trying to say is that you should move the radio and its antenna as far from the inverter as possible. Or if all of the above remedies fail, and you can find an FM station that you like, you can build an FM antenna.

Five-Element Yagi Antenna: Tuned to 98.0 MHz



FM Antenna

I began to wonder if there was any way we could pick up our favourite station on its FM rebroadcast signal, which is delivered by a very low-power FM transmitter to La Ronge. It didn't seem like a great idea because the signal from this mini-transmitter is very low power, and we are about 30 miles (48 km) from it. Another problem is that there are lots of high hills between our fly-in home and La Ronge. FM delivers a line of sight signal that is quickly eaten up by obstructions between the transmitter and the receiver.

But with lots of time on my hands at our cabin on Bob Lake, I began to experiment. I looked at a bunch of different TV/FM-type antenna arrays from Radio Shack, but couldn't find what I wanted. The problem with these antennas is that they are built to capture the entire FM broadcast range (88 to 108 megahertz—Wow, do I sound smart!), as well as the complete UHF/VHF television range.

In plain English, they try to do everything. All I wanted was to get one tiny, needle-sized signal out of this vast haystack of radio and TV signals these antennas were designed for. Besides not being what I wanted, they were huge ungainly things and cost a lot of money. So Lynda asked one day why I didn't just build one... "Yeah, right. Why not ask me to build a NASA spaceship?" I thought.

And from that tiny seed, an oak tree of an idea grew. After reading a series of books, I found that what I wanted to build was a Yagi directional antenna designed for the single frequency I wanted to receive, and that I should put an external signal amplifier on the antenna.

Homebrew

I got an old TV antenna and mast from a friend who had switched to cable. You'd be surprised how many of these are tucked away in garages and basements. With the aid of the diagram and table shown here, I designed my new antenna and cut the old one to bits and rebuilt it.

All I needed was a hacksaw, a plumber's tubing cutter, a multibit screwdriver, a drill, some metal plumber's strapping (flexible metal strapping with prepunched holes), and some sheetmetal screws. The antenna conductors (signal directors, signal reflector, and the folded dipole driven element; see the Yagi antenna diagram) were fastened down to the main boom with

Design Calculations for a Five-Element Yagi Antenna

Radio Frequency in (MHz)	98.00
Wavelength in meters (λ) = 300 ÷ Frequency	3.06

Item	*Reflector*	*Folded Dipole*	*Director 1*	*Director 2*	*Director 2*	*Spacing*
Factor (multiply by λ)	0.500	0.475	0.451	0.429	0.407	0.200
Calculation (cm)	153	145	138	131	125	61
Calculation (inches)	60.2	57.1	54.3	51.6	49.2	24.0

brackets made from the plumber's strapping, and screwed down with sheetmetal screws.

When you design an antenna, don't get carried away and start adding more conductors. You can make a Yagi antenna with as many directors as you want, but stick with the schematic I have shown you. You can't just start adding more directors to the design willy-nilly. The spacing of the conductors and their lengths are very precise to each design. And remember, any Yagi antenna design only needs one reflector and one dipole no matter how many directors.

FM Radio Antenna Parts

Item	*Radio Shack Part #*	*Cost (Can$)*
FM high-gain signal amplifier	15-1108	$49.99
Outdoor cable, 75 ohm, 50 feet	15-8526	19.99
Ground rod,10 foot	15-529	12.99
Ground wire, #8 aluminum, 40 foot roll	15-035	6.99
Transformer, 75 to 300 ohm	15-1140	4.99
		$94.95

The whole experiment took place one gorgeous fall Saturday. From paper design to built, installed, and happily listening to the FM signal I wanted, was about five hours of work. Reading the books and performing the failed experiments took what seemed as long as getting your tax return cheque back.

Yagi antennas are highly directional, and you need to orient them with a compass. Or do as I did and have your sweetheart listen to the radio as you twirl the antenna until she is happy. Feed the 75 ohm round coaxial cable into your home and to the radio. If you are using a signal amplifier, you will feed the cable to it and then to the radio. You will need a radio that has an input for either 75 ohm cable (a direct screw-in like on most new TVs) or for 300 ohm flat wire (two screw connectors on the back of the radio).

If you have a 75 ohm connection, screw your cable directly into the radio. If you have a 300 ohm screw-type connection, attach your 75 ohm cable to a 75 to 300 ohm (transformer) adapter and attach the adapter's two wires to the radio. I am using a Panasonic AM/FM/cassette ghetto blaster that I "liberated" from my son Zane when he went off to work in one of the northern mines.

Multiple Frequencies

In my case, I built an antenna for a single signal coming from one direction, so the whole experiment was relatively easy, and the Yagi was a perfect design. If you want to get the whole FM bandwidth (88 to 108 megahertz) and they are all coming from roughly the same direction, a Yagi built to the average signal wavelength of 98.0 megahertz will work fairly well. (The Yagi design calculation table and antenna diagram show the specifications for this average frequency.)

If you build a multibandwidth antenna, you should know that increased physical diameter of the conductors results in a wider antenna bandwidth reception. Translation: if you use bigger tubing, your radio will work better. So try making your antenna from 1/2 inch copper tubing fastened to a 3/4 inch copper main boom rather than from the 1/4 inch aluminum tubing that you can scavenge from an old TV antenna. You can make the curved corners of the dipole driven element with 90 degree plumbing elbows. As an added bonus, the increased diameter also makes a much stronger antenna.

If your signals are coming from multiple directions, things get tricky. This is when you may want to just spend the cash and buy one of the prebuilt Radio Shack arrays.

If you are in an area prone to lightning, you should ground your antenna mast to an earth ground rod with a #8 (8 mm^2) ground wire fastened to a ground rod clamp. I didn't because I have so many high trees and other objects that the lightning will probably strike first—but honest, it is on my list of things to do. And don't forget to watch for sales at Radio Shack—they have some awesome bargains!

Simple parts and tools are all that you need to significantly increase you FM radio reception.

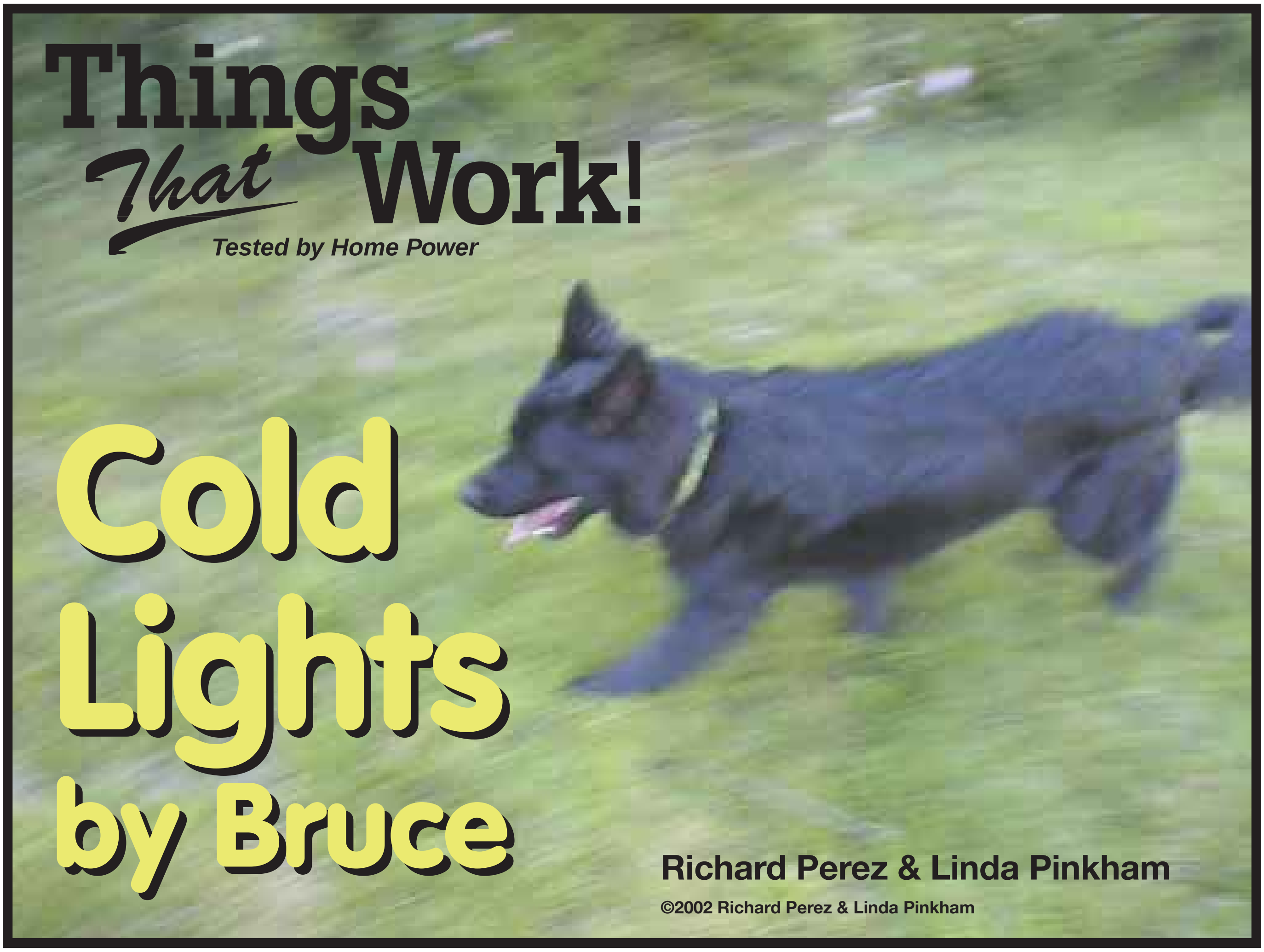
Smart Radio

Our antenna and amplifier are still working just fine after three years. Lynda no longer dreams of wounded sea mammals, and we stay ever so smart by listening to CBC (Canadian Broadcasting Corporation). My only worry now is how to get our federal politicians to promise to keep CBC alive, and stop poking it with pointy sticks like some poor wounded seal.

Access

Bill Layman, Layman Ventures, Ltd., PO Box 327, La Ronge, SK, Canada, S0J 1L0 • 306-425-2858 • Fax: 306-425-3231 layman@mail.cableronge.sk.ca

Radio Shack, 100 Throckmorton St., Fort Worth, TX 76102 • 800-843-7422 or 817-415-3011 • Fax: 817-415-3240 • support@tandy.com www.radioshack.com • www.radioshack.ca



Things That Work!

Tested by Home Power

Cold Lights by Bruce

Richard Perez & Linda Pinkham

Cold Lights by Bruce are plastic tubes filled with a chemical material that absorbs light and glows. They are very useful items to have around your home for locating paths, doors, staircases, and pets at night.

How Do Cold Lights Work?
Cold Lights use no electricity to operate. They store light in a patented, nontoxic, nonradioactive, silicate chemical compound. They absorb light during the day, or artificial light at night, and release this light energy as a soft, lime-green glow. Direct sunlight isn't necessary to charge up Cold Lights. Even if they are just in indoor light all day, they will glow all through the night.

Cold Lights are made from an ultraphosphorescent polymer that has the brightest continuous afterglow of any nontoxic, nonradioactive material. Glow-in-the-dark toys and novelties produce less than 30 millicandles of illumination per square meter while Cold Lights by Bruce can produce over 320 millicandles per square meter.

Cold Lights are too dim to read by or to illuminate objects. They are locators—navigational beacons. They are suitable for marking areas you want to find in the darkness—doors, paths, stairs, light switches, driveways, and fuse boxes, to name just a few.

Cold Light Testing
We've been using Cold Lights at *Home Power* Central for the last six months. We put them next to all the exterior doors leading into our buildings, and on the paths between our buildings. They show us where the doors and paths are at night. Having these Cold Lights has reduced our use of outdoor lights and even flashlights. Cold Lights are super easy to install—just two screws secure them to any surface. Since they are nonelectric devices, no wiring is necessary.

We installed a 14 foot (4.3 m) long Cold Light strip along the staircase between the first and second floors of our home/office. The crew around here has taken to calling

A Dark Tail

By Henry, as told to Linda Pinkham

How do you see a black dog like me on a dark night? I thought I would have to bite one of my people to teach them not to step on me when they get up at night. Instead, I got the world's coolest dog collar.

This green phosphorescent collar nearly rivals my puppy energy. When I go outside and run around the yard, it stores up the sun's energy. Late at night, when I'm having puppy dreams and getting some serious sleep, it's still glowing.

The glow is so bright, it actually casts enough light to almost work as a nightlight. I say almost because Linda and Michael thought they could use me and my collar to take a shortcut through the dark warehouse at *Home Power* without having to turn on a light. But I'm just a puppy, and I bumped into a wall right off and saw lots of stars.

I was suspicious when I first saw the collar, and wondered whether it would be used to control me or what! But few things can survive a puppy, so I wasn't too worried. I really knew I wanted it when I saw the envy in the eyes of Lady, another German Shepherd who lives at my house.

The collar has a series of very sturdy snaps for size adjustment, and a heavy duty D ring for attaching a leash. This thing sure stands up to the abuse! The other dogs I play with have grabbed the collar with their teeth to throw me to the ground when I irritate them. When I am on a leash, I haven't been able to wiggle free or break loose.

I am just a little worried that I will always wear a collar now, even if it is very chic. But as far as safety, my people—and their cats—are very happy because I can be seen easily at night.

this staircase strip a "glide path." It makes the stairs safer and easier to navigate in the dark. Since installing this glide path, we no longer need to use a light over the stairs at night.

Manufacturer & Pricing

Cold Lights are the brainchild of Bruce Brink. Bruce and his family have been using them for years, and decided to form a family business to bring the lights to the public. The cost varies with the size and type of Cold Light. The

A 6 inch Cold Light will illuminate a dangerous step, hidden driveway, or the path to the outhouse, all night long from light gathered during the day.

Yard Guard tubes for paths or doors (each about 6 inches; 15 cm long) are US$70 for a pack of ten, or US$8 each. Henry's dog collar was US$25.

Cold Lights carry a ten-year warranty. Contact Bruce for networking, pricing, and special Cold Light products. Chances are he can make whatever you want, just as he made us our staircase glide path. Cold Lights by Bruce even come in ultraphosphorescent colors like lime light, sky blue, and ultraviolet purple.

Cold Lights are a simple and durable way to locate doors, stairs, paths, and pets around the home. Since they don't use electricity, they are a natural for energy efficient homes. And on top of it all, it's just plain old fun to watch them softly glowing all night long.

Things That Work! Criteria

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1. The product must meet its manufacturer's specifications.
2. The product must be durable and last in actual service.
3. The product must offer good value for the money spent on it.

The reviewed equipment is not necessarily the best product for all applications.

Access

Richard Perez, *Home Power,* PO Box 520, Ashland, OR 97520 • 530-475-3179 • Fax: 530-475-0836
richard.perez@homepower.com
www.homepower.com

Linda Pinkham & Henry, *Home Power,* PO Box 520, Ashland, OR 97520 • linda.pinkham@homepower.com

Cold Lights by Bruce, Bruce Brink, PO Box 208, Azalia, OR 97410 • 541-832-2670
webmaster@coldlightbybruce.com
www.coldlightbybruce.com


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Hitting the Juice Bar

Shari Prange

An electric Ford Ranger fills up using an Avcon connector.

Driving an electric vehicle (EV) is a kind of declaration of independence. It says that the driver is an independent thinker, not just another lemming in the SUV pack. An EV is not dependent on foreign oil—or even domestic oil. In fact, if the driver has an adequate RE system, an EV isn't even dependent on utilities and power plants.

If an EV charges from the grid, it does so primarily during off-peak, overnight hours, when capacity is abundant. And it does it at home, freeing the driver from gas station lines.

But sometimes it is useful to get a little extra charge away from the home base. Where can a thirsty EV get a drink? Last time, we talked about off-site charging for homebuilt electric conversions. This time we'll look at options for factory EVs. These full function, street legal models are a completely different breed of critter.

What Flavor—120 or 240 VAC?

Conversions primarily use 120 V input for charging. Factory EVs sometimes have an onboard 120 V charger for emergency charging, but many of them rely on 240 V offboard chargers at their home base. A few owners have been known to pack their offboard 240 V charger along with them, but it was not designed with that in mind. Other factory models have onboard 240 V chargers built in.

Both onboard and offboard chargers use unique proprietary connectors. GM products use the MagneCharge "paddle," a flat, round, inductive charging plate with a handle on the end of a cord from the charger. It slides into a slot in the vehicle. The first paddles were large, but later versions are smaller. Both are still in use.

While GM at one time hoped to establish this as the standard, it has not been embraced by the industry, nor by the California Air Resources Board. With GM backing off its EV program, the usefulness of these chargers began to look doubtful. However, Toyota has now made its RAV4 EV available for sale to the general public, and it uses this charging system as well.

Some other vehicles, like the Ford Ranger EV, use a connection called an Avcon. This is, again, a specially shaped piece on the end of the charging station cable that mates to a receptacle on the vehicle. Unlike the paddle, this is a conductive interface, meaning that there's an actual physical connection between the Avcon unit and the receptacle on the car.

For safety reasons, the Avcon requires a pilot signal from the car, a kind of electronic handshake, before it will operate. This is to prevent electricity from flowing into, say, a car fender or person's hand.

All of these vehicles need to have access to the special chargers and connections that were designed specifically for them. Because manufactured EVs tend to be very high voltage vehicles (300 V or more, as compared to 96 to 144 V for most conversions), using the emergency 120 V charger doesn't provide much of a charge.

Some owners of factory EVs using the Avcon system carry a PowerPak with them. The PowerPak is a power supply unit with the correct connections to make the transition from a standard 240 V outlet to an Avcon connector.

Who Has Your Flavor?

It's not a good idea to wait until you need a charge before you start looking for a charging station. EVs tend to get driven repeatedly to the same handful of locations—work, the grocery store, a favorite restaurant, the theater, etc. So check out the neighborhoods where you are likely to be parking the EV in advance.

If you have a factory EV, you will need to look for formal charging stations (unless you carry a PowerPak for your Avcon connection). But these are not street corner fueling depots with a canopy and a minimart, like gas stations. Instead, they are likely to be small installations, just one or two chargers tucked into the corner of a parking lot. Some cities have installed public charging stations, as have some businesses. Parking lots near mass transit stations are good possibilities. The electricity is generally free.

So how do you find these chargers? Fortunately, there is a network of EV enthusiasts and supporters who gather and publish lists of public charging facilities. Look for an owners' club for your model of factory electric vehicle. Check to see if a chapter of the Electric Auto Association (EAA) or other electric car club is in your area. If you are in a metropolitan area, check with your local utility, or air quality management district (or similar agency) for lists of charging stations. A wealth of this type of information is available on the Internet. Start with the EAA, and follow their charging links.

A GM EV-1 gets a charge through the MagneCharge's inductive connector.

Is the Bar Open?

It's not enough to spot a charging station. You need to be sure it's actually functional. On a factory charging station, this will be pretty simple—plug it into your car and see if it works. Sometimes these stations are installed in a burst of goodwill. Then the person who championed the installation moves on, and the next person in that position is less friendly to EVs. Chargers may break down and not get repaired, or may have their power shut off from the main circuit breaker.

If you find a nonfunctional charging station, find out who is responsible for it. Approach the person in a friendly and nonconfrontational mode, inquire about the status of the charger, and encourage him or her to get it functional again. Sometimes those responsible believe that no one actually uses those darn things anyway, so why bother? If you show that a pleasant, rational, real live person has a genuine use for the charger, it may get put back into service.

A functioning charging station still won't do you much good unless it's also available. This means that an EV isn't already plugged into it, *and* that you have access to it. A too common experience among EV drivers is getting "ICEd out" of charging. This happens when an internal combustion engine (ICE) vehicle parks in the spot intended for the EV, blocking the charger. This is similar to able-bodied people who park in handicapped zones.

If the charger seems to be frequently in use by EVs, great! That means you have an active EV population in your area. It may be grounds to lobby for even more charging stations. If you often find the spaces blocked by ICE cars, this may indicate a need to lobby the responsible authorities for better placarding and enforcement of parking regulations.

Mind Your Manners

Some etiquette issues need to be addressed. For example, what if you get to the charging station, only to find another EV plugged in? If it's a factory EV, it will have an indicator showing state of charge. If it's a conversion, you may be able to see the state of charge, or you may not.

The generally accepted protocol is, if you can tell that the car is at least 80 percent charged, it is acceptable to disconnect it and plug in your car. However, you should check the dashboard first. Some EVs actually need 90 percent to complete their travels. If so, they should display a "90%" placard on the dash. When you disconnect and leave a parking space, it is also proper protocol to plug the charging connection into any adjacent EV that is waiting for a charge.

GM EV1 drivers may have the option of using either the large or small paddle. If there's a choice, use the large one, since other cars may require the small paddle only.

What if you find an ICE car parked so that it blocks the charger? You never know whether the driver is a nice person or an arrogant jerk, but start by giving the benefit of the doubt. As I mentioned earlier, many people don't believe that any electric cars are around to use the charger. Some may not have understood that it was an EV charging space.

Rather than just leaving in frustration, try leaving a friendly note explaining that you need to use the parking space to charge your electric car. Be a Johnny Appleseed, scattering seeds of EV education, and hoping that some will sprout. If this is a chronic problem, however, you should talk to the authorities responsible for the charging station to see about getting it more clearly marked as "EV Parking Only," or to get better enforcement of this rule.

Special Requests

OK, you've scoured the neighborhood, and there just aren't any charging stations to be found. See if you can create one. City officials can often be convinced that having a couple of EV charging spaces in public parking areas will demonstrate that they are on the cutting edge of prudent city planning. EV charging stations can be touted as ways to lure EV-driving shoppers and high-tech oriented businesses into the area, as well as encouraging clean, quiet transportation. Metropolitan areas that are under the gun for failing to meet federal air quality standards might be anxious to demonstrate their good faith efforts to correct the situation.

Business owners or managers can be convinced that a charging station would be good for business. Introduce yourself and chat them up. Explain that you patronize their business, and would like to do so even more, but it would be easier if you could get a charge for your car while there.

It's important to know just how much juice your car sucks up, and what this translates to in dollars and cents, so you can assure the business owners that you aren't merely looking for a free ride at their expense. You can calculate this easily if you know your car's worst case charging draw, which occurs at the beginning of the charge cycle when the pack is on "empty." Multiply your kilowatt-hours of worst case draw by your local electricity rate. You will find that, even worst case, the cost for the juice is very small.

Perhaps you can let owners of potential charging sites know that a club of EV owners is in the area, and that they would be likely to share information about such a charging station, and would then consider the business a "destination." Even better would be an informal petition signed by members of the local EV club, expressing their interest in using such a charging station. There is always more power in numbers.

The last hurdle is money for installing the charging station. The sources of money for such installations include utility company grants or special programs, air quality management district grants, and incentives at state and federal levels. Many of these incentives and grants can be located through the Clean Cities Program, a project of the U.S. Department of Energy. Electric car clubs also may offer equipment or other assistance for installing public charging stations.

The Perfect Recipe

A few simple actions will vastly improve the success of any charging station project. First, *don't* locate the EV spaces right in front of entrances, like handicapped spots. They are too likely to get ICEd. Instead, locate them at the end of the row. EV drivers don't mind walking a little farther if it means they can actually use the charger when they need it.

Second, be sure the EV spaces are boldly marked as "EV Parking Only," possibly with a large green emblem in the middle of the space. Finally, there should be an effort at public education, with small placards at the chargers, and prepared press releases that correct misconceptions about the costs and safety issues involved. This will help defuse "fear and loathing" from gas car drivers. It is most effective if the agency responsible calls a press conference and issues these releases as a pre-emptive strike, rather than waiting for angry anti-EV letters to appear in the local paper and then trying to do damage control.

The EAA offers placards, guidelines for installing charging stations, and information on financial assistance for charging station installations. Anyone lobbying for charging station installation should team up with the EAA.

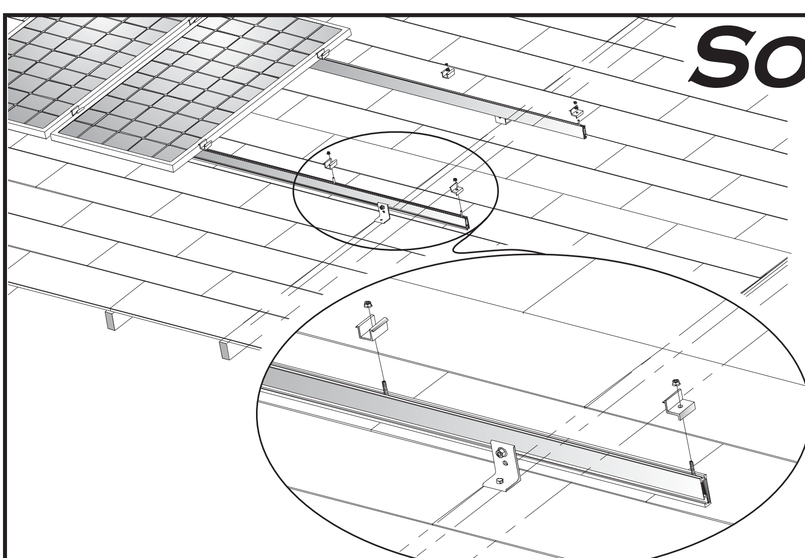
To Your Health!
To really take advantage of the benefits EVs can provide, we need to break away from thinking in gas car terms. Refueling is not something you do by going to a special street corner business, a brief detour on your way to somewhere else. Instead, this is what your car does all by itself when it's parked—at home or in town.

The infrastructure for gas cars is thoroughly embedded in our culture. For EVs, it's still in the early, formative stages. The nice thing about this is that we still have the power to shape it, if we will just get involved.

Access
Shari Prange, Electro Automotive, PO Box 1113-HP, Felton, CA 95018 • 831-429-1989 • Fax: 831-429-1907 shari.prange@homepower.com • www.electroauto.com

Electric Auto Association, 2 Smith Ct., Alameda, CA 94502 • 510-864-0662 • contact@eaaev.org www.eaaev.org

Clean Cities Hotline, 9300 Lee Highway, Fairfax, VA 22031 • 800-224-8437 • Fax: 703-934-3183 ccities@nrel.gov • www.ccities.doe.gov



Things *That* Work!

Tested by Home Power

P3 International's Kill A Watt Watt-Hour Meter

Joe Schwartz

Most *Home Power* readers are hip to the fact that the first step in designing a renewable energy system is a thorough evaluation of the electrical loads that the system will power. P3 International is now manufacturing a low-cost, watt-hour meter that will help you determine which of your appliances are keepers, and which ones ought to be relocated to your favorite recycling center.

If you live off grid or are aiming to, every dollar spent on efficient appliances will save you roughly three to five dollars in PV system component costs. The exact figure depends on a number of variables, including the appliances involved, the system's geographic location, array shading, and other system design specifics.

If you live on the grid, your home is undoubtedly equipped with a utility KWH meter that measures the cumulative electrical energy consumed by all the appliances in your home. Each utility bill shows your home's monthly KWH energy use, and often breaks this figure down into average daily KWH use. But how do you find out how much energy individual appliances are using? Watt-hour meters let you do just that.

The power drawn by a given appliance (volts x amps) can be calculated using a digital multimeter. But an accurate measurement of the energy (volts x amps x time) that an appliance consumes requires a watt-hour meter. This is especially true for appliances that cycle on and off, such as refrigerators or pumps.

Several manufacturers make watt-hour meters for residential or office use. P3's Kill A Watt meter (model P4400) is new to this lineup. It's ETL listed for safety. At US$49.95 (manufactured in Taiwan), this feature-packed meter comes in at a little over half the cost of the nearest priced competition. But how does it measure up?

Not for Use with (Some) Inverters!
We received two Kill A Watt meters from C. Crane Company for testing. The meter packaging included the following sticker: "Not for use with inverters." I contacted P3 International, and spoke with an applications engineer about this warning. He said that P3 had not anticipated the use of the meter in

P4400 Tolerance Specs

Function	*Normal*	*Maximum*
RMS Voltage (Vrms)	0.2%	1.0%
RMS Current (Arms)	0.3%	1.0%
Watts (W)	0.5%	2.0%
Volt-amps (VA)	0.5%	2.0%
Frequency (Hz)	±0.1	±1.2
Power Factor (PF)	±0.01	±0.03
Kilowatt Hours (KWH)	0.5%	2.0%

conjunction with modified square wave inverters. The less than ideal waveform of these inverters resulted in the failure of one of the unit's resistors.

We tested the meter on the grid, and on sine wave inverters manufactured by Exeltech, Statpower, and Xantrex. The Kill A Watt meter operated without problems on the waveforms of all these units. The P4400 has a six-month warranty that *does* cover failures resulting from use of the meter with modified square wave inverters. P3 informed me that the meter has been redesigned, and the new version of the meter will operate on modified-square waveforms. (But we hope this doesn't keep you from purchasing a sine wave inverter!)

Design Features

The meter is designed to be plugged directly into a 120 VAC, three-prong (grounded) electrical receptacle. The appliance being tested is in turn plugged into the receptacle on the front of the meter. In most cases, this arrangement works fine. But some receptacles are located behind the appliance (refrigerators are a prime example.) In this case, a short extension cord will allow you to place the meter in a more convenient location.

The Kill A Watt meter was designed from the ground up for its intended use. A custom designed, integrated circuit samples voltage and current 2,048 times per second. The meter uses an 8 bit CPU with a 12 bit analog-to-digital converter and an 8 channel multiplexer. The meter's electronics are housed in an attractive-looking, custom enclosure with a fairly large LCD display. The buttons for changing meter functions are easy to use and have a positive feel.

Product Specs

For the price, the P4400 meter is loaded with measurement capabilities. The meter measures AC volts, AC amps, watts, volt-amps, frequency, power factor, kilowatt-hours (up to 9,999 KWH), and elapsed time (up to 9,999 hours).

The table details the tolerance specs of the meter. Normal operating ranges are defined by the manufacturer as 90 to 125 VAC, and 0.2 to 15 amps. I checked these specifications with a Fluke 87 digital multimeter and a Fluke 43B AC power quality analyzer. Note that loads drawing 0.2 amps (23.4 watts at 117 VAC) or less are operating outside of the normal window. But the maximum inaccuracy of the P4400 is only two percent when measuring outside of its normal range. This is more than adequate for home or office use.

Current & Voltage Limits

The Kill A Watt meter has a maximum current rating of 15 amps. The P3 International applications engineer I spoke with stated that the meter would accurately measure loads up to 15 amps (at 120 VAC). If loads greater than 15 amps are powered via the meter, the unit's display will flash and a warning tone will sound. The P4400 can withstand a maximum current of 29 amps for about one second before an overcurrent protection fuse blows. (This fuse is not user serviceable.) Data for loads above 15 amps will not be accurate, so there's no reason to push it and operate the meter above this 15 amp threshold.

The meter has a specified upper voltage limit of 125 VAC. In some locations, grid voltage can be higher than this value either regularly or sporadically. The P3 engineer informed me that higher voltages only affected accuracy. The meter is in fact designed to withstand up to 250 VAC for one minute.

What's Missing?

The one feature I really missed on this watt-hour meter was a surge or peak power function. This data is important when specifying an appropriate inverter for a given combination of loads. A peak power function would be a great addition.

The meter's memory is volatile. If you unplug the unit or power is lost during measurement, the data will be lost. So remember to record your measurements before unplugging the unit. Also, the display is not illuminated. While this isn't a big deal, a backlit display would make the meter easier to use in some locations.

Nice Tool

P3 International's Kill A Watt meter will provide you with accurate appliance energy consumption data whether you buy electricity from a utility or make your own. At less than US$50, this meter is an outstanding value. The information it provides will help you easily identify inefficient electrical appliances. In most cases, your energy savings will quickly recoup the cost of purchasing the meter, and allow you to save energy (and money) year after year.

Things That Work! Criteria
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Access
Joe Schwartz, *Home Power*, PO Box 520, Ashland, OR 97520 • 541-512-0201 • joe.schwartz@homepower.com

P3 International Corp. • 888-895-6282 or 212-741-7289
Fax: 212-741-2288 • sales@p3international.com
www.p3international.com

C. Crane Company, 1001 Main St., Fortuna, CA 95540
800-522-8863 or 707-725-9000 • Fax: 707-725-9060
ccraneco@aol.com • www.ccrane.com

Buying A Used EV, Part 2

Mike Brown

In the previous article in this series, I discussed what to look for in the body and chassis of a used electric vehicle (EV) you might buy. I also looked at the conversion components themselves, pointing out which ones were desirable, and which ones were to be avoided.

In this article, I'll finish the component overview with looks at the battery charger, the gauges, and most important of all—the battery pack. Next time, I'll wrap up by looking at how the conversion components were installed in the donor vehicle and how this affects the desirability of the EV.

Charger

The battery charger is a very important component. It is the link between your energy source, the AC wall outlet; and your energy storage system, the DC battery pack. The charger must accomplish this linkage without overloading the AC system, and without under or overcharging the battery pack. The battery charger must be a professionally built, commercially available product.

The last thing you want is an AC transformer hooked to a half or full wave rectifier with a timer on the AC side to control how long you are going to abuse your batteries. If this or some other homebrew lash-up is presented as the conversion's charger, the price of the conversion should be lowered by an amount equal to the purchase price of a modern charger.

Some of the older conversions may have a 240 volt input, offboard Lester charger. If the conversion is one of the Jet Industries cars, it will have an onboard 240 volt input charger, which was built for Jet by Lester. Both of these chargers are good if you have 240 volt service available. Unfortunately, neither of these chargers nor an equivalent is in production.

The surge of interest in EV conversions in the 1990s brought about the development and marketing of the 120 volt onboard charger. The chargers of this type that you are likely to see in a modern conversion are made by K&W Engineering and Russco from the U.S., and Zivan from Italy. These three chargers have similar features, are currently in production, and are supported by their manufacturers.

The big advantage these onboard chargers have is the wide availability of 120 volt outlets, which allows opportunity charging or charging at work during the day. Either of these options will extend the range and usability of an EV.

The charger should be checked to see if it is operating properly. This can only be done if the EV is operational. The battery pack can be anywhere in its lifespan for the charger checkout.

First, perform the battery test on the fully charged battery pack as described in the last section of this article. Next, plug in the charger and let it run while you are looking at the rest of the conversion. The charger should go into its finish mode fairly soon after it's plugged in.

Some chargers are programmed to shut off completely when the pack has reached a certain voltage (2.5 volts per cell x number of cells per battery x number of batteries per series string = finish voltage). If the EV has this type of charger, check the pack voltage immediately after the charger shuts off.

Other chargers go into a "float" mode when the finish voltage is achieved. This float mode has the charger still running at the finish voltage, but at low amperage until the charger is unplugged. If the charger goes into either of these finish modes shortly after being plugged in to a fully charged pack, the charger is OK in the finish part of its cycle. However, if it doesn't go into the finish mode, check the individual battery voltages and see if one or two batteries are lower than the rest. One or more low batteries would keep the battery pack from reaching the voltage necessary to trigger the charger's finish mode. If the battery voltages are very close to the same, there is something wrong with the charger.

The test of the charger's start-up mode takes place after a test drive of at least 10 miles (16 km). Plug the charger in when you get back, and observe the ammeter on the charger. The charger should be putting out 12 to 16 amps on a 120 volt input charger. A 240 volt charger should be putting out 25 to 35 amps. If the charger on the car you are looking at meets these specs and enters the finish mode correctly, it is a good charger. If the battery pack is dead, you have no way to test the charger, and you will have to take the owner's word for its operation.

Instrumentation

Since it is important to know what is going on with your EV, some gauges are required. The conversion should be equipped with at least a voltmeter or state-of-charge meter and a high current ammeter. The voltmeter or state-of-charge meter is the EV's fuel gauge, telling how much energy you have in the battery pack. The ammeter is an energy consumption meter that lets you know how much energy you are using as you drive.

These gauges should be round, automotive-style gauges for maximum readability and accuracy. If the conversion has panel meters like those found on stationary electronic equipment, you might want to replace them with the automotive style gauges. See the *EV Tech Talk* article in *HP85* for an in-depth discussion of EV gauges.

Batteries

The number and type of batteries that are installed in the conversion determine both the usability and desirability of the vehicle. Since changing the battery racks and boxes to fit a different type of battery would be almost the same amount of work as doing the conversion yourself, it pays to buy a converted car that is suited to your needs.

It has been our experience that a nominal battery pack voltage of 72 volts or less is appropriate in the small, lightweight, low speed EVs that are now being called "neighborhood" vehicles. This is not a suitable pack voltage for a steel-bodied conversion that is expected to do battle in traffic on busy main streets or freeways. Battery pack voltages of 96, 120, or 144 volts will give you the speed, acceleration, and range necessary to be safe and comfortable in normal traffic.

The type of battery used in the battery pack is a very important factor to consider when deciding if the conversion EV you are looking at is suitable for your range and performance requirements.

If the battery pack is made up of 6 volt golf cart batteries, you can expect good acceleration and range. If the newer, 8 volt golf cart battery is installed, you will get slightly better acceleration (fewer batteries for the same pack voltage means less weight), but slightly less range. (Range is determined by battery capacity, which amounts to how many pounds of lead you're packing.) Using 12 volt batteries will further amplify the characteristics of better acceleration and less range.

EVs have been built with absorbed glass mat (AGM) sealed batteries, which offer no acid mess and even faster acceleration. They give better acceleration because their different internal design allows them to release their energy more quickly. The tradeoff with these batteries is that they have such a low amp-hour capacity, it is necessary to run two or three parallel strings of the same voltage to get any usable range.

A used conversion may have older model components and batteries, but this need not be a problem if they are of good quality.

The most common AH capacity for 6 V batteries is 230 AH at the 20 hour rate, which is the rate usually quoted by suppliers. For 8 V batteries, 165 AH is the most common capacity. For flooded, 12 V batteries, AH capacity can be all over the map, depending on what kind of 12 V battery is used. For AGM batteries, it's generally only 55 AH. For more detail about different battery types, see *HP72* and *HP74.*

Another concern with the type of battery used in a conversion is what it will cost to replace the battery pack when it has reached the end of its life. Since the 6 and 8 volt flooded batteries are built in large numbers for the golf cart market, they are affordable at US$60 to US$70 each. The 12 volt, flooded batteries are in the range of US$100+ each. But since you only need half as many for the same pack voltage as a 6 volt pack, they are still reasonably priced. The AGM 12 volt batteries are also in the US$100+ price range, and since you need two to three strings of them, the battery pack gets expensive in a hurry.

The lifespan of the battery pack is also important. The 6 and 8 volt batteries are good for $3\frac{1}{2}$ to 4 years if given good care and used sensibly. The 12 volt batteries usually last about 2 years. AGMs only last 1 or 2 years. How often you have to purchase a new battery pack should enter into the decision process when looking at buying a used EV.

If the battery pack in the conversion is suitable for your needs, find out how old it is. The present owner should know. If you want to confirm this, look for the letter-number code stamped into one of the terminals. The letter indicates the month (“A” equals “January,” etc.), and the number is the last digit of the year. So “F9” would translate to “June 1999.”

For an actual look at the battery pack’s condition, ask the seller to have the batteries fully charged when you arrive. Then use a digital voltmeter (DVM) to check each battery in the pack and record the individual voltages and the total pack voltage. Do this test before doing the battery charger finish mode test described earlier. Next, give the EV a good hard test drive, and note the mileage driven. Then check each battery’s voltage and the total pack voltage again immediately after the test drive, and record the voltages.

Compare all of the “before” voltages to spot any batteries that aren’t taking a full charge. (Fully charged is 2.16 volts per cell at 78°F; 26°C.) Look at all the “after” voltages for any batteries whose voltage has fallen significantly lower than the other batteries in the pack. (A difference of 0.2 volts is considered significant.) Compare the beginning and ending pack voltages. If you have a large difference and only drove a short distance, the battery pack is probably close to the end of its useful life.

If the battery pack is so low that the EV can’t be driven or is completely dead, the price of the conversion should reflect the need for a new battery pack.

Two Down, One to Go

I’ve examined two out of the three important areas of your potential used EV purchase. The first was the donor chassis itself, both in terms of the make and model of the chassis, as well as its age and condition. The second area of concern was the electric drive system components that were used for the conversion. With the exception of the batteries, the model of component used is more important than condition, since these pieces don’t gradually wear out like a gas engine does. They either work, or they don’t.

Next time I’ll look at the final area of concern. This is the level of skill, knowledge, planning, and attention to detail that was demonstrated by the builder as he or she installed the components in the chassis.

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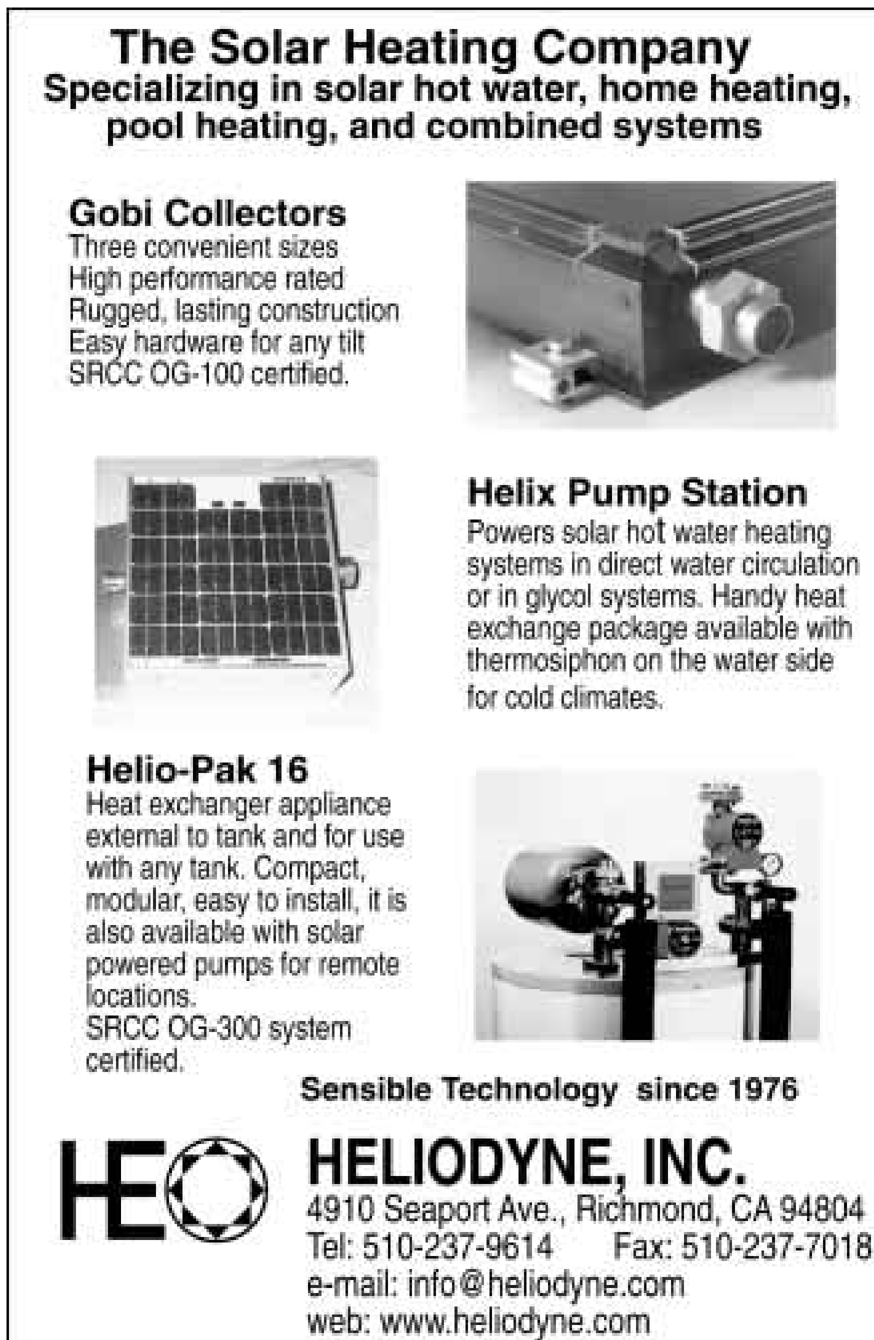
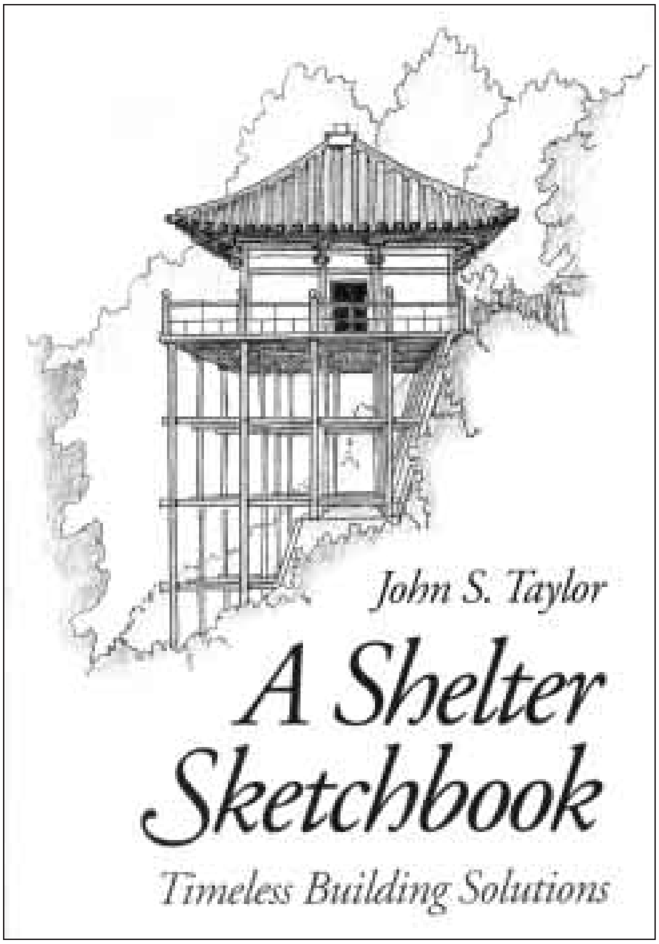
Mike Brown, Electro Automotive, PO Box 1113-HP, Felton, CA 95018 • 831-429-1989 • Fax: 831-429-1907
mike.brown@homepower.com • www.electroauto.com





Reviewed by Richard Engel

When I first picked this book up, I flipped through the pages and thought I'd be done with it in a couple of hours. A week later, I was still poring over the hundreds of detailed and inspiring drawings, and the short snippets of hand-lettered text that make up John S. Taylor's unusual little paperback.

It was originally published in 1983 under the title *Commonsense Architecture,* but has more recently been updated by the author and republished by Chelsea Green. The book is laid out in three sections:

- Protection from the Environment
- Accommodation of Human Needs
- The Building Itself

Subchapters address specific topics, such as staying warm, cooking, and the roof.

The author/illustrator's small but very clear drawings and accompanying text show how cultures all over the world and throughout history have built environments to meet specific human needs, in most cases employing the simplest of technologies in startlingly inventive ways. Who knew that in ancient times Peruvians, Egyptians, and Afghanis were all using similar-looking rooftop wind scoops to direct fresh air into their homes?

In some instances, Taylor takes one step further back in the evolution of architecture to show how animals use "smart" building techniques that take advantage of natural processes. For instance, we see in a cross-sectional drawing of a brush turkey's nest how these birds use waste heat from fermenting organic matter to incubate their eggs.

Taylor has a wonderful eye for building innovations that cut across cultural and historic boundaries worldwide. For example, on a single page he illustrates the basic principles of passive solar design with drawings of a South Dakota farmhouse, Australian termite mounds, ancient public baths in Pompeii, and a pre-Columbian pueblo in New Mexico.

In the introduction, Taylor explains how the book originated as a study in passive solar design, but soon took on a life of its own, evolving to tackle the broad subject of how people everywhere have housed themselves through the ages. Most of us at some time have visited a historic building, or perhaps a traditional village in a developing country, and said to ourselves, "Ah, this is a great idea—why isn't my house built this way?" To read this book is to be confronted by that feeling over and over again. If you're planning to build, expand, or remodel your home, you're sure to find at least a few great ideas you can borrow from *A Shelter Sketchbook.*

Taylor does a fine job of reminding us that today's industrial building techniques, while perhaps the newest and the most high tech, are not necessarily the best methods humans have yet devised to shelter ourselves.

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Richard Engel, Schatz Energy Research Center,
Humboldt State University, Arcata, CA 95521
707-826-4345 • Fax: 707-826-4347
rae7001@humboldt.edu • www.humboldt.edu/~serc

A Shelter Sketchbook: Timeless Building Solutions, by John S. Taylor, 1997, ISBN 1-890132-02-0, 168 pages, softcover, US$18.95 plus shipping from Chelsea Green Publishing Company, PO Box 428, White River Junction, VT 05001 • 800-639-4099 or 802-295-6300
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Wŏrd Pow´ẽr

Renewable Energy Terms

Electrons—Charged Particles

Ian Woofenden

Derivation: From the Greek word for amber, "elektra." Amber is petrified tree resin, which when rubbed with a cloth, builds up an electric charge. This phenomenon led to the word "electricity," and Irish physicist G. Johnstone Stoney coined "electron" in 1891.

When we talk about electric currents in wires, we're talking about the movement of electrons. But what are electrons? To understand that, we have to look at some chemistry basics.

All matter is made up of "elements," materials that cannot be broken down further by chemical means. Hydrogen, oxygen, nitrogen, carbon, and copper are all elements. The complete list of currently acknowledged elements can be found in the Periodic Table of the Elements.

The single unit of an element is called an atom. An atom is made up of three major components—protons, neutrons, and electrons. Protons and neutrons form the "nucleus" or center of the atom, while electrons surround the nucleus.

Protons have a positive charge, electrons have a negative charge, and these opposite charges are attracted to each other. (Neutrons have no charge.) The electrons are racing around the proton, and are repelled from each other. A simplified model is a tiny solar system (and I don't mean a solar-electric system), with the protons acting like a sun, and the electrons acting like planets. In fact, electrons may be more like clouds moving around the nucleus.

The electrons travel in "shells" similar to orbits—each a specific distance from the nucleus. Each different element has a specific number of shells in its atom and a certain number of electrons in each shell. In its neutral state, an atom has the same number of electrons as protons. When there is an imbalance, electrons begin to move in an effort to regain the balance of charge.

If you pick up a piece of copper wire and walk across the room, you've moved the electrons in the wire. Is this movement an electric current? Of course not. The electron movement that we use to power our appliances is the electrons moving while the protons don't. This is what we call an electric current or "amperage." An amp is one coulomb per second, and a coulomb is about 6 billion billion electrons.

Heat, friction, pressure, light, magnetism, and chemical activity can all move electrons through a circuit. In PV modules, light dislodges electrons. In alternators, magnetism in motion moves electrons. And lead-acid batteries move electrons via a chemical reaction. The other three ways are less common. Piezoelectricity (pressure) is used in stove and grill igniters. Thermoelectricity (heat) is used in the safety shutdown mechanism of some on-demand water heaters. And friction is mostly used for shocking yourself on doorknobs.

When you flip a light switch, the bulb lights up almost instantaneously. So you may think that the electrons are traveling very quickly. In fact, an electric current is quite slow, like "a river of warm putty," as science misconception maven Bill Beaty says. The electrons may travel less than an inch per minute in DC; in AC, of course, they just wiggle back and forth.

It's the energy transfer that's nearly instantaneous. This is easier to imagine when you remember that electrons are not something that we have to fill our electrical pipe with. Electrons help make up the pipe—they are part of the metal in the wire. We're simply jostling them along in the wire when we flip the switch and energize the circuit.

Think about what happens when you pull on a rope. Your pull is felt at the other end almost immediately. The rope is like electrons, which move slowly. The "pull" is like energy, which moves almost instantaneously.

So electrons are charged particles that are a basic part of all matter. When they move in relation to protons, an electric current results. Electrons are tiny—one coulomb of electrons in copper is about the size of a grain of salt. But their movement powers our homes. In future columns on conductors and insulators, I'll cover how they behave in different materials.

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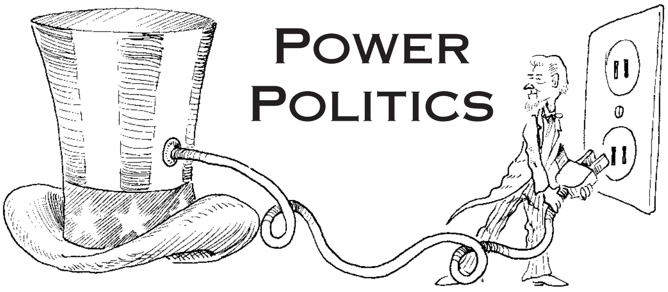
Ian Woofenden, PO Box 1001, Anacortes, WA 98221
Fax: 360-293-7034 • ian.woofenden@homepower.com



Thais Stick Together Against Coal

Michael Welch

"Imagine if an electricity company tried to build a dirty coal fired power plant on a rural beach near a national park in, say, southern California in 2002. Now, imagine if that coastal area was a breeding ground for whales and dolphins. Most likely, the company would be laughed out of the state." So starts a Greenpeace brochure entitled, "Edison Out: The Struggle to Stop Coal Fired Power Plants in Bo Nok and Ban Krut, Thailand."

The guilty party is Edison (aka Edison International), the parent company of the huge utility, Southern California Edison (SCE). It is also the parent of Edison Mission Energy (EME), another large company responsible for building and owning power plants throughout the world. EME has 76 plants, with a total capacity of 19,000 MW, in places like Australia, Thailand, Italy, Puerto Rico, New Zealand, and the Philippines. They have coal mining interests in Australia and Indonesia. They would own about 40 percent of a 734 MW plant proposed for Bo Nok, in Thailand's Prachuap Kiri Khan province.

A 1,400 MW coal plant is planned for nearby Ban Krut, also in the Prachuap province. This proposed plant would be owned by a consortium of electric and development companies from Japan and Hong Kong.

Corporate Sleaze

Edison International is no stranger to corporate sleaziness. SCE has been teetering on the edge of bankruptcy after the PG&E and Edison restructuring scandals in California, and the related Enron fiasco. Like PG&E's parent corporation setting up its utility subsidiary for bankruptcy, Edison has managed to insulate itself from its subsidiary's financial woes.

Edison's Laughlin, Nevada coal plant is another offender—possibly the number one polluter in the U.S. Too few environmental controls exist on the plant, and it is the largest single source of greenhouse gases in North America. It is responsible for much of the acid rain that reaches the northeastern U.S., and its smog impacts visibility at Grand Canyon National Park. This same plant pumps 3 million gallons of "ancient" water a day out of the local aquifer, one of the few water resources in the region.

But this article is not just about the bad things that soulless, multinational corporations like Edison do in the name of profit. Rather, this is a story that shows how the locals in Thailand are doing a great job of grassroots organizing to overcome odds stacked against them.

The Thai government has been avoiding promised announcements about the future of the coal plants. Speculation is that the prime minister has decided to let the plants die quietly by missing approval or financing deadlines, rather than make a negative public decision. This nonaction is the politically expedient thing to do.

Of course, no project like this is dead until the developers have thrown in the towel. A lot of money is at stake. Huge profits and U.S. subsidized loans make projects like this look good for developers. In an attempt to sway Thai public opinion, Edison spent more than US$1.3 million on ads and public relations campaigns.

Citizens Not Buying It

While local manufacturers and the Thai government may have been influenced by such campaigns, the Thai populace is not fooled. In 1995, when the idea of Thai coastal power plants was first mentioned, 4,000 citizens protested. In 1997, the Love Bo Nok group was formed when it was disclosed that a coal plant was really being planned, and not the relatively innocuous golf course that villagers expected on that site. Several more protests with thousands of participants were held all the way into 2002. In January, 533 academics signed a petition calling for review of the plants' power purchase contracts, saying that the projects represent an example of "policy-based corruption."

The Thai public was further outraged when another coal power plant in Thailand leaked toxic gases, causing hundreds to be hospitalized, killing livestock, and creating breathing problems for 42,000 people. Then under pressure from Thai and U.S. NGOs, the Export-Import Bank of the United States (EXIM) withdrew the Bo Nok plant from funding consideration.

Thai citizens were further mobilized when reports surfaced that U.S. Ambassador to Thailand Richard Hecklinger had been interfering with the public debate on this project, and pushing the coal project on behalf of Edison Mission Energy. Of course, the U.S. government denied meddling in Thai affairs.

Greenpeace, Friends of the Earth (FOE), and other international environmental organizations got involved in the efforts. FOE and other NGOs worked to block U.S. subsidized loans from EXIM. Greenpeace took part in an information campaign to focus Thailand interest on renewable energy and cleaner electricity sources. In early May, they donated two photovoltaic systems—one to a Ban Krut temple and the other to a Bo Nok school—and received the blessing of Buddhist monks for doing so.

“Thailand does need energy—energy from the sun, the wind, and the ocean. But not from dirty, old fashioned technology dumped on them by big international companies like Edison,” said Greenpeace International’s executive director, Gerd Leipold. “If we are to prevent dangerous climate change, we need a massive global boost in these renewable technologies.”

The Thai government seems open to RE possibilities, having recently passed a very favorable net metering law allowing system sizes up to 1 MW. Thai officials have a lot to learn about that sort of thing—they rely on fossil fuel and hydroelectric for 99 percent of their electricity. Not much on-grid RE—yet.

Real Effects

Climate change is not the only environmental factor involved. More personal to the Thai villages surrounding the plant is the marine life. The Gulf of Thailand is rich in fish, whales, and other marine mammals. Villages on the Thai coast rely on seafood for subsistence, as do the whales that inhabit the area.

The Thai Science Ministry reported that a minimum of 550 minnows per minute could be drawn into the Bo Nok coal power plant’s intakes along with the water for the generator and cooling. “That would affect the marine ecosystem severely, and this was not taken into consideration in either of the EIA (environmental impact assessment) reports for the two projects,” said Suphavit Piamphongsarn, head of the ministry’s investigation committee. “This figure we have is the minimum. It’s possible that the real impact would be more.”

After running through the plant, the very same water would be expelled back into the gulf, but it would be heated and possibly contain contaminants, further endangering sea life. Other negative impacts could include wetlands damage, health effects, and loss of farming income from acid rain and ash fallout. The locals realize that all these problems are real. And the locals are proving to the world and their own government that appropriate action pays off.

Thai politicos are more concerned about the economic realities of the plant than its effects on the environment. When two local NGOs, TERRA and the Alternative Energy Project for Sustainability, studied the plants’ economics, they discovered errors in electricity demand forecasts. They were then able to come up with compelling arguments that ultimately caused the prime minister to take another look. The bottom line is that the electricity isn’t needed, and the plants are a bad deal for Thai ratepayers. The rest of the world should feel empowered by the results of Thai grassroots efforts.

More Sleaziness Back at Home

In my research for this article, I came across yet another southern California utility that intends to exploit a third world community with its dirty power plants. Sempra Energy, the parent company of San Diego Gas & Electric, is planning to build gas pipelines, gas power plants, power transmission lines, and an LNG plant just south of the California border in Mexico.

The idea is to take advantage of Mexico’s lack of environmental regulation and labor laws, and still have access to selling power in lucrative California markets. For more details visit: www.cleanenergynow.org /cleanenergynow/sempra_bad.html on the Web.

Vote with Your Pocket

Just to keep your conscience clear, you might want to sell your shares in Edison, Sempra, and other similar companies. No sense in profiteering from the exploitation of the environment and the third world. You may not even know that you are invested in these kinds of money-sucking corporations.

For example, the top few investors in Edison include Capital Research and Management Co., State Street Corp., J. P. Morgan Chase and Co., Capital Guardian Trust Co., and Putnam Investment Management, Inc. All of these companies have publicly available investment plans or mutual funds that many innocent folks invest in without knowing what their money is being used for.

Check out your investments—you may be surprised. And if you participate in employer retirement programs, you can have a huge influence over where they invest. Most large employers have employee relations departments that will pass your opinion on to the investment policy makers. Many retirement programs have inadvertently spawned grassroots watchdog groups that have an effect on where their retirement money is invested.

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Michael Welch, c/o Redwood Alliance, PO Box 293, Arcata, CA 95518 • 707-822-7884
michael.welch@homepower.com
www.redwoodalliance.org

Towards Ecological Recovery & Regional Alliances (TERRA), 409 Pracharatbampen Rd., Soi Rohitsook, Huay Kwa, Bangkok 10310 Thailand • 66-2-691-0718
Fax: 66-2-691-0714 • terraper@ksc.net.th
www.terraper.org

Alternative Energy Project for Sustainability, 801/8 Soi Ngamwongwan 27, Ngamwongwan Rd., Meung, Nonthaburi 11000 Thailand • 66-2-591-5076
Fax: 66-2-952-7606 • aeps@ksc.th.com

Greenpeace USA Clean Energy Now! Campaign, 75 Arkansas St., San Francisco, CA 94107
415-255-9221 • Fax: 415-255-9201
kristin.casper@sfo.greenpeace.org
www.cleanenergynow.org

Greenpeace Southeast Asia, Room A201, 60/1 Monririn Building, Phaholyothin soi 8 Road, Phayathai, Bangkok 10400, Thailand
662-2727100-2 • Fax: 662-2714342
greenpeace.southeastasia@th.greenpeace.org
www.greenpeacesoutheastasia.org

Friends of the Earth, 1025 Vermont Ave. NW, Washington, DC 20005 • 202-783-7400
Fax: 202-783-0444 • foe@foe.org • www.foe.org

Incentives: Buydown vs. Performance Based

Don Loweburg

The most successful state-run PV incentive program in the United States today is the California buydown. This program provides a rebate of up to US$4.50 per watt of system capacity, decreasing the final system cost to the customer by about 50 percent.

The buydown, plus net metering, creates a simple payback time of seven to fifteen years, depending on the customer's utility rate schedule. For details about simple payback and rate schedules in California, read my columns in *HP85* and *HP87.* And for a broader examination of the payback issue and the California buydown, read Allan Sindelar's "Payback on RE?" in *HP87* and Eric Hansen's "State Funds Available for RE Systems in California" in *HP82.*

The design of the California buydown program was a collaborative effort. During the development of the current program, there was much discussion of performance-based incentive programs such as those in Germany and Japan. Unlike the single-meter, net metering systems in California and 34 other states, programs in these countries use two meters. One meter records consumption while the other records PV production. The customer pays the full price for the PV system up front. A premium price is paid for the PV production, and the customer recovers the cost of the PV system over time.

After considerable debate, a majority of the discussion participants opted for a buydown program. It was agreed that making systems more affordable was of primary importance, and that a two-meter system was administratively cumbersome compared to a single net metered approach.

Though we are many years into a very successful program, there are those who continue to lobby for a performance-based program. Rewarding performance, rather than installed capacity, they argue, will result in better installed systems.

One of the arguments forwarded in support of this premise is the supposed poor performance of systems installed under the California buydown program. This criticism is substantially unsupported. It is agreed that during the first two years of the rebate program, random field samplings revealed problems in about 25 percent of installed systems. This is an unacceptable figure. However, there are facts that should temper our interpretation of this number.

Many of these early rebate systems were Y2K systems with battery storage. These systems are significantly more complex than nonbattery systems and therefore prone to more problems. Many early systems were installed by do-it-yourselfers, and in many cases, system performance expectations were out of line with reality. Also, not all the problems were performance problems.

In spite of the problems detailed in the early technical samplings, a report commissioned by the California Energy Commission (CEC) in early 2000 reported 90 percent customer satisfaction. These customers would "recommend a PV system to friends and neighbors."

Today, over two years since the initial field survey and with thousands of systems installed, things have changed substantially. First, most installations are simpler, nonbattery systems that are less prone to installation errors. Second, a higher percentage of systems are installed by professionals. Third, system output performance is now better understood, and competent installer-designers can provide accurate performance information to the customer.

Customers should demand performance information before signing a contract. Since most inverters installed today also include KWH metering, customers can easily verify system performance. And since customers today are installing PV systems primarily to reduce high utility bills, these customers are very performance oriented. They expect to get what they pay for.

In no way am I suggesting that the industry can be complacent or ignore installed system quality and performance. Responsible parties in the industry must support certification and training programs so that competent PV designers and installers are available. Independent agencies must test components and system performance. It is no longer acceptable to rely on manufacturers' data alone, data that is too often massaged by corporate marketing departments.

Those who publicly impugn installed system quality as a tactic to forward a favored incentive model may not be serving themselves or the industry well. Installed system performance is a function of good hardware, good design, and good installation. It does not depend on a particular incentive model.

The California buydown program is working very well. Providing a rebate to the customer makes the PV system immediately more affordable. The customer then continues to benefit by lowered utility bills. The PV system provider benefits from significantly increased sales, which results in increased volume for manufacturers. This program has created a dynamic economic engine for the PV industry. Why try to fix something that isn't broken? Especially when the rationale for the fix is based on the erroneous fiction of "poor system performance."

Inverters of the Future

Today when we say inverter, we think of a box, usually wall mounted, that has PV modules connected to it. Discrete inverters used for photovoltaic systems have led the way in inverter technology due to the global surge in the market for renewable energy. An inverter's basic function is to change electrical energy from one form to another. As a power conversion technology, inverters are already being used in many other applications, such as motor speed controls, pumps, fuel cells, and even engine generators and microwave ovens. In these applications, the inverter may not be visible or even recognized. These inverters are "embedded" in a variety of devices.

Along with the anticipated proliferation of discrete inverters, we can expect a growing number of embedded applications. The pattern of development is analogous to computers. Inside every computer is a microprocessor, itself a computer on a chip. Not only is there a computer in your computer, there is a computer in your phone, car, TV, VCR, stereo, and the list goes on. The growing market for renewable and distributed energy, coupled with the need for energy efficiency, will push for a new generation of inverters, discrete and embedded. They will be based on the development of an "inverter on a chip," and we can expect them to be everywhere.

The nature of this next generation inverter and how it may be developed is the topic of a recently released white paper published by Sandia National Laboratories. Titled "Status and Needs of Power Electronics for Photovoltaic Inverters: Summary Document," it begins, "Photovoltaic inverters are the most mature of any DER (distributed energy resource) inverter, and their mean time to first failure (MTFF) is about five years. This is an unacceptable MTFF, and will inhibit the rapid expansion of PV." The authors assert that the industry must move to a new level, a quantum jump if you will, and achieve reliability or MTFF of ten years. This cannot be achieved by continued incremental improvements of current design and practices.

Today's inverter designs have evolved from the basic "chopper" or switch design along two pathways. One is smarter switching control and logic, and the other is improved switching components. Future designs, Sandia reports, will use digital signal processing (DSP). A DSP chip translates signal information into mathematical values. It digitizes the waveform. Once digitized, the waveform can be processed, evaluated, and modified in very short time periods, since the DSP chips are fast.

By being able to gather and feed information back in real time, the output signal can respond quickly to a wide range of situations. These include changes in load, changes in input waveform, and internal inverter changes (temperature and component aging, for examples). Improved control responsiveness will improve reliability.

From a manufacturing perspective, a single DSP chip could serve a wide range of inverter applications. Manufacturers could choose, with software, which DSP features to implement. By having a single universal "inverter on a chip," volume production should reduce cost while significantly improving reliability.

The second pathway for improving inverter reliability while lowering cost discussed in the Sandia report is improvement in the output devices themselves. These are the electronic components that handle the power. Think of the DSP chip as the brains, and the output module as the muscles. With the growing inverter market, we can expect to see tailor-made output devices for this application. Made-to-order power electronics, designed with software, can provide the next generation of power modules with the reliability required for distributed energy applications.

A third area needing standardization is the software that will control the inverters. Sandia suggests that developing a set of software modules, tailored to address the features of the DSP chip, would eliminate the need to write software for individual inverters. Again, the manufacturing cost will be lowered and reliability increased.

Lower cost, higher reliability inverters are certainly desirable goals. Sandia thinks the time has come for an initiative like the one above because of the growth in the residential PV market. Now, if we can only survive the growing pains (see *IPP88*) while it takes place.

Change Is the Norm

The recent purchase of Siemens Solar by Shell Renewables continues the trend toward ever larger corporate players in RE. Among the large corporate players, there seems to be a differentiation into two camps. On the one hand, we have the large traditional energy companies like BP Solar and Shell Renewables. In the other camp, we have companies like Kyocera, Schott, and Sharp.

This latter group is not traditionally associated with energy. Sharp is an electronics company and very large manufacturer of PV modules in Japan. Kyocera has a background in specialty ceramics and high tech electronics, and manufactures modules as well. Schott is focused in specialty glass products, and can't be too far from involvement in module manufacturing. There are also independent PV manufacturers like AstroPower and ASE. I take some comfort in the diversity offered by these nontraditional energy companies, hoping that they will provide competition and balance.

While large corporations now dominate the manufacturing side of RE, the delivery end is still dependent on the skills of the installers and designers of systems. Even when large manufacturers offer complete systems (I'm not referring to the lame kits currently marketed, but rather engineered systems based on inverters and modules manufactured by the same company that are intended to be used together), there will continue to be a need for trained installers.

As we look forward to a very bright and dynamic future, those of us who are established need to ask ourselves what we can do to facilitate this transition. Certainly one primary action is to grow our own companies. In the process, we are training workers who, like most of us, are learning on the job. I do foresee a time when other avenues of entry into the field will be required. Training and certification for installers and designers will eventually be part of this industry. And there is, understandably, contention around the need for and character of any such program.

A recent NABCEP survey, seeking input from a wide range of industry players including manufacturers and installers, provided some interesting results. It was anticipated that installers—for the most part independent, small companies—would have the greatest resistance to certification. It turned out that this group was the most responsive, and provided many constructive comments.

A big surprise came when a major solar trade organization in this country, initially unresponsive, failed to endorse the concept. Behind their lack of engagement, I found out later, was the fact that major module manufacturers did not support this initiative. It would be unwise to name these companies at this time, since NABCEP is seeking support from all sectors, and is actively seeking constructive input. I am sure there will be continued work and discussion concerning certification.

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Don Loweburg, Independent Power Providers (IPP), PO Box 231, North Fork, CA 93643
559-877-7080 • Fax: 559-877-2980
don.loweburg@homepower.com • www.i2p.org

Status and Needs of Power Electronics for Photovoltaic Inverters: Summary Document (SAND2002-1085), U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161 • 800-553-6847 • Fax: 703-605-6900
orders@mtis.fedworld.gov • www.ntis.gov

The North American Board of Certified Energy Practitioners (NABCEP), PO Box 260095, Highlands Ranch, CO 80163 • Phone/Fax: 720-344-0341
wparker@ispq.org • www.nabcep.org

Adopt a Library!

When Karen and I were living with kerosene lamps, we went to our local public library to find out if there was a better way to light up our nights. We found nothing about small scale renewable energy.

One of the first things we did when we started publishing this magazine thirteen years ago was to give a subscription to our local public library.

You may want to do the same for your local public library. We'll split the cost (50/50) of the sub with you if you do. You pay $11.25 and Home Power will pay the rest. If your public library is outside of the USA, then we'll split the sub to your location so call for rates.

Please check with your public library before sending them a sub. Some rural libraries may not have space, so check with your librarian before adopting your local public library. Sorry, but libraries which restrict access are not eligible for this Adopt a Library deal—the library must give free public access. — Richard Perez

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More Grid Connection Details—

Grounding, Backfed Breakers, & PV Disconnect

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

In *Code Corner* for *HP89,* I discussed some general requirements for connecting a PV system to the grid. This time, I'll go a little deeper into the grounding and intertie requirements by applying some of the material covered in previous columns to a utility-interactive system.

Grounding for a utility-interactive PV system starts at the modules and ends at the ground rods, with all of the balance-of-systems equipment in between. The *NEC* requirements for grounding are some of the most complex and confusing requirements in the code.

Equipment Grounding

The instruction manual for a PV module will tell where and how the module frame must be grounded. Hardware is usually supplied to connect a bare copper conductor to the module frame at a designated location. Usually the hardware consists of a stainless steel, self-tapping screw and a stainless steel washer.

The screw is used in a marked hole in the module frame to cut threads into the aluminum frame. The tight threads are needed to penetrate the normal oxidation or intentional anodizing on the surface of the aluminum, which can be a partial insulator. The washer is used to isolate the copper wire from the aluminum surface to minimize galvanic corrosion. Just bolting the module frame to a grounded rack does not meet the code requirements for a good, long lasting, electrical connection for grounding. The tough aluminum anodizing or oxide film makes it difficult to achieve or maintain a durable, electrically conductive, bolted connection.

The equipment-grounding conductor for a PV module must be about the same size as the circuit conductors for the module (*NEC* 690.45). The actual ampacity of the equipment-grounding conductor must be 125 percent of the short-circuit current (Isc) of the module. If the system has a PV ground-fault protection device (*NEC* 690.5), either built into the inverter or as an external unit, the equipment-grounding conductor may be sized according to *NEC* Section 250.122—see the table.

If there is any possibility of physical damage, the equipment-grounding conductor should be increased to a #6 (13 mm^2) conductor, and possibly be provided with some sort of mechanical protection (250.120[C]). These requirements generally indicate that a #10 (5 mm^2) conductor would be suitable for most installations if protected from physical damage. The equipment-grounding conductor should be run with and in near proximity to the circuit conductors (if in free air) or in the same conduit with the circuit conductors.

If the system design uses a source circuit combiner box near the modules (rather than a combiner circuit in the inverter), the equipment-grounding conductor from that box to the inverter will have to be increased in size based on the short-circuit current of the combined PV output circuit. Again, the 125 percent Isc rule applies if no ground-fault device is used, and *NEC* 250.122 is used if an *NEC* 690.5 ground-fault device is in the system.

If long distances are involved between the PV array and the inverter and the conductors have been increased in size to minimize voltage drop, the equipment-grounding conductors must also be increased in size proportionately. However, they never have to be larger than the size of the circuit conductors.

If you have distances sufficient to require oversizing the current carrying conductors due to high resistances, the equipment-grounding conductors will also have high resistances. They must be oversized to lower the resistance in a fault circuit. In most cases, it is backfed currents from the battery, line-tie inverter, or from parallel strings that make up the high available fault currents that trip the overcurrent devices.

Equipment grounding of other circuits (AC and DC) should follow *NEC* 250.122, which requires the equipment-grounding conductor to be based on the rating of the overcurrent device protecting that circuit. The table shows some typical values for copper conductors. The larger sizes would be associated with utility-interactive systems that have battery backup supplies with battery cases that must be grounded.

Equipment-Grounding Conductor Size

Overcurrent Device Size (Amps)	*Conductor Size (AWG)*
15	14
20	12
30	10
40	10
60	10
100	8
200	6
300	4
400	3
500	2

System Grounding

Normally, AC and DC system grounding is handled inside the utility-interactive inverter. This is particularly true of inverters that include the *NEC* 690.5 ground-fault protection device. These inverters often provide grounding lugs or points for connecting external grounding conductors. In most cases, these grounding connection points are equipment-grounding points (tied to the chassis) that also serve as system grounding points for connection of the grounding electrode conductor to the grounding electrode (usually a ground rod).

In an installation where there is an existing AC load center and utility service entrance, this grounding point in the inverter can be connected to the grounding bus bar in the existing AC load center. The grounding bus bar in the AC load center is usually where the grounding electrode conductor is attached. For want of a better name, I would call this conductor a ground-bonding conductor. It should be sized as the larger of the conductors specified by *NEC* 250.106 (usually #6; 13 mm^2), or the largest equipment-grounding conductor in the system.

The actual name and size of this conductor is not specifically called out in the code. Since it may have to carry fault currents, as well as serve as a portion of the DC grounding electrode conductor, the size specified above should meet all code requirements. This bonding conductor should be routed in close proximity to the AC circuit conductors from the inverter to the AC load center.

It would also be possible to run a grounding electrode conductor from the grounding point in the inverter to a separate ground rod, and this ground rod should be bonded to any existing AC ground rod. If this approach is taken, an AC equipment-grounding conductor should still be run between the inverter and the AC load center, and sized per *NEC* 250.122.

Backfed Breakers

The National Fire Protection Association (NFPA) has issued an informal opinion (just as good as a formal one, but you get it quicker and not in writing) that the backfed circuit breakers used to connect a utility-interactive inverter to the load center must be clamped.

"Clamped" means that the individual circuit breaker must be attached to the load center back plane with a screw or other device specifically made for the purpose of preventing the breaker from being inadvertently pulled loose from the bus bars of the load center. The screw or other device is supplied by the manufacturer of the load center. Many load centers have no provisions for clamping, and therefore are not suitable for backfeeding.

NEC 690.64(B)(5) requires that such breakers be "identified" for backfeeding. According to Underwriters Laboratories (UL), an identified breaker is one that does not have terminals marked "line" and "load." The clamping requirement comes from *NEC* 408.16(F) in Chapter 4 of the code, one of the general chapters. A proposal to modify Article 690 will be submitted for changes to the 2005 *NEC*. But until then, the Chapter 4 requirement is the governing requirement, since nothing in Article 690 overrides it or even conflicts with it.

Most inspectors will accept the following reasons for not clamping a breaker being backfed from a utility-interactive inverter:

- The plug-in breaker will immediately become de-energized (dead) when the breaker is accidentally unplugged from the load center because of the anti-islanding circuits built into the listed inverter under UL Standard 1741.
- The front panel on most load centers actually clamps all circuit breakers to the bus bars, and this panel cannot be removed without a tool.
- Access to the inside of any load center connected to a utility feeder allows an unqualified person to easily come into contact with any exposed bus bar and the main feeder wires.

Here are several solutions if the inspector requires that the backfed breaker be clamped:

- Determine whether the existing load center has a kit that can be used to clamp breakers into position, and use that kit.
- Install a second service panel disconnect that bypasses the existing load center, as described in *HP89.* This service panel can be purchased from a number of vendors, and has only a single breaker that is bolted in place.

- Install a fused disconnect as the second service panel disconnect.
- Install a new load center that does have a breaker that can be clamped.

In the second and third options above, the second service panel or fused disconnect will have to be marked as being suitable for use as "service entrance equipment." After the utility power has been turned off (usually by the utility), the second service panel or fused disconnect will have to be connected in parallel with the existing lines between the meter and the original service panel.

PV Disconnect Location
A new requirement in Article 690 of the 2002 code, *NEC* Section 690.14(C)(1), is that the PV disconnect must be at the point where the conductors from the PV array first enter the building, or immediately inside the building at that point. Furthermore, the disconnect must be in a readily accessible location. Bathrooms are excluded as a possible location.

These requirements are really not new, and are very similar to the requirements for an AC utility service disconnect as described in *NEC* Article 230. Generally it means that it will no longer be possible to penetrate an attic and run cables through the house to a disconnect located inside the house near the inverter. Normally, the conductors from a roof-mounted PV array must be run down the outside of the building to a readily accessible (no ladders, locked doors, or limited access) location where the PV disconnect is to be mounted.

If the utility-interactive inverter is mounted outside on the wall and has the PV disconnect built in, that is acceptable. Mounting the inverter and built-in disconnect immediately inside the building at the point of penetration should also be acceptable. Installations requiring a remote location for the inverter could use a circuit breaker or fused disconnect on the outside of the building, and then have the inverter placed wherever required. There may be a requirement for a second PV disconnect near the inverter if a disconnect is not built into the unit.

For those inverters having multiple source circuit combiner functions, the source circuits may need to be combined in an external combiner box. Then the combined output is run through the readily accessible disconnect switch (one pole), and the PV output circuit is connected to the remotely located inverter. If this is not done, there is a requirement to have a multiple pole disconnect switch—one for each source circuit—mounted in a readily accessible location.

Proposals for the 2005 *NEC*
Proposals for the 2005 *National Electrical Code* are due by Friday November 1, 2002. The clock is running. The PV industry will be collaborating through the Industry Forum to write and substantiate a number of well-justified proposals in the next few months.

In the past, these proposals from the PV industry have had the highest adoption rate of any proposals submitted by a single group. Wrenches are encouraged to participate. E-mail your proposals to me with your substantiations as soon as possible. We will get them into the proper format, and circulate them throughout the industry via e-mail for comment. Normally we have our proposals reviewed by UL and others on the Code Making Panel to ensure that we get the votes needed to pass. Of course, you can always submit directly to NFPA—see the form in the back of the *NEC.*

Even if you don't want to submit a proposal, but do want to participate in the review process before submittal, send me your name, phone number, and e-mail address, and we will put you on the list.

Questions or Comments? If you have questions about the *NEC,* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work is supported by the United States Department of Energy under Contract DE-FC04-00AL66794. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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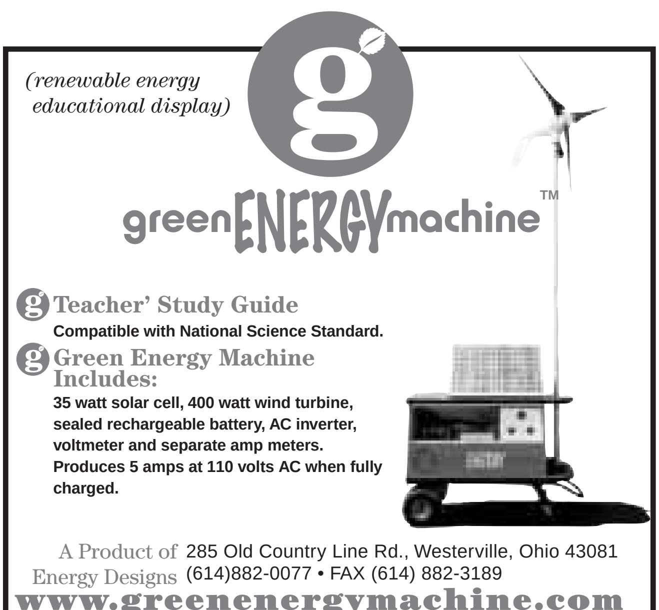
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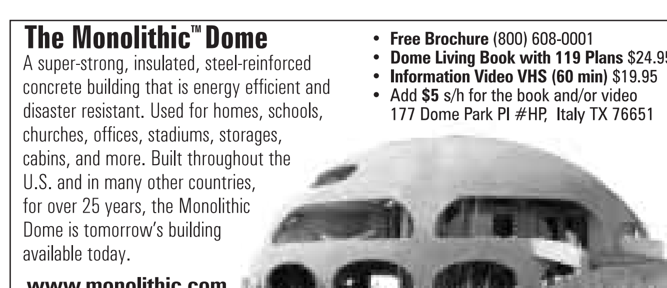
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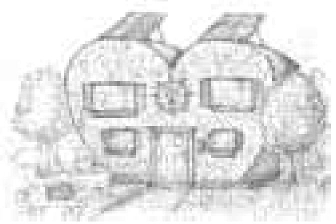

Kathleen Jarschke-Schultze

As a teenager and young adult, I listened to a lot of radio. I had never talked on a radio though. I had a friend who was really into citizens band radio, but I thought that was kind of weird. I never realized then that radios would play a big part in my life.

First Contact

Bob-O and I met and courted through the mail. (That's a whole 'nother story.) He told me he was a ham radio operator. I vaguely knew what that was. After we had exchanged letters for a while, he suggested that I could actually talk to him at Starveout (the extremely remote cabin where he lived) by ham radio. He told me the name and address of a ham in Napa, where I lived. If I would go to this ham's house between 6 and 7 PM, he could connect me with Bob-O over a 75-meter net group called Western Public Service System.

I went there, and that was the first time I spoke to Bob-O. It seemed awkward since you needed to say "Over" at the end of each transmission. The conversation went something like:

"Can you hear me? Over."

"Yes, I can hear you fine. Over."

"This is pretty cool, huh? Over."

"I'm so glad to be able to talk to you. Over."

Well, you get the picture. It was not a long conversation, but a momentous one.

Hamming It Up

Soon after joining Bob-O at Starveout, I started studying for my ham license. I was already using the 11-meter CB radio when I was out driving on the river road, and from the cabin whenever I needed it. I had become very comfortable talking over a keyed microphone. The first ham license back then was called a Novice ticket. I had to learn Morse code at five words per minute and be tested on that. I did, I was, I passed, and received my call letters from the Federal Communications Commission (FCC). I became KB6MPI.

For our honeymoon, we went to a Hamfest in Seaside, Oregon. While there, on the spur of the moment, I took the test for the next grade ham license, Technician. I missed it by three questions. We went home, and I studied some more. Bob-O made up a song so I could remember the frequencies each ham license allows you to use. He had me do the math and build a Yagi antenna. I took the test again. Again I didn't make the grade. I studied even more. I made sleep tapes for myself that I listened to awake and asleep.

I drove out to the coast, three-and-a-half hours away, which was the closest place to be tested. There in the basement of the sheriff's office, I took the Technician's test for the third time. This time I passed it. I had a license to use 2-meter radio. Although I could have received new call letters at that time, I chose to remain KB6MPI.

KJS Phone Home

Several years after I moved to the river, Bob-O set up a 2-meter phone/radio for us at Starveout. We had a base unit hardlined to a phone connection at a friend's house a couple miles from Forks of Salmon. We put up an antenna there also. With 2-meter radios in each of our rigs and the cabin, we could access the phone from wherever the antenna signals could reach.

After the system was first set up, whenever the phone rang at our house, it would also ring at Glady's house. Glady was the Forks postmaster and had held that position since the year I was born, 1953. You could say that by being postmaster at the tiny Forks post office, she had a hand in Bob-O's and my courtship.

Bob-O called the local phone company and got ahold of a knowledgeable, friendly technician. When they had discussed it thoroughly and Bob-O had tried all the things the tech recommended, the problem still persisted. Finally, weeks later, the guy says, "You know, once when I was working on a very rural phone system in Mexico, we ran into a problem like this because the phone system was set to ten pulses per second instead of the normal twenty." That indeed turned out to be the case, and the problem was solved.

We had to get microphones that had numerical, touchtone keypads on the back for each 2-meter radio. To get a dial tone or answer a phone call, we would have to hit the star button and then the two button. This would open the line. After a call, to close the line, we would again press the star button, then the two button.

Since our side of the phone had a handheld microphone, like a CB radio, only one side of the conversation could be spoken at a time. In other words, both of you could not talk at once.

My mother, fueled by her desire to talk to me on a regular basis, grasped this concept quickly, and became quite adept at it. She also became experienced at dealing with skeptical phone operators. I believe she came to relish it.

To call into the Salmon River region from the outside world, you had to follow a certain procedure. First, you needed to convince the usually disbelieving phone operator that they could, and, indeed, had to connect you to "the Fort Jones operator." It was best to just give that operator the whole sequence of dialing marks and routing numbers. It would take a while for them to realize that you weren't joking. Eventually, they would believe that there was such a person, and finally connect you. But operators would sometimes hang up on what they thought were prank calls.

From here, the process speeded up. The Fort Jones operator was used to the rural phone system and knew what to do. You would give her the special dialing marks and routing numbers, too. For Forks of Salmon, they were 888192916063181, then our number, toll station 4740. As you might guess from the degree of difficulty, Mom was my only regular caller.

Emergency Phone

Because we had the only phone for miles in any direction, our phone became the emergency contact phone for the community members around us. Sometimes the message was brief and easy to relay. After a short phone conversation, the radio message would go out.

"Indian Creek, Indian Creek, this is Starveout for relay."

"I'm here, Starveout, let's go up."

After moving off channel 18, the road channel, to channel 23, the talk channel, the conversation would continue.

"Indian Creek, you here yet?"

"I'm here, what's up?"

"Good news, Sarah! Your sister had twins, a boy and a girl. Everyone is excited and doing fine. Call when you can, Auntie."

"Thanks, Kathleen. I'm going to tell Rex. Indian Creek out."

"Starveout out."

Sometimes the relays were distressing and more complicated. A family member would call us seeking their relative, having been given our number in case of an emergency. I would have to explain how the phone/radio conversation worked. I would sit with a microphone in each hand—one for the phone/radio and one for the CB. After contacting the river person, I would tell the phone person to go ahead. Whatever they told me, I would repeat directly into the CB mike. I became like a translator, just repeating what was told to me by each party, trying to be an invisible part of the conversation.

I remember one particularly desperate call, late one night. To this day if the phone rings in the middle of the night, I think it's bad news. Fran's sister called from New York. I put out the late night call on the CB.

"Main House, Main House, wake up! This is Starveout with an urgent relay. Main House, Main House, wake up, Main House! This is Starveout with an urgent relay."

Someone at Main House answered and woke Fran up. As soon as she was on frequency, I told her sister to go ahead.

"Fran, something terrible has happened. Swifty's been in a car accident, and he's hurt pretty bad."

Swifty was Fran's husband. I repeated it into the other mike. There was a pause, then:

"Where is he? Is he going to live?"

Key and repeat.

"He's in the hospital here. We don't know yet. He has a lot of injuries. His chest. His leg."

Key and repeat.

"I'm coming out there. I'll leave tomorrow."

Key and repeat.

"Mom bought you a ticket and it's waiting at the airport for you. I'll see you soon. I love you, take care."

Key and repeat.

"I love you too. I'll be there as soon as I can. Good-bye."

Key and repeat.

"Hurry. Good-bye."

Key and repeat. Hang up phone radio.

From Fran, "Thanks, Kathleen."

"I'm so sorry, Fran. I hope he's going to be okay. Good night. Starveout, out."

"Main House, out."

Several months later and still limping, Swifty returned to the river.

It was after this that I realized people’s lives were passing through my hands. Births, deaths, anniversaries, graduations, and tidings glad and tragic—I relayed them all. It was a unique experience. I didn’t know then that my time in the radio shack at Starveout would become even more dramatic and filled with adventures, unlike any I had lived through before. Next time I’ll tell you about the forest fires of 1987.

Access

Kathleen Jarschke-Schultze is raising chicks in her home in Northernmost California. c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520
kathleen.jarschke-schultze@homepower.com

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Aug. 17, '02; S. CA RE Expo; Fairplex, Pomona, CA, Exhibits, demonstrations, wkshps, dealers, & manufacturers. Info: Ray Boggs, Solatron Technologies, 19059 Valley Blvd., Suite 219, Bloomington CA 92316 • 888-647-6527 www.socalenergyexpo.com

August 24–25, '02; SolFest, Solar Living Center, Hopland, CA. RE, green building & sustainable lifestyles, 100+ exhibitors, 50+ wkshps, tours, food, entertainment, children's ocean mural. Solar Living Institute • 707-744-2017 www.solarliving.org

Sep. 20–22, '02; CA Energy Expo, San Diego Convention Center. RE technologies & energy conservation strategies. Info: Richard Brown, 23672 San Vicente Rd. #363, Ramona, CA 92065 • 760-653-4022 • rcb@mail2usa.com www.californiaenergyexpo.com

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

Rebates for PV & wind. CA Emerging Renewables Buydown Program, CA Energy Comm. • 800-555-7794 or 916-654-4058 renewable@energy.ca.gov www.consumerenergycenter.org/buydown

Energy Efficiency Building Standards for CA. CA Energy Comm. • 800-772-3300 www.energy.ca.gov/title24

Solar e-Clips, free weekly email newsletter. CA news & info solar energy. Email with "Subscribe" in subject to: solareclips-request@californiasolarcenter.org

COLORADO
Aug. 9–11, '02; Women's Carpentry Wkshp; Carbondale, CO. For women with little or no experience in construction or carpentry. Hands-on projects to familiarize participants with tool use, final project to take home. US$300. Info: see SEI below.

Sep. 8, '02; Rocky Mountain Sustainable Living Fair, Lincoln Center, Fort Collins, CO. Free, 50+ exhibitors, wkshps, demos, live jazz. Info: Christa Reed, Village Earth Consortium • 970-377-1392 Fax: 970-377-0140 • Creed9196@cs.com www.SustainableLivingFair.org

Sep. 3–24 '02; The SunEarth Camp, So. Colorado. Three 1-week sessions, incl. passive solar, rammed earth, radiant floor, solar H_2O, energy conservation, solar greenhouse, organic gardening, adobe, strawbale, & AER block, PV. Camping, meals, scholarships. Info & costs: 303-443-9015 • sun8@earthlink.net

Sep. 9–13, '02; Loveland, CO. Biodiesel Fuel Wkshp. Fundamentals, making your own fuel & processor, & convert a diesel engine. US$500. Info: see SEI below.

Carbondale, CO. SEI hands-on wkshps. PV Design & Installation, Advanced PV, Wind Power, Microhydro, Solar Cooking, Environmental Building Technologies, Solar Home Design, & Straw Bale Construction. Info: Solar Energy International (SEI), PO Box 715, Carbondale, CO 81623 • 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org

IOWA
Prairiewoods & Cedar Rapids, IA. Iowa RE Assoc. meets 2nd Sat. every month at 9 AM. All welcome. Call for schedule changes. IRENEW, PO Box 355, Muscatine, IA 52761
563-288-2552 • irenew@irenew.org
www.irenew.org

KENTUCKY
Livingston, KY. Appalachia: Science in the Public Interest. Projects & demos in gardening, solar, sustainable forestry, more. ASPI, Rt. 5, Box 423, Livingston, KY 40445 • Phone/Fax:
606-453-2105 • aspi@kih.net • www.kih.net/aspi

MASSACHUSETTS
Greenfield Energy Park. Help preserve the historic past, using today's energy & ideas, & creating a sustainable future. Greenfield Energy Park, NESEA, 50 Miles St., Greenfield, MA 01301 • 413-774-6051 • Fax: 413-774-6053 nhazard@nesea.org • www.nesea.org

MICHIGAN
Intro to Solar, Wind, & Hydro. West Branch, MI. First Fri. each month; System design & layout; on or off grid; for homes or cabins. Reservations. Contact 989-685-3527 • gotter@m33access.com

MONTANA
Whitehall, MT. Sage Mountain Center: one-day seminars & wkshps, inexpensive sustainable home building, straw bale constr., log furniture, cordwood constr., PV, more. SMC, 79 Sage Mountain Trail, Whitehall, MT 59759
406-494-9875 • cborton@sagemountain.org

NEW YORK
RE Loan fund: low interest financing: NY Energy $mart Program, NY State Energy R&D Authority 518-862-1090 x 3315 • Fax: 518-862-1091 rgw@nyserda.org • www.nyserda.org

NORTH CAROLINA
Aug. 23–25, '02; So. Energy & Environment Expo, Fletcher, NC. Exhibitors, wkshps, presentations, activities. RE, sustainable businesses, green economic development in the So. Mt. region. S.E.E. Expo 2002, P.O. Box 1562, Etowah, NC 28729 • 828-696-3877
nedryandoyle@earthlink.net

Sep. 9–13, '02; Celo, NC. PV & Installation Wkshp. PV system design, components, site analysis, system sizing, tours, & a hands-on installation. US$550. Info: see SEI in COLORADO listings.

Saxapahaw, NC. How to Get Your Solar-Powered Home. Seminars 1st Sat. each month. Solar Village Institute, PO Box 14, Saxapahaw, NC 27340 • 336-376-9530 • Fax: 336-376-1809 solarvil@netpath.net

OHIO
Oct. 13, '02; Athens Area Sustainability Festival, Athens County Fairgrounds, Athens, OH. Recycling, solar & wind, watershed restoration, organic farming, alternative transportation, local artists, musicians, theater, food, educators. Info: 740-448-1016 • isbalkits@hotmail.com

OREGON
Sept. 21: All-day Solar Cookery Equinox Extravaganza, Seneca, OR. EORenew, PO Box 485, Canyon City, OR 97820 • 541-575-3633 info@solwest.org • www.solwest.org

Oct. 5, '02; Umpqua Community College's Alternative Energy Fair, Roseburg, OR. Lectures, wkshps, exhibits, energy conservation, fuel cells, solar, hydro, wind, & hybrid cars. Fri. Oct. 4th: Dinner forum on RE. Fri. at noon: Energy conservation talk in the UCC campus center. Thurs. the 3rd: Tour of landfill energy projects. Info: 541-440-4601 • CEWork@umpqua.cc.or.us

Nov. 2, '02; EORenew Annual Meeting; John Day, OR. See above for info.

Feb. 21–23, '03. Successful Solar Businesses; Ashland, OR. All aspects of small RE business. Richard Perez, Bob-O Schultze, & Bob Maynard. For details & info, see display ad in this issue.

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 8 weeks, 4 interns per quarter. Aprovecho Research Center, 80574 Haxelton Rd., Cottage Grove, OR 97424 • 541-942-0302
apro@efn.org • www.efn.org/~apro

RHODE ISLAND
Energy Co-op provides RE, energy efficiency & conservation services, & group purchases of EnergyStar products. Erich Stephens
401-487-3320 • erich@sventures.com

TENNESSEE
Summertown, TN. Kids to the Country: nature study program for at-risk urban TN children. Sponsors & volunteers welcome. The Farm, Summertown, TN 38483 • 931-964-4391 • Fax: 931-964-4394 • ktcfarm@usit.net

TEXAS
Sep. 20–22, '02; Texas RE Roundup, Green Living, & Sustainability Fair, Fredericksburg, TX. Info: TX Solar Energy Society & the TX Renewable Energy Industries Assoc.
866-786-3247 • Roundup@txses.org
www.RenewableEnergyRoundup.com

Nov. 12–15, '02; UPEx'02—The PV Experience Conference & Exhibition. Austin, TX. With TX Renewables 2002 & USGBC's Green Building Conference & Exhibition. Info: Julia Judd, Solar Electric Power Assoc., 202-857-0898
SolarElectricPower@ttcorp.com
www.SolarElectricPower.org

El Paso Solar Energy Association bilingual Web site. Info in Spanish on energy & energy saving. www.epsea.org/esp

El Paso Solar Energy Association: meetings 1st Thur. each month. EPSEA, PO Box 26384, El Paso, TX 79926 • 915-772-7657
epsea@txses.org • www.epsea.org

Houston Renewable Energy Group: meets last Sun. of odd months at TSU Engineering Building, 2 PM. HREG, PO Box 580469, Houston, TX 77258 • jferrill@ev1.net • www.txses.org/hreg/

VERMONT
Aug. 10, '02, RE for Your Home; N. VT. Tour PV system; theory, design, setup off-grid system, some wind & hydro.US$50. Reservations. Contact: Flack Family Farm, 2063 Duffy Hill Rd., Enosburg Falls, VT 05450
sarahflackfarm@hotmail.com
www.flackfamilyfarm.com.

PV, Wind, & Solar Hot Water Basics wkshps. 1st Sat. each month, through Sep. Info: VT Solar Engineering, PO Box 697, Burlington VT 05402 800-286-1252 • Fax: 802-863-7908
www.vermontsolar.com

VIRGINIA
Info & services on practical solar energy apps in VA. VA Solar Energy Assoc., the VA Solar Council, & the VA chapter of SEIA. Info: VA Div. of Energy • 804-692-3218

WASHINGTON, D.C.
Sep. 19–Oct. 9, '02; Solar Decathlon, on National Mall. College competition to design & build energy-efficient solar-powered homes. Info: Gary R. Schmitz, NREL 1617 Cole Blvd., Golden, Colorado 80401 • 303-275-4050 • Fax:
303-275-4091 • gary_schmitz@nrel.gov
www.solardecathlon.com

WASHINGTON STATE
Sep. 20–22, '02; NW RE Festival. Whitman College, Walla Walla. Keynote: Amory Lovins. Tours, eco-friendly concert, panelists, speakers, wkshps, & vendors. Energy conservation, solar, wind, hydro, geothermal, biomass. Industries, commercial buildings, residential. NWREFest, PO Box 1501, Walla Walla, WA 99362
info@nwrefest.org • www.nwrefest.org

Oct. 11–13, '02; Intro to RE Wkshp, Guemes Island, WA. Intro to solar, wind, & microhydro for home owners. US$200. Fri. evening free & open to public. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden
360-293-7448
ian.woofenden@homepower.com

Oct. 14–19, '02; PV Design & Install Wkshp. Guemes Island, WA. System design, components, site analysis, system sizing, & a hands-on installation. US$550. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448
ian.woofenden@homepower.com

Oct. 21–26, '02; Wind Power Wkshp with Mick Sagrillo, Guemes Island, WA. Design & install a complete wind-electric system. System sizing, site analysis, safety issues, hardware specification, & hands-on installation. US$550. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448 ian.woofenden@homepower.com

WISCONSIN
MREA Wkshps: Ind. & Comm. Solar Utilization: Aug. 8, Madison, WI; Basic PV & Site Audit: Aug. 15–16, LaCrosse, WI; Int. PV: Aug. 17–18, LaCrosse, WI; Wind Install: Sep. 15–21, Lewiston, MN; RETScreen: Oct. 3, Madison, WI; Urban PV: Oct. 18–19, St. Paul, MN; RE for the Developing World: Oct. 21–25, Custer, WI. SOs half price. MREA, 7558 Deer Rd., Custer, WI 54423 • 715-592-6595 • Fax: 715-592-6596 mreainfo@wi-net.com • www.the-mrea.org

the Wizard speaks…

Magnetic Energy

The free energy sweepstakes has a new entry. It is called a magnetic energy generator, or MEG for short. This device is based on some new concepts in physics that are similar to ones I have described in the past.

The MEG essentially draws its energy from the electromagnetic energy potentials and flows inherent in the nature of the vacuum energy field of the space-time continuum. Using a permanent magnet with a nanocrystalline sheath and various energizing and transforming coils, the MEG transforms these potentials and flows into a usable form of energy.

The MEG is a device that has no moving parts. A patent has been issued, and the MEG is expected to be in commercial production within a year or two. A prototype of the device has been built and tested. The preliminary data results I have read seem to indicate that the MEG is actually capable of producing more energy than is used to activate it. Additional testing and verification procedures are now, or soon will be, in progress using an additional research prototype.

Often "free energy" devices like these are highly touted, but in the end fail to live up to their promise. One article on the technology included three Ph.Ds as authors, and the theory is based on work that, in some cases, has been going on for many years. Let us hope that this is the one that works. If it does work, it will solve the energy problem, and make a dent in many of the other problems that plague our planet.

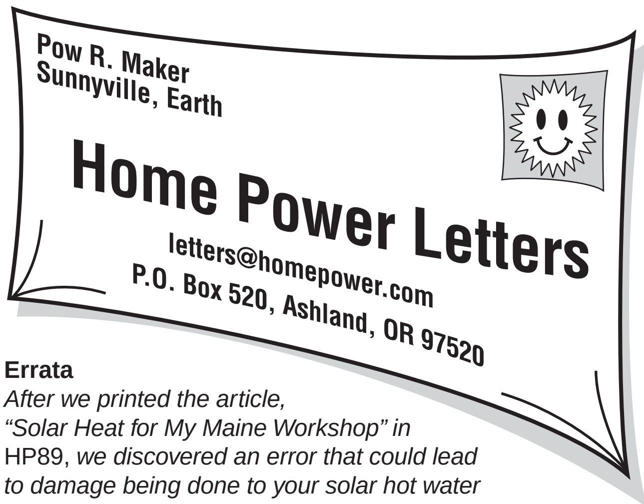
Some Web sites concerning this and similar technologies:

www.rense.com/general21/free.htm

www.cheniere.org

www.flynnresearch.net/parallel_path_magnetics_vs__similar_devices.htm

www.flynnresearch.net/Page_1.htm



Errata

After we printed the article, "Solar Heat for My Maine Workshop" in HP89, *we discovered an error that could lead to damage being done to your solar hot water panels. The erroneous section of the article reads:*

> *My understanding is that the antifreeze formulation in the Dow Frost propylene glycol mixture that I used is rated to 350°F (177°C), as opposed to other mixtures that are only rated to 280°F (138°C).*
>
> *In the summer months, I'm going to disconnect the PV modules from the circulation pumps and let the collector loop fluid stagnate. This will shorten the life of the glycol in the system, but I still expect to get five years or so out of it before it needs to be changed. I plan on checking the pH of the glycol before the heating season begins to make sure it hasn't degraded and is up to snuff.*

If the glycol is allowed to stagnate, the panel could bring the temperature of the glycol higher than the glycol is designed to handle. According to the manufacturer, the panel could get as hot as 375°F, while the glycol is actually rated at 325°F. At those high temperatures, the inhibitors that prevent the glycol from turning to acid can quickly break down. This could cause destruction of the collector's thermal absorption plates. According to experts in the field, the rate of change in the pH is fairly sudden at the end, so measuring pH is not a good indicator of how much life is left in the glycol. So, do not allow your collectors to stagnate!

These high temperatures are also above the glycol's boiling point, so it is possible that in your similar system, the glycol would cause the system's pressure relief valve to open. That would mean that the system would have to be recharged after each summer season anyway, thus eliminating the only benefit of not draining the system if it is not going to be used during the hot months. In addition, too high a temperature in pipes could cause harm to their insulation.

We've fixed this mistake in the Web and CD versions of HP89. *The new version of this section says:*

> *My understanding is that the the antifreeze in the Dow Frost HD propylene glycol mixture that I used is rated at 325°F (163°C) for one year. The lower the operating temperature, the longer it will last.*
>
> *For the summer months, my inclination is to leave the system running, and see if the heat build-up in my utility room gets to be an issue. If it does, I'll either drain and flush the system or cover the collectors. Using custom canvas covers (available from boat outfitters) seems like the simplest solution for my needs now. I like the idea that I could uncover one collector at a time as needed.*

Our sincere apologies for any inconvenience to our readers. Many thanks to Tom Lane of Energy Conservation Services for pointing the problem out to us, and to Smitty and Chuck of AAA Solar for helping come up with information and solutions. The Home Power *Editorial Staff*

Slick Trick on Battery Cables

I enjoyed your article on homebrew battery cables in *HP89.* I have done a bunch of them in similar fashion, but I used a slightly different approach. I made up a soldering pot from a piece of folded over half-inch conduit. I snip off enough solder to fill the pot halfway. Then I dip the terminal for a few seconds into the hot solder. The solder is soaked up real nice and the terminal is tinned. I then drill the hole and use shrink tubing on the end. The drilling after soldering prevents the strands from falling out on the ends. 73s N4KSM • hansflo@juno.com

I often fantasized about using a solder pot when I was making many of those connectors. Your method is far faster and better. It helps prevent the cable insulation from burning during the process, and coats the connector so that it will be less likely to oxidize. The cute trick is using a bit of conduit for the pot—it's cheap and saves solder. Richard Perez richard.perez@homepower.com

Quiet Inverter Question

Dear *HP*. Great magazine. Ever since I got a Honda EV+, I have used "time of use" electric metering, not the special EV-only rates. Before I got the car, I found time of use to be break-even, since I am not at home during the day. The rates are a good blend for me. I loved that car, and I am considering a DIY conversion.

Also, I am considering putting up 300–500 W in solar-electric panels, to drive the peak usage to near zero. I went to compact fluorescent lights years ago during a summer heat wave when I wanted light but no more heat. I expect a US$3,000 system to pay back in 6 years if I get California rebates. I will do it anyway. From your experience, what are the three quietest inverters?

Also, I accept that economics cannot adequately evaluate intangibles. The notion that you *can* show 20+ year payback on a 25+ year system is gravy. Solar energy is still the cleanest energy available. I consider solar energy to include: PV, solar thermal, wind, rain, and hence, hydro-electric. David Gardner, Los Angeles, California • david.gardner@trw.com

Hello David, A good choice of inverter for your system would be the GC-1000 from Advanced Energy, Inc. The inverter is quiet. Its design includes adequate heat sinking of the FETs and uses passive cooling (no cooling fan) to keep the inverter at acceptable operating temperatures. The unit has a 48 VDC nominal input voltage, which allows you to operate the system in either two or four module increments depending on the nominal output voltage of the PVs. This fits nicely with the system size you mention, and also gives you some headroom for future expansion. Joe Schwartz joe.schwartz@homepower.com

Microwave on Sine Wave
Do you know whether the new microwave ovens put out by Panasonic will work off of a Trace SW4024 inverter? The most I can get out of Panasonic is that my warranty will be void if I try it. This microwave is of interest since it is very efficient. One model states that for 1,350 watts in, you will get 1,200 watts out! Perhaps you could do a "Things that Work!" article on it. Note that it can be very confusing discussing these microwaves since they are labeled "inverter technology inside," and we have two meanings for the word inverter in the same paragraph. Martin Nicoll, Pinantan Lake, BC Canada, rosnmartn@hotmail.com

Hello Martin, We have one of Panasonic's new "inverter aboard" models here (model number NN-T990SA), and it works just fine on our Trace SW4024 and on our Exeltech MX inverters. This is one of those 1,350 watts in and 1,200 watts to the food models. We replaced our old 1987 GoldStar microwave with this new Panasonic and the difference is amazing—less cooking time, and less energy use because the Panasonic is way more efficient. Makes great popcorn!

This microwave is computer controlled. When it isn't in use, it draws so little (about 4 watts) that the Trace SW inverter goes to sleep and the microwave computer is powered down. This creates a deadlock. The computer won't come up until the inverter is booted (16 watts), so it's necessary to bring the inverter out of sleep using another, larger load, and then turn on the microwave.

When it comes to warranties, we never tell the vendor or manufacturer that we are running the appliance on inverter-supplied electricity. Modern sine wave inverters are far cleaner and more stable than the grid. I fail to see why we RE users should be penalized because of manufacturer butt-covering. Richard Perez • richard.perez@homepower.com

Generator Net Metering
Dear Sirs, I live in rural Minnesota, have a 15 KW diesel generator. I want to run it on waste fryer oil and generate my own electricity as well as push the excess back through my meter to use the grid as a "battery."

Net metering is the term for what I would like to do. I'm looking for advice on a Web site or two that could help me out with the switching equipment needed, transfer switches, etc. I am sure that there are articles in the magazine that would be helpful as well. Please point me in the right direction. It is a very interesting project. Jim Bjork

Hello Jim, Minnesota was one of the first states to adopt net metering legislation, passed in 1983. All renewable energy sources are covered under the legislation. So you shouldn't *have any trouble getting utility approval to net meter your biodiesel powered generator system.*

A Trace SW series inverter (www.traceengineering.com) and a Trace Grid-Tie Interface (GTI) have the utility-intertie capability and safety features required to put electricity onto the grid using your generator. This setup would use the AC output of the engine generator to charge batteries. The inverter would then create an AC sine wave from the DC energy stored in the batteries, synchronize the frequency with the grid, and feed electricity back through your utility KWH meter. The only additional devices required are AC and DC overcurrent protection fuses or breakers, and a lockable disconnect accessible to utility personnel between the inverter output and the mains panel.

This setup would result in a pass-through efficiency of approximately 70 to 80 percent. There may be engine-generator controls that would allow you to run AC directly between the grid and the engine generator, which would be more efficient. This would be a good question for the generator manufacturer. Let me know if you have any additional questions or ideas. Joe Schwartz joe.schwartz@homepower.com

Grid Losses
Dear Sir/Madam, A friend saw Randy Udall's "In the Belly of the Beast" in *HP87,* with the chart of energy use from Lawrence Livermore National Laboratory (LLNL). Using the data from the chart, he calculated that for each kilowatt-hour of electricity in household consumption the utility company needed to generate 1.7 KWH. However, when using solar-electric systems, only 1.1 KWH generated is required for each 1 KWH consumed. Is the data correct? I have contacted the author of the LLNL study, Ms. Gina Kaiper, and have permission from LLNL's Technical Information Department to re-post their latest chart (for the year 2000) in an article I am preparing on the subject, Thank you for any additional information you can provide. Gilles d'Aymery, Menlo Park, California • aymery@ix.netcom.com

Hello Gilles, I'm not much of a number cruncher, but I've done some quick research to try to confirm this. According to a study described on the EPRI Web site (www.epri.com), "Bulk transmission system losses account for approximately 4 percent of the total electrical energy produced. At peak load, approximately 5 percent of system capacity is lost." One North Dakota rural electricity co-op reports that their line losses are about 10 percent. In a rural area, line losses may be higher than most places.

But this doesn't account for generating inefficiencies and losses. The Rocky Mountain Institute's Web site (www.rmi.org) says, "Electricity is not a fuel per se, but rather a carrier of energy. Because of conversion and grid losses, it typically takes three or four units of fuel to produce and deliver one unit of electricity." Former HP *staffer Chris Greacen says, "Perhaps more relevant from an environmental perspective is that the U.S. generates most of its electricity from thermal generation, which is typically 35 to 50 percent efficient. This means that closer to 3 KWH of energy is consumed to generate 1 KWH used in a home." Data from the U.S. DOE indicates that it's about 2 to 1. Pick your favorite numbers. It would be useful to have a complete and accurate loss comparison between grid electricity and distributed RE. It seems to me that on-grid RE would increase the efficiency of both, since each would be consumed closer to its source. Perhaps some of our grid-savvy readers will be able to help you more. We'd like to see your article when you're ready to publish it. Regards, Ian Woofenden ian.woofenden@homepower.com*

Throw Away that Compass
Hello Richard, Here is a trick I learned in survival school. It is how to find true solar south without a compass. This is handy if either you don't know your magnetic deviation, or live near ore bodies, power lines, or other magnetic interference.

Step 1: Locate a flat level surface that you can write on that will receive full noon sun (I nailed a 6 inch square scrap piece of plywood on top of a fence post).

Step 2: Install a vertical pointer near the side that you figure is south (I put in a 3 1/2 inch nail 1/2 inch deep into the board.)

Step 4: Sometime before noon, say 10 AM, take a marker and put a dot at the end of the pointer's shadow. Repeat this approximately every 15 minutes until midafternoon (2 PM).

Step 4: Connect the dots with a single line, forming an arc. Then measure the shortest line possible from the base of the pointer to the arc. This line will be the north/south line with the base of the pointer being south. (Reverse these directions in the southern hemisphere.)

This works because the sun will cast its shortest shadow when directly south at its most "overhead" position. The accuracy is affected by how level the surface and how vertical the pointer, as well as how "pointy" a pointer, and the accuracy of the line drawing and measuring.

I used this system to site my solar-electric panels because I have enough iron ore in my area to significantly throw out a compass. I hope this will help any readers in a similar situation. Dennis Donohue

Guerrilla Solar Safety Question
I read one of your guerrilla solar articles. I live off the grid and have ten, 100 watt solar-electric panels. I am also an electrician. I do not agree with your belief that the safety of the line crews should be left to the electronics of the inverters. I only work on systems that are mechanically locked out with my own lock. I have many years' experience with CPU-based machines and have seen electronic failures that have caused triacs and SCRs to short in a way that leaves them on. One failure like this—let's say after a lightning strike where one of the utility's line fuses blows—and the transformer now is backfed from your system. The line crew is now working on a line that is powered by your system, and not by their company's generating plants. Jeff Purdy

Puzzled over Net Metering
Hello, I just have two questions about net metering:

1. What happens when the utility needs to work on the power transmission lines? Do they have to contact each homeowner and tell them to disconnect their solar-electric array?

2. What happens in a power outage during a storm, when a falling tree takes down the lines? Does the power company have to contact each homeowner and tell them to disconnect their solar-electric array? Can the solar household still have power to run their house while the rest of the grid is down, or do they lose power like everyone else? Thanks in advance for your help. Sincerely, Matt Arner, solar supporter

Hello Jeff and Matt, Thanks for writing. Unapproved utility-interactive (UI) PV systems use the same inverters as approved ones.

UI inverter grid disconnect and anti-islanding strategies are rigorously tested to both UL and IEEE. Many of the electrical engineers involved in IEEE inverter testing are engineers employed by U.S. electric utilities. The approved safety features related to UI inverters meet these utility engineers' technical standards. Utility-interactive inverters are certified by IEEE and UL to pose no safety hazard to utility workers. These inverters are designed to go off line in under two seconds (typically in milliseconds) based on all fault conditions that result in the loss of grid power. These systems are as safe as can be. See my article on the technical details of utility-interactive inverter safety in HP71, *available for free download on our Web site.*

Most utilities still require a lockable RE system disconnect between the inverter output and the mains panel. No one in the RE industry I've ever talked with (and I've talked with a lot of folks) has heard of any instance where utility workers have used these disconnects during line maintenance, or even heard of a utility that has gone to the trouble of creating a database identifying the location of these systems. This sure puts the utilities' concern over the safety of these systems into perspective. And an interesting side note is that utilities have been known to shut down and lock out utility intertied RE systems based on things like lack of administrative policy or IBEW electricians looking to control the RE system installation market.

Utility linemen work under hazardous conditions on a daily basis. Utility safety protocol dictates the grounding of all potentially energized conductors. Incorrectly installed engine generators pose a hazard to utility personnel that surpasses that of UI inverters by orders of magnitude.

About 70 percent of the grid-tied solar-electric systems in the U.S. include batteries. With a batteryless system, you lose power when the grid goes down, just as your neighbors do. Some utility interactive inverters are designed to operate in conjunction with a battery bank for back-up power in the event of a utility outage. But this adds levels of cost and complexity that many homeowners don't want. When talking with folks about battery vs. batteryless grid-tied systems, I always ask them the following questions:

1. When was the last time your home experienced a power outage?

2. How often do outages occur at your location, if at all?

3. How long do they typically last?

4. How much do these outages affect your lifestyle?

Each individual system owner needs to determine if backup power is necessary based on their application and location. It's nice that the hardware available gives us this choice. Joe Schwartz • joe.schwartz@homepower.com

Thanks for Solar Thermal
I am glad to see solar thermal finally included in recent installation articles in *Home Power* magazine. Countless PV

installations in the past have covered almost every efficiency detail except for the omnipresent water heating question—a huge energy load. It has usually been answered by gas, while the solution is a simple solar thermal system that works in concert with the PV system. While solar thermal has a tainted history in the recent past due to the failures of wrongly engineered innovations in the solar industry, it remains one of the first venues requiring attendance prior to (or in concert with), the road to energy independence. Dave Johnson, West Palm Beach, Florida

Dave, Thank you for your letter of appreciation. I am happy to report that solar thermal articles will hold a regular place in Home Power *magazine. In future issues, you can look forward to articles about solar hot water, hot air, passive solar design for heating and cooling, and energy efficiency.*

Solar thermal energy is very economical for much of our energy needs. The solar thermal industry is technologically mature, but the market is vastly underdeveloped. Do-it-yourselfers can take advantage of simple, straightforward technologies.

We hope that by sharing the profound wealth of knowledge and experience that exists with solar thermal applications, more of us will find a way to benefit from our greatest and cleanest energy resource of all—the sun. Ken Olson, HP *Solar Thermal Editor • Sol@Solenergy.org*

Straw Bale Update
Hello! I was wondering how the straw bale walls of the bathhouse had done with the indoor humidity over the years. I'm thinking about doing a sauna project, and am looking for some info about how the bales are around moisture. I'd appreciate any help! John

Hi John, As far as we know, the straw bale walls are doing great, but... The number of plants inside, compared to the volume of the Home Power *greenhouse, is pretty low. This is because there is a lot of other utility room stuff going on in there. My point is that it doesn't seem very humid in the bathhouse. Joe Schwartz is planning to do some data logging on temperature and humidity on that building so we should have some real data in the future.*

Now, a true sauna (the Scandinavian definition, as I understand it) is dry heat, and should do great with straw walls. A wood heater should help keep the interior dry by sucking moist room air through the stove, and any residual moisture would be driven out through the walls of the building. Great huh?

But many people consider a sauna to be steam heat (which I actually prefer) and this may not go well with straw at all. Unless you were able to burn the place dry after every use, any water vapor that was pushed into the walls would condense as the room cooled down after use. That sounds like a potential problem to me. I don't know how you could measure this without embedding electronic sensors in the wall. That's great if you are an energy nerd, but perhaps overly complicated if all you want is a relaxing sauna.

Another potential drawback of straw bale sauna walls is the stucco used to coat them. In a home situation the thermal mass of the stucco is used as a "heat battery" to help keep the house at a constant temperature. But you want a sauna to heat up fast, for use, but not to retain that heat after use. In this situation, extra mass only means extra energy and time to get your sauna up to temperature.

That said, there are people building saunas using cordwood construction, which seems pretty massive to me. I have no idea how those are performing for folks. So there—some positives, some negatives. And all of it pure speculation from me. Ben Root • ben.root@homepower.com

Modern Wind Turbines Are Designed Poorly!
Dear Sirs, I would like to state for the record, that the present day designs for wind turbines are all wrong. I have studied wind turbines for many years, and the technology being used today is based around a propeller style design, which is the wrong technology. A propeller is designed to be turned at very high rpms by a power plant. A wind turbine is not. To generate torque for turning a generator, you would not want to use a propeller. It does not have enough surface area to generate the proper leverage. A basic farm-style wind turbine (like those used to pump water) of the same diameter will easily outproduce the three bladed turbines now being used. They can easily redesign them to handle much larger applications, and high wind conditions.

Why not take some of this money being thrown around, and show the world what real technology is all about? Let's build a super wind turbine that really produces. I have a design that generates over 75 percent more torque than these propeller style blades. And I have the designing and engineering ability to explain how to build them at the larger scales. I guarantee at least a 30 percent greater output in high wind areas, and a 75 to 95 percent greater output in medium wind areas. This is where my designs really shine. I have yet to see basic strengthening technologies being used in these so called modern designs.

I can show you how to build much better wind turbines! We are throwing away hundreds of millions of dollars if not more, on a bad design! We need to *stop* and take another look. I am willing to share my wisdom. What would it hurt to listen? My designs produce much of their potential simply by utilizing the vacuum created behind the turbine, while these so called modern designs produce little to no vacuum. My testing has shown that my designs generate great torque-ability from this vacuum. I tested one design that produced 93 percent more torque than a three bladed design that had 25 percent more blade diameter. So that should tell you something. We have the ability to do better. Investors have rushed into this way too fast in an effort to capture the market in light of Enron's troubles and high energy costs. I hate to say it, but, they missed the boat! Thank you! Randall S. DeWitt (an old Dutch master), La Center, Washington

Randy, You are not the first nor the last to believe you have a world-beating wind turbine design based on a low-speed rotor. There is no easy way to tell you this, but you are wrong. It is true that a farm style windmill has much higher torque than a modern wind turbine, but power is not all about torque. Power is about speed times torque. At high rpm, very little torque is required to convert all the power the wind can give *you. This is good, because applying a torque to the wind wastes power.*

The biggest loss of power from a farm windmill is the torque applied to the wind. Newton's third law says if the wind applies a force to the blades, the blades apply an equal and opposite force to the the wind. This torque force produces a swirl velocity in the wake, which robs a large part of the power you could have had.

High speed rotors have their problems too, but overall, they are usually more efficient, and certainly more appropriate for producing electricity. Generators need high shaft rpm to work efficiently. Utility scale wind turbines could not possibly use farm windmill rotors, because the torque would be so massive that you would need an incredibly heavy shaft and gearbox. Anyway, the whole machine would be absurdly heavy and impossible to control or protect from storms.

We are not throwing away hundreds of millions of dollars on a bad design. Modern wind turbines are amazingly efficient, and produce much more energy than farm windmills could from the same swept area of wind. Hugh Piggott hugh.piggott@enterprise.net

PV Embodied Energy
Hello, I was quite interested in solar-electric panels, and I found out on your Web site that they had a quite short lifetime of 20 years. Calculations made, I found out that solar energy wasn't that much cheaper than the electricity I get from my plug. Considering the fact that the manufacturing of solar-electric panels pollutes in different manners, I was quite deceived. But I still wonder if my information is really true and if old solar panels are renewable. Maybe you have the answer for my question but anyway, thanks for taking your time. Emre Neftci

Hello, Most PV modules are warranted for 20 to 25 years. Jet Propulsion Laboratories has done accelerated PV longevity testing and concluded that the majority of PV modules manufactured today will still be producing 50 percent of their new, out-of-box power output 50 years from now. You can will them to your kids.

We're really comparing apples to oranges when we look at the price per KWH of various electric generation technologies. In the U.S., renewable energy generation sources (PV, wind, biofuels) receive 1.8 percent of federal money slated for subsidizing electric generation. Established generation sources (coal, nuclear, natural gas, large-scale hydroelectric) receive the lion's share of the rest. What most folks don't realize is that fossil fuel generated electricity may be cheap at the meter compared to PV, but they're paying the difference every year in their federal taxes. If all federal energy subsidies were eliminated, PV would be competitive in today's energy marketplace.

This financial evaluation does not include the hidden costs associated with fossil fuel powered electric plants. These include decreased agricultural productivity and increased health care costs associated with the emissions of fossil fuel powered generation. Check out HP16, *page 21 for more details.*

The pollution created by PV manufacturing is insignificant compared to generation sources that pollute every time they generate a KWH. If you compare the energy it takes to manufacture a PV module (embodied energy) to the energy the module will produce over a conservative 30 year lifetime, the results are mind blowing—a crystalline module will generate approximately nine times the energy used in its production, and a thin film module will generate approximately seventeen times the energy used in its production. Take a look at HP80, *page 42 for more info. Thanks for writing. Joe Schwartz • joe.schwartz@homepower.com*

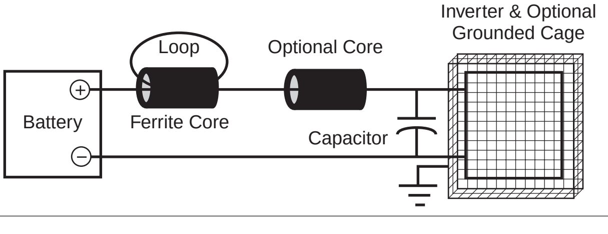
Re: PV Panel Placement Problems
Hi Ian, I have had quite a bit of experience aiming panels in different directions (re: your answer to PV Panel Placement Problems, *HP87,* page 141) with good all day sun. I can recommend this for several reasons. 1) My charge controller operates much less when the incoming power is spread throughout the day, thus wasting less energy. 2) The batteries are cycled less deeply since power is still being delivered in late afternoon. 3) The batteries start getting charged earlier in the day, further reducing depth of discharge. Besides, in the summer the sun is still high in the sky until late in the day. I hate to not get some use out of it! Sincerely, Mark Heinlein, Bend, Oregon

Hi Mark, If you have sun on the modules between the hours of 10 AM and 2 PM, facing the modules directly south is the best way to go. This captures 70 percent of the available solar energy. Facing the modules elsewhere will capture less energy unless the modules are tracked. If your charge controller is operating, your batteries are full and incapable of storing any more energy. Richard Perez richard.perez@homepower.com

How to Fix that RFI Problem
HP, I wish to address the RFI problem experienced by Bob Kidwell (*HP89*). As an amateur radio operator, I would find Bob's conditions unacceptable and would take steps to remedy them.

Switchmode power supplies generate square waves in the switching circuitry (i.e. on or off). These waves are controlled in such a way as to provide 90+ percent efficiency rates. Square waves contain an infinite number of harmonics, which may be detected across a very wide bandwidth—audible to microwave frequencies.

Suppression can be from simple to borderline impossible. I hope Bob's RFI woes will be the former. Obtain a ferrite core from Radio Shack. This is the cylinder found on many computer cords. Two capacitors, 470 and 0.01 microfarads at a minimum of 25 V for a 12 V system, 50 V for a 24 V system, etc. Connect as follows: Turn off power—kill switch, breakers, etc. Remove the positive DC power lead to inverter. Place



lead through core, looping wire as shown in the diagram. Connect capacitors to inverter as shown. Observe polarity on electrolytic capacitor! Reconnect positive DC lead. Double check work. Reapply power to inverter, and test noise level with a cheap AM radio. If the level is still too high, add additional cores as needed. You can also pass through the ferrite core without a loop. Also you can try passing through multiple cores, looping if needed.

If all else fails, place well-supported wire mesh around the inverter and connect to ground. Or call the manufacturer for assistance. Best of luck, y 73 de N9YOD, John V. Baer, Goshen, Indiana

You *Can* Take Them with You
HP, After reading up on how to connect my PV system to the grid in *HP89,* I got to wondering about how to *disconnect.* Chances are that when I move, I'll want to take my PV panels and inverter with me for a couple of reasons. First, because they'll be paid for—I'll be taking advantage of the up to 50 percent California rebate. Second, since no one else in my neighborhood has a PV system, I don't think that I'll get my money back when I sell (and thus won't have that cash to invest in another comparable system). Any suggestions or experiences? Thanks for putting out a great magazine! Jeremy Adams, San Lorenzo, California

Hey Jeremy, Glad you're enjoying the mag. We have a good time putting it together. If you're planning to move your PV system in the future, here are some things to think about.

1. Don't mount the PVs on the roof. When you pull the mounts off later, you'll be left with a bunch of roof penetrations that will be hard to seal in a cosmetic manner. If your site allows, a pole mount or even a tracker would be a better choice for PV mounting. Keep the top of the cement footing six inches below grade. Then the pipe can be cut off and the remainder buried.

2. If you have a long DC wire run, install it in conduit (instead of direct burial cable) and pull the wire when you split.

3. The rest of the system components can be easily removed and taken with you. Some folks even mount the inverter, disconnects, etc. on a piece of plywood screwed to the wall. Disconnect the PVs and batteries (if you're using them), pull the rest of the components off the wall, and they're prewired for the next site.

4. We were just talking about whether the California buydown program addresses relocating the system components out of state. I wonder if they'd bill you, follow you to the end of the earth, or...? It would probably be a good thing to read up on. Take it easy, Joe Schwartz • joe.schwartz@homepower.com

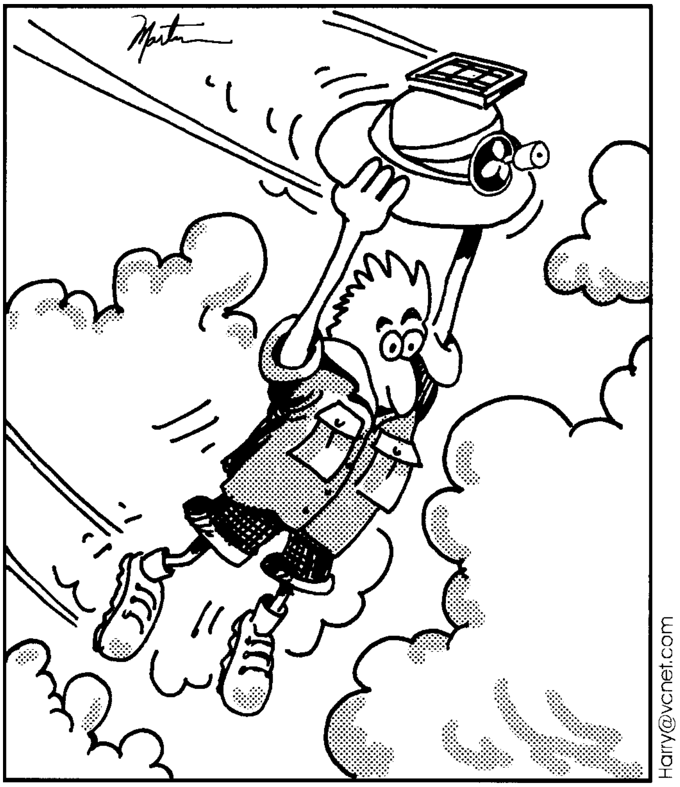
PV Powered Apartment Possibilities
Hi *HP,* I would like information on apartment renters using solar electricity. I am looking for something that will not alter the apartment. The apartment I live in does not allow alterations to its structure, and I can use no nails larger than picture nails. Mary

Hi Mary, Clever system design and installation can work within those parameters. Check with a local renewable energy professional to assess your situation. There are several ways for renters to use solar electricity.

First off, it's best to make your apartment as energy efficient as possible. This includes changing your incandescent light bulbs to compact fluorescent lighting, turning down your hot water heater and insulating it, eliminating phantom loads, doing without old and inefficient loads or replacing them with newer efficient models, and being aggressive about conserving electricity. After you've significantly reduced your energy consumption, look at adding a small, unobtrusive solar-electric system.

Possibly the most simple route is a utility-interactive system. This can be as small as 100 to 120 watts of photovoltaics (PV) and an OK4U or MicroSine inverter (see the guerrilla solar profile in HP84*). Usually you can install this system without major damage to your apartment. Mount your panels in the sun and plug the inverter into the wall. Place your PV panels in your yard or on your porch, using a mount with weights, like sand bags. Larger utility-interactive systems may require more permanent installations that need holes drilled in your walls, conduit, etc.*

Another route is to take some of your loads off the grid. This option can entail some PV, sealed (maintenance free) batteries, an inverter, a charger, a controller, and safety equipment. For instance, you can install a small battery-based system that is dedicated to a fairly predictable load, such as a computer work station. Place the PV as above, and safely run its wire through a window to the charge controller. It's possible to install a small battery-based system so you don't have to alter the apartment too much, and so you can take it with you when you move out.



The solar powered safari helmet...not for people who weigh less than one hundred pounds.

No matter what kind of solar-electric system you choose to design and install, it's important to do it safely! If you feel you have the knowledge and experience to do it yourself, great. If you have any doubt, It's best to enlist the help of a competent professional. See our Web site for a database of renewable energy professionals in your area who can help you design and install your system.

I'm a renter too. I live with a 300 watt, battery-based, stand-alone PV system that's not utility intertied. When we move out someday, we'll take our system with us. We managed to safely install it with only one conduit hole in a closet ceiling, and a couple mounting holes on our patio roof. Best of luck and keep us posted on your progress. Best REgards, Eric Grisen • eric.grisen@homepower.com

Solar—The Right Thing to Do
I like being informed by intelligent, concerned people who share the same goals I have, and are excited by the possibilities ahead of us and somewhat frustrated by the lack of interest in the practical wonders of renewable energy out there among John Q. Public in Pleasantville, U.S.A. John Q. seems to be much more concerned (in Orange County, California anyway) about decorating his big house, with the big screen TV he brings home in his big SUV.

As a solar energy enthusiast for many years, and now a potential new business owner (I own the business, I just haven't made any money yet!), I welcome the chance to share my dreams with someone, even if it is done vicariously for now. Thanks for doing the right thing. Tom Burrows, owner, South Coast Solar, Lake Forest, California.

Requesting Submittals for Architecture Book
Book Concept: Designing a Sustainable Home. I am very interested in highlighting methods of harmoniously integrating alternative energy systems with architecture. Appropriate use of this technology is always a must, as well. My book will specifically highlight single family residential responses.

The book will include real and imagined residential projects of all types, which demonstrate design features that enhance and enable the occupants' ability to live sustainably. All aspects of design will be covered, ranging from community and site planning, climatic considerations, energy sources and efficiency, space planning and use, material selection and detailing. Although these topics are broad in scope, no project will be truly sustainable unless it considers these issues holistically.

The book will be written for the layperson beginning the process of building a custom home, and will focus on the design and decision-making process, rather than an outcome of a particular style or aesthetic. Attention will also be paid to such aspects as how to select an architect and contractor, as well as budgeting for the project.

We are looking for built projects that highlight the above aspects. Since the collection will include submissions from across the country, particular attention will be paid to the regional and climatic response of the design. Depending on the specific project and ideas to be highlighted, photos, plans, and details may be necessary. There will be no required format for drawings, since the author will produce a common format and style for all submittals. If you are interested, please contact me. Thank you, Angela Dean, AIA, 801-322-3053 amd@sisna.com

Payback on RE
Concerning the discussion of payback on renewable energy technologies, I agree with Ian Woofenden that criticism of the ordinary person's desire to save money is misplaced. The consumer concern about the payback for alternative energy is due to a concern about saving money on energy costs. Looking to save money is part of the cost-benefit analysis that goes with any financial decision. Like it or not, in the real world, most people take personal cost and benefit into account when making decisions, because financial resources, like natural resources, are limited. Most people consider the personal cost and benefit of their decisions, in addition to such factors as social good. Yet, the attitude displayed by the professional wrenches seems to be "shut up about money and enjoy your expensive hobby."

I too am tired of the analogy to cars and couches, particularly where cost-benefit analysis also plays an important role in the purchase of these and other consumer items. When we buy a couch, we look at its cost relative to its comfort, appearance, and projected life span. In other words, we look at whether the expenditure is affordable and is warranted when compared to the increased personal comfort and pleasure that the item would give us. When we buy a farm truck, we look at its affordability and its cost relative to the work it will perform in transporting people, equipment, livestock, and so forth. Personal cost-benefit analysis is directly relevant to every consumer purchase decision, and is weighed against what the proposed purchase has to offer to the consumer.

Yet, many commentators seem to expect that the consumer will put aside personal financial considerations and analyze the renewable energy system strictly from a societal cost-benefit analysis. This is unrealistic in a world of limited resources, including financial resources. Yes, people would likely be outraged to learn that the government takes money from them and uses their tax dollars to subsidize dirty energy. However, that outrage may or may not translate into a willingness to spend whatever they have left after taxes on expensive alternative energy technologies. Like it or not, family finances do not, first and foremost, exist to counterbalance foolish government subsidies.

Of course, many people are willing to spend money solely for societal gain. Hence, people donate money to charities and not-for-profit organizations that work for the social good. Similarly, people who have affordable access to the dirty grid install elaborate alternative energy systems that cannot possibly save them money, no matter how long the alternative systems last. With many forms of alternative energy, the benefit to the grid-connected consumer is more akin to a charitable donation, as the expenditure is made strictly out of societal concerns: there will never be a financially positive impact for the consumer, nor any measurable improvement in the consumer's life that a less expensive alternative could not provide. The grid-connected alternative energy consumer gets to feel good about doing something for the larger social good, and this is positive.

However, to deride the cost-savings concerns of those who do not have sufficient disposable income to in essence make sizeable donations to the charitable cause of grid-connected alternative energy is foolish. Better would be to acknowledge that the purchase of an RE system while one is connected to the grid is an attempt to achieve a social good much like a sizeable charitable contribution to an environmental organization. This up front acknowledgement would tend to direct those who are more interested in saving money to look at efficiency technologies that will help them achieve their savings goals while helping to reduce the total amount of dirty energy consumed (compact fluorescent bulbs, geothermal HVAC systems, switched outlets, etc.). Redirecting the consumer who is wanting to save money with upfront acknowledgements concerning costs vs. savings would ultimately prevent much frustration for the wrenches who are selling the more "charitable" off-grid technologies to those on the grid. Gloria Morris • gloriafarms@famvid.com

Thanks for your wise words, Gloria. I'll only add that there are plenty of places where RE does *have a reasonable financial payback, even when compared to super-subsidized and irresponsible grid electricity. But in my state, the cost of subsidized grid electricity is low enough (2 to 8 cents per KWH) that it often doesn't "pencil out" well if saving money in the short term is the goal. While this isn't my interest or priority at all, I very much want people to be realistic. I frequently find myself asking newbies to RE what their motivation is. We all have different ones, and it's more productive to find out what others' motivations are than to try to force fit ours on them. Thanks for writing. Ian Woofenden ian.woofenden@homepower.com*

Alternate Alternator Question
Wow, I ended up buying two copies of *HP88*—one for the cabin in Long Beach, Washington, and one to wear out dragging back and forth to work.

The article that I really enjoyed was the one about the Wood 103, especially the part about building my own blades. Which brings up a question that I am sure you have answered before, but I haven't seen yet (only been reading your mag for 6 months). How do I convert an automobile alternator into a directly driven windmill? How do I hook up and control the output by the amount of input voltage to it? How can I turn a 12/16 volt unit into a 24 volt unit? I have been given a good 24 volt, 750 amp-hour, 1,600 pound battery out of a pallet jack, and I want to use it for my cabin power. Man, we get plenty of wind at the coast. Any info about the above would be appreciated. Thanks from the Ugly Coyote thefurhunter@hotmail.com

Hi Fur-Hunting Coyote, Car alternators are an attractive idea for the home-builder because they are readily available new and secondhand, and they are designed for charging batteries. Unfortunately the advantages end there.

Car alternators are designed to charge batteries in a vehicle. They are designed to run at high speeds (high rpm) and to be lightweight and robust. You can fix a set of blades (a "wind rotor") on the pulley, and put it up on a homebuilt wind turbine, but the results will be disappointing. The blades will not run fast enough to produce any power except in high winds, so the wind turbine will not produce much power on a normal day. In high winds the bearings may not last very long, since they are not designed for this type of use.

A car alternator's internal regulator is not appropriate for a wind turbine because: a) the voltage at the wind turbine is usually higher than the battery voltage, due to losses in the cables, so the regulator will not function correctly, and b) when it does function the regulator reduces the load on the alternator, which in turn will lead to the blades overspeeding, and consequent wear and tear and damage to the structure. It is best to bypass the regulator and use a shunt regulator, located at the battery instead. Also, some modifications will be required to make sure the alternator can "self excite" (feed its own field coil with a current) without draining the battery in low winds.

Alternators can be modified to work at lower speeds by rewinding the output coils, using more turns. This will allow them to cut in and produce power at (say) 500 rpm instead of 1,000 rpm. But the longer, thinner wire used in the rewind will heat up more than the original stator, so the efficiency will go from bad to worse. In any case, the output in low winds will be limited by the need to provide power to the field coil in the alternator. This field coil draws about 50 watts all the time the alternator is working. The blades have to be able to produce this much power before anything is available to charge the battery. In low winds, there is not much power available. A larger diameter of wind rotor could catch more power, but larger rotors turn more slowly, which aggravates the speed matching problem.

Wind generators need low speed alternators with good efficiency at low power levels, so as to make the best of all wind speeds. Car alternators do not fit the bill. It is possible to use them for a simple homebuilt machine for very high wind speeds, but the results are disappointing because the efficiency is poor. Hugh Piggott • hugh.piggott@enterprise.net www.scoraigwind.co.uk

Ozonal Notes

Home Power & the Web

Richard Perez

This planet really is turning into a "global village." This is most apparent in the field of information, and mostly thanks to the World Wide Web, called simply the Web by most of it users. The Web is a lot like Alice's Restaurant—you can find anything you want...

When the digital communications revolution began in the early 1990s, *Home Power* operated what was called a bulletin board system (BBS). The *Home Power* Bulletin Board was started by Michael Welch and Redwood Alliance in 1992, and was used by folks all over the world. People called in with their computer modems to access the RE info we had posted on this BBS located in Arcata, California. We had callers from as far away as Denmark and Colombia.

The BBS was crude in comparison with the modern Web. The interface had no graphics, and we had text files, compressed spreadsheets, software, and .gif-style graphics before we had PDFs. It was a far cry from today's files, complete with color pictures. But folks were happy to be able to access this information, even though it meant huge, long distance phone bills for the hours spent connected to the BBS with slow modems.

As the Web became available, it made our BBS, and everyone else's, obsolete. Why call long distance when you can access more information with just a local phone call? In 1995, *Home Power's* first Web site went on-line. We had a field day packing our server with RE information. In 1996, we began making our current issue available for free download. Today, *Home Power's* Web site gets about 85,000 unique visitors each month, and more than 65,000 people download each electronic edition of *Home Power*.

Coupled with the growth of the Web came new advances in computer software. New Web browsers made viewing and downloading information from the Web a snap. Search engines gave us the ability to locate the specific information we want from the virtual ocean of data on the Web.

Adobe made a fantastic program called Acrobat, which enables folks to share documents across a very wide variety of computer platforms. Acrobat allows us to create portable document format (PDF) files from the very same page layouts we use to print *Home Power.* This makes putting our electronic edition on the Web a snap, and it looks just like the print edition—color photos, line art, text, and all!

Truly, the Web is a George Jetson kind of world. We use the Web daily from our solar powered computers on Agate Flat. A bidirectional satellite link, also solar powered, supplies high-speed Web access. Although we are located in a mountainous wilderness, six miles from the nearest commercial electricity or hardline telephone, we are as thoroughly connected and informed as anyone. George Jetson's got nothing on this.

Home Power's New Web Site

On June 1, 2002, we unveiled our new and improved Web site. You'll find a host of new features that folks have been asking for. A whole-site search engine helps you find the information and files you are looking for. We now offer news of the RE world and keep you up to date on RE developments. You can access real-time cloud maps to help you determine what today's sunshine is like anywhere in the world.

An on-line searchable directory of RE companies helps you find pros to give you a hand with your system. A regularly updated calendar keeps you advised of RE events and energy fairs worldwide. A special section informs you of RE tax incentives and net metering laws in your location. A job listing section can help you find a job in the RE industry. We have expanded the educational functions so you can learn more about RE—on-line. A modern, Web shopping cart helps you get the *Home Power* products you want.

A new, experimental feature of our Web site is foreign language translation. Using Google's language tools, users can translate any Web page into Spanish, German, French, Italian, or Portuguese. This translation is not 100 percent (it's still in beta), but it's good enough to get the point across, and we're pleased to be able to share RE info with a wider audience.

To accomplish this new supercharged Web site, we needed and got help. The newest member of the *Home Power* crew is Rick Germany, who comes to us with ten years of Web design experience. Months of Rick's time went into designing and testing our new Web site, and we all hope that you will use it and learn.

So accept our invitation to drop by and check out our latest endeavor. The address is www.homepower.com. The information is pure *Home Power!*

Access

Richard Perez, *Home Power,* PO Box 520, Ashland, OR 97520 • 530-475-3179 • Fax: 530-475-0836
richard.perez@homepower.com • www.homepower.com

Rick Germany, *Home Power* Director of Web Services
rick.germany@homepower.com

Q&A

Send your questions to letters@homepower.com

Battery Reconditioning

Dear Richard, I had an accident here and some of my nickel iron batteries lost their electrolyte. I need to know how to recondition them and where to purchase the electrolyte. Thanks for your help. Bob Feyen, Muscoda, Wisconsin • bncfeyen@mwt.net

Hello Bob, Reconditioning alkaline cells (either NiCd or NiFe) means cleaning them out, replacing the old electrolyte with new electrolyte, and charging the hell out of them.

Safety first! Use rubber gloves and goggles! Have a supply of vinegar on hand in case you spill electrolyte on yourself. While alkaline electrolyte is not as fierce as the sulfuric acid used in lead-acid cells, it can still burn, especially if it gets into your eyes.

Rinse the emptied cells with distilled water until they are clean. Dispose of this wash water, and any spent electrolyte, in a responsible manner. In NiCd cells, the electrolyte can contain minute amounts of cadmium, so handle it as hazardous waste. In NiFe cells, the electrolyte is easier to dispose of—just neutralize it with vinegar (or hydrochloric acid, HCl, available from any pool supply house) and you can compost it.

Mix the new electrolyte using technical grade potassium hydroxide (KOH). This is available from most chemical supply stores. Stir the KOH into distilled water in a large plastic container. I use a clean, 32 gallon, heavy duty, plastic trash can. Keep adding KOH until the specific gravity of the electrolyte is between 1.2 and 1.25. This amounts to about 1 pound of KOH to 1 gallon of distilled water. If you add too much KOH, simply bring the specific gravity down by adding more distilled water.

Use a clean (never used with a lead-acid battery), temperature-compensated hydrometer to measure the specific gravity of the new electrolyte. When the KOH dissolves, it will give off heat, so add the KOH slowly (about a pound at a time), mix thoroughly (I use a hunk of clean plastic conduit to stir the mixture), and wait for everything to cool off before making the specific gravity measurement. Mix all the electrolyte you will need at the same time if possible. This assures uniformity in the electrolyte.

When the electrolyte is cool and at the proper specific gravity, refill the cells. Add a thin (1/8 inch thick) layer of pure (USP) mineral oil (from any drug store) to the top of each cell and you're ready to put the cells back in service. Expect the cells to take five or six cycles before coming up to full capacity. Richard Perez richard.perez@homepower.com

Hot Air vs. Hot Water

HP, I have a natural gas boiler with hydronic heat and a small south-facing, mudroom roof area that could fit one or two panels. All else being equal, which would be more energy efficient at capturing the sun's energy and converting it to heat—solar hot air panels or solar hot water panels?

I like solar air's simplicity—just dump the hot air into the home. Solar hot water has a year-round benefit, but involves water and piping, and is probably more expensive. I was curious about comparing them, apples to apples. Mike

Hi Mike, As a general rule, solar water heating gives a better return on investment than solar air heating. There are several reasons for this. You have already identified the primary one.

1. Domestic water heating is a year-round use; air heating (for space heat) is a seasonal use. Water pays you back every month of the year.

2. Hydronic solar heating panels (this covers collectors using any liquid heat transfer fluid) generally operate more efficiently than air collectors. This is because water has a specific heat five times greater than air. The practical significance of this is that water can capture this heat without such a large temperature rise. The higher the collector operating temperature, the greater its heat loss and the lower its efficiency.

3. Air ducts are much larger than water pipes to move equivalent amounts of heat.

4. Hydronic circulators (pumps) are more efficient than blowers for moving an equivalent amount of heat.

To be fair to the air, simple solar air-heating systems have some advantages. Wall-mounted solar air collectors can supply daytime heat directly to spaces on the other side of the wall. This can be done very economically with minimum duct work; a fan-assisted panel uses a very small blower; a thermosyphon air panel is designed to operate without a blower. The south-facing, vertical orientation automatically shuts off in summer. Either way, it is a good retrofit application of solar energy. See the articles in HP25 *and* HP72. *You'll be seeing more detail on these designs in future issues of* HP.

These vertical, wall-mounted collectors really shine on large metal-clad buildings with south-facing walls. Such buildings are often primarily day-use. Ken Olson Sol@Solenergy.org

Need Comm System Details
Hello *Home Power* folks, I'm building a solar home about a mile from the nearest telephone line. I'm considering options for telephone and computer communications in that remote location. I read somewhere that you have some kind of link for your comm system. Would you send me info about that?

Any other ideas you have would be appreciated. I'm also considering a cell phone interfaced to a laptop computer. Thanks and keep up the good work. See you at the solar fair in John Day. Bill Graves

Hey Bill, Here are my views on off-grid communications, which continue to change as technology does.

For voice service, the first thing I'd try is cellular. The rates available for cellular plans beat the hardline phone company rates at my location, and I'm guessing most others. If your site has poor cell reception, an external Yagi directional antenna can be added. Up at Home Power *Central, our cell phones get no reception or service on their own. A few years ago we installed a Yagi, and cell reception has been full scale ever since. The cost of the Yagi antenna, premium Heliax coaxial cable and appropriate connectors came to about US$400. Contact your cell phone provider for details on operating their phones in conjunction with external antennas.*

In addition, cell phone docking stations are now available that allow you to connect your cell phone into standard two-wire phone cabling. This allows you to route the cell service throughout your house to multiple, standard phones. Pretty cool. Check out: www.cellantenna.com/Dockingstations/dockingstations.htm for info on these units.

For data service, some cell phone companies are claiming 56 Kbps data transfer rates. But this service gets expensive fast if you spend a lot of time on the Web, and 56 Kbps is slow compared to today's high speed internet connections. We have a StarBand satellite data service installed up at HP *Central, and have been very happy with the system overall (80–120 Kbps downloads, uploads are about 25 percent of this). I have heard a few horror stories from folks with poorly installed or configured systems. Right now StarBand is only available for PCs, or Macs used in conjunction with a PC server and the appropriate software. See* HP84, *page 108 for more info. Take it easy, Joe Schwartz joe.schwartz@homepower.com*

Two-Stroke Biofuel and Lubricant
I am interested in using biofuel and lubricants in two-stroke engines. Please, if you have any information, I want to protect the environment and, if possible, make my own fuel. Montana's DEQ is studying the issue because of the problem of snowmobiles. I am building an ultralight airplane and will almost certainly need to use a two-stroke engine because of weight and power issues. Any help would be appreciated. Will Turner rhondat@charter.net

Hi Will, We've had some initial success with biodiesel mixed with 5 percent chainsaw oil in small model aircraft engines, as well as some success with biodiesel/ethanol mixes in two-stroke engines. I'm working with a couple of organizations that hope to do more comprehensive engine testing and emissions studies for biodiesel in two-stroke engines and will let you know when I have more information. Thank you, Joshua Tickell • Tickell@VeggieVan.org

Generator Windings
Hi, I was wondering if anybody there knows the formula for the number of windings and diameter of wire to produce electricity in a generator? Where can someone find this info? I want to build a three-phase AC generator, but I need to know how many turns, and what size of wire to use. Thank you for any assistance you can provide in this matter! Sincerely, Dan Schroeder windrider991@comcast.net

Hi Dan, The industry approach to designing windings is to build one and find out. But I have an equation in my book, Windpower Workshop, *which says that the number of turns per coil should be 1,200 ÷ (air gap area in square mm x 12 volt cut-in speed in rpm x number of coils in series). The calculation depends on the strength of the magnetic flux, so this is only a rough guide, based on the use of ferrite magnets with large air gaps. Diameter of wire will depend on the available space, and this will also determine the resistance of the coil and thus affect the ability to deliver current. I hope this helps. Hugh Piggott • hugh.piggott@enterprise.net*

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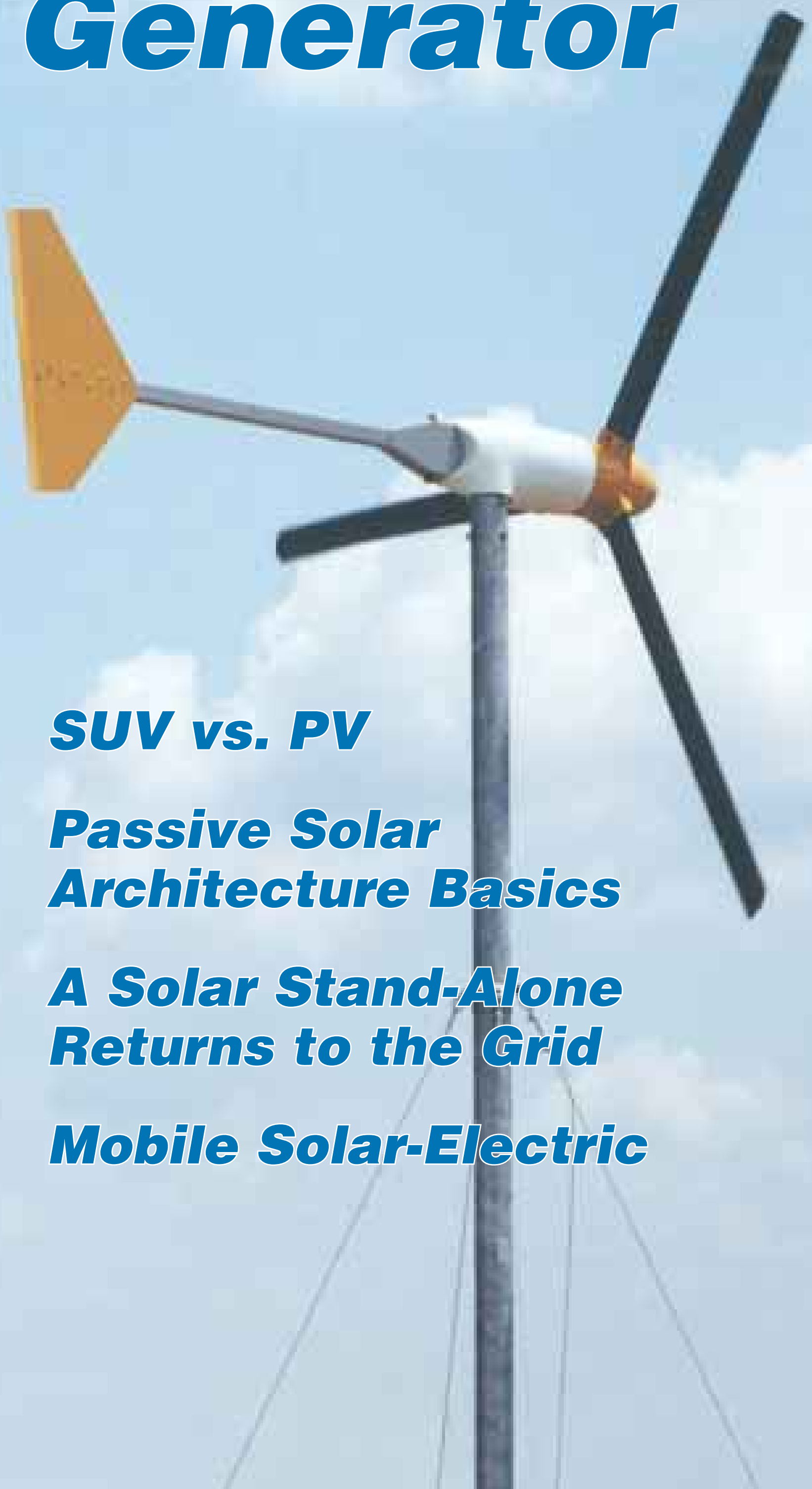

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