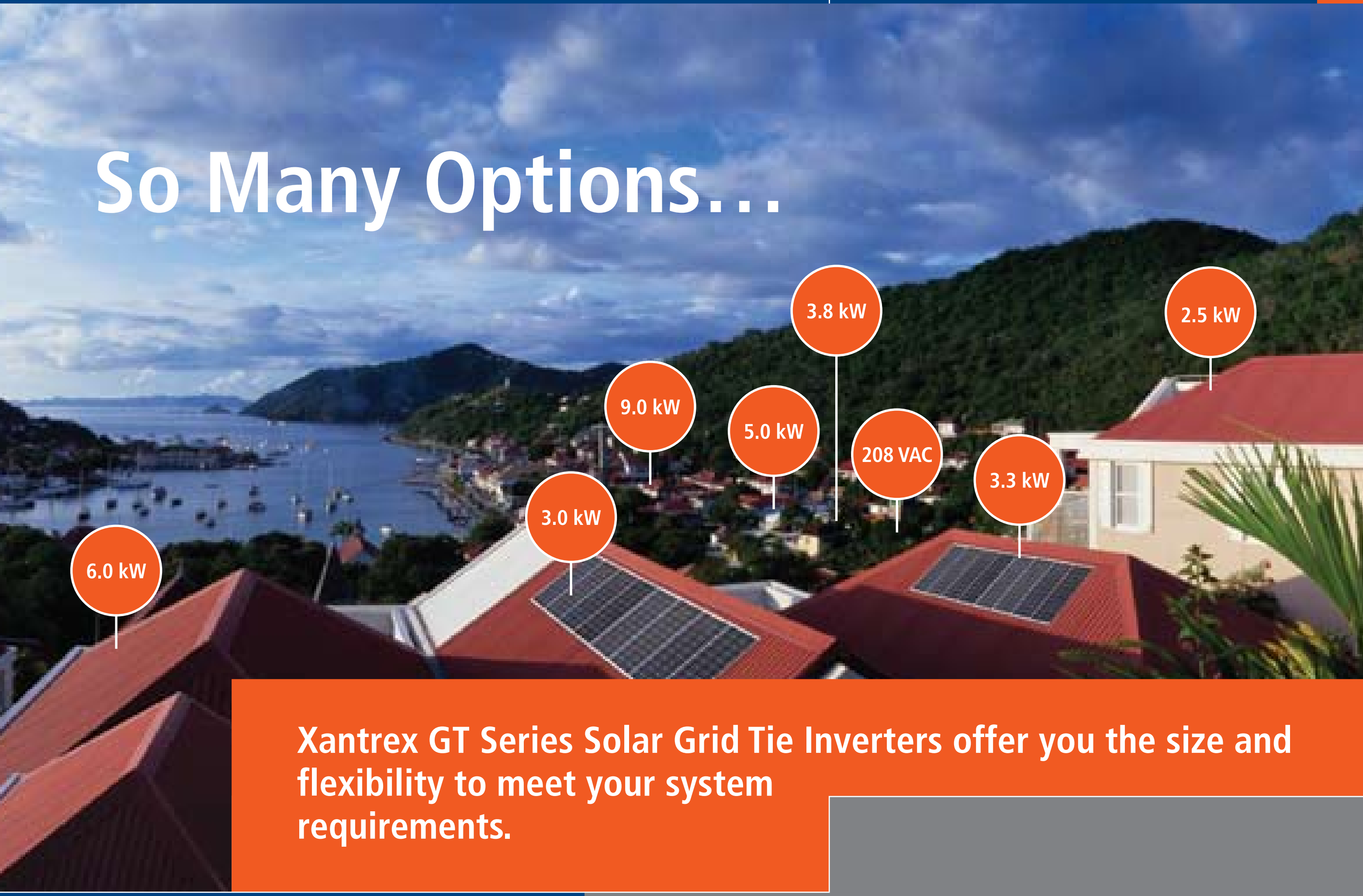
Smart choice for power

xantrex

So Many Options…



Xantrex GT Series Solar Grid Tie Inverters offer you the size and flexibility to meet your system requirements.

Available in 2.5, 3.0, 3.3 and 3.8 kilowatt power levels

Each GT Series inverter includes:

- Mounting bracket
- Code compliant DC/AC disconnect
- Backlit LCD display
- Wide input voltage range 195 - 600 VDC
- Monitoring ports and capability
- Positive ground units available
- 3.3 kW available in 208 VAC

Dealers continue to ask for inverters with system flexibility and ease of installation to keep them competitive. They want inverters that are scalable to use with small and large systems. Xantrex GT Series inverters are the answer.

GT Series inverters are available in power ratings of 2.5 kW, 3.0 kW, 3.3 kW and 3.8 kW. The identical building block design of each inverter allows you to mix inverters of various power levels to create a system that matches the requirements of your array. The lightweight, ease of installation and included features make Xantrex GT Series inverters the smart choice for power.

To learn more about Xantrex GT Series inverters, visit www.xantrex.com/grid tie.

www.xantrex.com

ReadyWatt®
Be Ready.

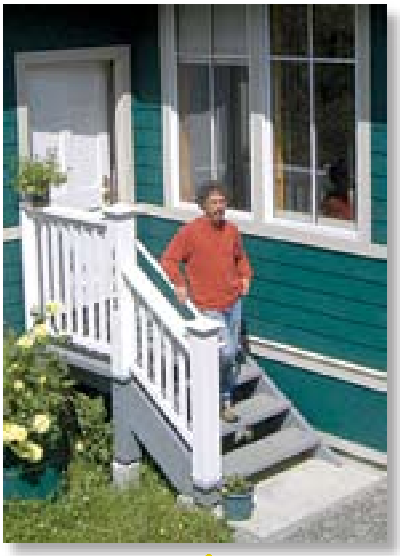
The ReadyWatt® Family of Products

The growing ReadyWatt® family of renewable energy products includes integrated power systems for grid-tie, off-grid, and remote cabins – as well as pass-through and combiner boxes, remote water pumping kits, wire and cables, and RV solar power kits. Each is designed and built to our high standards and is ETL® listed, offering you a dependable system that is code-compliant, aesthetically pleasing, and quick and easy to install. Call today to find out more about how our family can make life a little easier for yours.

Energy Outfitters®

Call for dealer referral. Dealer inquiries welcome.
800 GO SOLAR • www.energyoutfitters.com
Grants Pass, OR • Cedar Grove, NJ • Bozeman, MT
Denver, CO • Calgary, AB • Barrie, ON

HP112 contents



On the Cover

Larry Schlussler on the roof of his high tech California bungalow, designed for super energy efficiency and renewable energy technologies. **See page 14.**

Photo by Shawn Schreiner

Regulars

from us *to you*

I spent a rainy Oregon afternoon on the couch, flipping through a pile of old *Home Power* magazines. I came across an article I authored that discussed grid-tie solar-electric (PV) inverter safety. As I was reading, it occurred to me that the steady stream of questions that we used to receive about the safety of grid-tied PV systems has nearly dried up.

That article was written seven years ago, at a time when reliable and efficient residential grid-tie inverters were still rare here in the United States. Today, we can choose between numerous grid-tie inverters that have both high quality and high performance. Most utilities have become familiar with the equipment, and view the components simply as household appliances that make, rather than use, energy.

But the gear we use is not the only thing that's changed. Today, all but a few states have net metering legislation, which requires that your utility let you offset your electricity usage with solar-generated electricity.

In conjunction with net metering policies and new federal tax credits, many individual states also have financial incentives that make solar energy more affordable than ever. The California Public Utilities Commission passed a sweeping US$2.8 billion measure that will provide solar rebates to Californians for the next decade. The states of Colorado, Washington, and North Carolina also have implemented progressive incentive structures that will drive the installation of solar energy systems.

Seven years from now, I expect to page through some back issues of *Home Power* and see again how our solar community has grown. Looking back, solar energy has come a long way in a short time. And looking forward, the future of solar energy has never been brighter.

—Joe Schwartz for the *Home Power* crew

Think About It...

"Change is the law of life. And those who look only to the past or present are certain to miss the future."

—John F. Kennedy

Legal: Home Power (ISSN 1050-2416) is published bimonthly for $22.50 per year at PO Box 520, Ashland, OR 97520. International surface subscription for US$30. Periodicals postage paid at Ashland, OR, and at additional mailing offices. POSTMASTER send address corrections to Home Power, PO Box 520, Ashland, OR 97520.

Paper and Ink Data: Cover paper is Aero Gloss, a 100#, 10% recycled (postconsumer-waste), elemental chlorine-free paper, manufactured by Sappi Fine Paper. Interior paper is Connection Satin, a 50#, 80% postconsumer-waste, elemental chlorine-free paper, manufactured by Madison International, an environmentally responsible mill based in Alsip, IL. Printed using low-VOC vegetable-based inks. Printed by St. Croix Press Inc., New Richmond, WI.

HP staff

Publisher	Richard Perez
Publisher & Business Manager	Karen Perez
CEO & Technical Editor	Joe Schwartz
Advertising Manager	Connie Said
Advertising Director	Kim Bowker
Marketing Director	Scott Russell
Customer Service & Circulation	Jacie Gray Shannon Ryan
Acting Managing Editor	Claire Anderson
Senior Editor	Ian Woofenden
Submissions Editor	Michael Welch
Art Director	Benjamin Root
Graphic Artist	Dave Emrich
Chief Information Officer	Rick Germany
Solar Thermal Editor	Chuck Marken
Solar Thermal Technical Reviewer	Ken Olson
Green Building Editors	Rachel Connor Laurie Stone Johnny Weiss
Transportation Editors	Mike Brown Shari Prange
Regular Columnists	Kathleen Jarschke-Schultze Don Loweburg Richard Perez Michael Welch John Wiles Ian Woofenden

HP access

Home Power Inc.
PO Box 520, Ashland, OR 97520 USA
800-707-6585 or 541-512-0201
Fax: 541-512-0343
hp@homepower.com
mailbox@homepower.com

Subscriptions, Back Issues & Other Products: Shannon & Jacie
subscription@homepower.com

Advertising: Connie Said & Kim Bowker
advertising@homepower.com

Marketing & Resale: Scott Russell
marketing@homepower.com

Editorial Submissions: Michael Welch
submissions@homepower.com

www.homepower.com

Ask the EXPERTS!

Electricity or Hot Water?

I want to use solar energy, but can't decide whether to start with solar electricity or solar hot water. Can you help?

Sue Benson, Charlotte, NC

Hi Sue, The technologies, costs, and benefits are quite different between the two solar energy systems. I assume your home has electricity available through a utility grid. If your home is off grid, you will almost certainly benefit more from a solar-electric (PV) system. For an on-grid home, the answer is a little more involved.

If the monetary return on your investment is a primary concern, you will find that a solar water heating system is a better value in the United States. Solar water heating collectors are simpler-to-manufacture, more efficient products. Hot water collector efficiencies are about 55 to 65 percent, with system efficiencies of 40 to 50 percent. PV module efficiencies are about 12 to 18 percent, with system efficiencies about 10 to 15 percent.

The costs to have a typical hot water system installed are from US$3,000 to $6,000, and typical PV systems run from US$5,000 to $25,000. The lower cost of the equipment and higher system efficiency translates into more bang for the buck. This economic advantage can be offset if a PV system is eligible for any local, state, federal, or utility incentives that don't apply to hot water systems. These must be factored into the equation if they are available.

Although the equipment is more expensive, solar-electric systems integrated into the utility grid tend to be a cleaner, simpler installation. If cosmetic appearance is a big concern, PV systems are probably better looking, but that's in the eye of the beholder. If this doesn't help you make a decision, you can always flip a coin, or install both. Chuck Marken, AAA Solar, Albuquerque, New Mexico • chuck.marken@homepower.com

Which Hydro Runner?

Can you give me some basic guidelines about when to use a Pelton wheel hydro turbine and when to use a turgo? I can ask my dealer or turbine manufacturer which is best for my head and flow, but I'm trying to understand how they decide.

John Betts, Fairbanks, AK

Hello John, Since both the turgo and the Pelton design are impulse-type turbines, they are quite interchangeable. The Pelton has little advantage over the turgo, except it may be slightly more efficient. The turgo has a higher capacity at a smaller diameter, resulting in a higher shaft speed, which is often an advantage. Turgos have the capacity to offer power at quite a low head, making them an ideal choice for DC output systems with as little as 3 meters (10 ft.) net head. A Pelton, at 3 meters, works quite well hydraulically, except that it has such a low capacity for flow that the output is much lower than the turgo with the same shaft speed.

For projects under 100 KW, offering more than 20 meters (66 ft.) of head, it may be best to compare what is available in both turgo and Pelton designs. Even though the site may be better suited to one design, either type will likely work quite nicely and efficiently. Before you start on your project design, you need to look at what is available, compare prices, and review the manufacturers' performance data as it relates to your own site. Best regards, Dan New, Canyon Industries, Deming, Washington • dan.new@canyonhydro.com

Natural Home Choices

I want to live in a natural house. How do I decide which natural building method to use and find a contractor to build the house for me? Can you suggest good questions to ask and point me to some good resources?

Ben Long, Minneapolis, MN

Hello Ben, Your questions certainly raise very important issues. The good news is that your choices are not as intimidating as they might initially seem. Selecting your building method is often best postponed until the choice can evolve from a thoughtful and comprehensive building design program. We suggest starting your home building program by focusing on your personal needs, lifestyle, site constraints, and local resources. Very often it turns out that a combination of methods—a hybrid solution such as combining materials like straw bales with stressed-skin panels—might meet your personal needs and site constraints.

There are many green building options. The new generation of beautiful photo books on natural home building (NHB), like Catherine Wanek's *The New Strawbale Home,* can be a great starting place. Beautiful images can help you begin to identify how you want your home to look and feel. As professional home designers and architects are wise to remind us, good design always begins with the site. There is no substitute for spending thoughtful time evaluating your building site. Often the critical site issues of access, drainage, microclimate, soil types, view, on-site materials, and privacy will help select appropriate building methods.

Likewise, it often requires a bit of a process to find an appropriate building contractor. The good news here is that there are a growing number of quality professional NHB contractors, and they are looking for you too! Your local RE installing dealer, and your local or regional official building department can often provide helpful informal guidance. *The Last Straw Journal* (www.thelaststraw.org) is a great resource. Help with design, financing, selecting building materials, finding green products, specialty tools, consulting services, and hands-on NHB workshops—it's all available. In your region, the Midwest Renewable Energy Association (www.the-mrea.org) is a good resource. You are not alone!

When selecting a contractor, you should interview applicants diligently. Get references and visit past clients and homes. Your job is to quarterback the design–build team, keep your sense of humor, and enjoy building your natural home. Johnny Weiss, Solar Energy International (SEI), Carbondale, Colorado • johnny@solarenergy.org

To submit a question to
***Home Power's* Ask The Experts,**
write to:

AsktheExperts@homepower.com
or
Ask the Experts
Home Power
PO Box 520, Ashland, OR 97520

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

Extreme Efficiency

How Low Can You Go?

What do you get when you give an industrious engineer and solar energy enthusiast with an eye on the bottom line the chance to design his own abode? An extreme home—extremely energy efficient, that is. Larry Schlussler shows how far he can go in his quest for whole-house efficiency.

I moved into my new 960-square-foot (89 m^2) bungalow in Arcata, California, on the fall equinox—September 21, 2004. I wanted to run my house strictly on renewable energy, and demonstrate several energy conserving technologies I have been developing. I also wanted to build a home whose net carbon emissions would be zero.

To achieve this, I incorporated passive solar design strategies, a solar thermal system for water and space heating and cooling, a grid-tied solar-electric (photovoltaic; PV) array, and some special energy and water efficient features. On a yearly basis, my house is a net producer of energy—without burning *any* type of fuel, nonrenewable or renewable.

Larry Schlussler, PhD

Ushering in the Sun

Located on the northernmost coast of California, Arcata has a unique climate with mild winter temperatures and cool summers that typically peak at 65°F (18°C). Only two cities in the United States (both in Alaska) have smaller summer cooling loads. Despite the mild climate, Arcata has almost as many "heating degree days" per year as Philadelphia does (4,650 vs. 4,759), and essentially no cooling degree days. (One "heating degree day" is one day with the temperature 1°F below 65°F. Heating degree days and cooling degree days indicate when supplemental heating and cooling may be needed to maintain comfortable indoor temperatures.)

This unique climate has a number of implications for solar home design. Good ventilation can control overheating caused by too many east- and west-facing windows, and deep overhangs on south-facing windows, which usually prevent summer solar gain into the house, are not needed.

My house incorporates 70 square feet (6.5 m^2) of south-facing windows, and a sunspace entryway that has an additional 70 square feet of glazing. The sunspace has single-pane windows, which only cut out about 10 percent of the incident solar radiation. The fraction of incident solar radiation that passes through a window is called the solar heat gain coefficient (SHGC). With an SHGC of 0.9, these windows maximize heat gain into that space. During the night, I close the door between the sunspace and living space, so heat loss through the single-pane windows is not a primary concern.

Interior windows on the south side of the house incorporate clear, double glazing with an SHGC of 0.8. The standard low-E (low-emissivity) glazing offered by my window manufacturer has an SHGC of only 0.41—not something you'd want if you're trying to depend on solar gain for passive heating.

Designing for optimal heat gain and minimizing heat loss through the windows is an important consideration in passive solar design. Heat loss through a home's windows can be nearly as large as the total heat loss through all its walls. The windows on the north side of my house, where solar gain was not a consideration, have low-E coatings to minimize heat loss. Low-E, double-glazed windows lose about 35 percent less heat than clear, double-glazed glass. Argon gas-filled windows reduce heat loss by about 50 percent. (The total loss in a window is always greater because of heat loss through the frame.) Windows come with a variety of coatings to control solar heat gain, visible light transmission, and R-value. Consideration should be given to the array of coatings possible before specifying a glazing.

Above: Homes designed for extreme efficiency can also embody elegance and charm.

Right: Two, 4- by 10-foot solar thermal collectors located on the roof of the utility room heat the home's water. A small solar-electric panel powers a pump to circulate water through the system.

South-facing, single-pane windows in the sunspace let in lots of sunshine for natural lighting and passive solar heating.

South-facing windows were set into the wall as high as possible so that the light and heat penetrate into the space as far as possible. Several small clerestory windows on the east and west walls provide additional natural light without admitting too much heat. A tubular skylight brings light into the windowless bathroom, eliminating the need for using artificial light during the day.

To reduce nighttime heat loss, I installed "double honeycomb" cellular shades, which incorporate a small air space between two layers of fabric. When closed, these shades roughly double the R-value of the double-glazed windows. The 6-inch-thick (15 cm) walls of the house are insulated with R-19 fiberglass insulation and the ceiling is insulated to R-30.

An efficient home means using energy saving appliances, such as a Sun Frost refrigerator, on-demand water heating, and foot-pedal activated faucets.

House-Warming by Design

I opted not to put any additional thermal mass into the house. In Arcata, we often get prolonged periods of rainy weather during the winter months. Considering the climate and my lifestyle, additional thermal mass would be a detriment. When the house is unoccupied during the day, heat is not necessary. On rainy days, I want the house to warm up quickly in the morning and when I arrive home at night. With additional thermal mass, the house would not heat up as rapidly, but would stay warmer further into the night when I am sleeping. It would also stay warmer later into the morning when the house is no longer occupied. Keeping the house warm when it is not necessary would increase heat loss and energy consumption, even if the heat was provided by thermal mass.

Without any additional thermal mass, on sunny days during the winter the house stays at a comfortable temperature until I go to sleep. Indoor temperatures are typically in the low 60s by the next morning, when the temperature outside is in the low 40s.

The house also incorporates 80 square feet (7 m^2) of solar thermal panels, which heat up 160 gallons (605 l) of water. This water is used for domestic hot water, cooking, and space heat. The 160 gallons of hot water can be thought of as thermal mass that is isolated but can be called upon to heat the living space when desired. If I need heat in the morning and it was sunny the previous day, the heat stored in the hot water tank will heat the house.

But when the rains began in November, my solar thermal system was not always producing an adequate amount of heat. I then added a 5,500-watt instantaneous electric heater to boost the water temperature. For space heating, the hot water is distributed by fan coil heaters. These devices look like car radiators. To heat the bathroom, I constructed a combination radiator–towel warmer. The fan coils were oversized so that comfortable conditions could be attained with relatively low-temperature hot water—an advantage with solar hot water because the solar collectors become less efficient as the water gets hotter.

Radiant heating is an excellent way to provide comfortable, uniform temperatures, but convective heat also has its place. In convective heating, air is heated more than surrounding surfaces. The fan coils I use are convective heaters. The advantage is that they can rapidly warm up a space without keeping the space warm long after heating is needed. It would take about 20 times more energy to heat the thermal mass in my house than to heat the air. Typically, the air will get about 7°F (4°C) warmer than the surrounding thermal mass; thermal

Solar-heated water cycles through fan coils inside this built-in enclosure. Air enters from the top right and exits lower left.

comfort is dependent on both the air temperature and the mean radiant temperature (the temperature of surrounding surfaces).

Water Misers

I also set my sights on reducing my hot water consumption. A major component is my energy efficient shower. This totally enclosed shower allows me to take a comfortable shower with a water flow rate of only 0.5 gallons per minute (0.03 lps), when 2 gpm (0.13 lps) is usually considered low flow. The shower stall has a clear Plexiglas ceiling located about 1 foot (30 cm) below the bathroom ceiling. A 2-foot-wide (61 cm) shower curtain serves as the shower door. Clips seal the curtain at its bottom and sides. The rest of the wall is clear Plexiglas. This configuration allows for a comfortable shower even if the air temperature in the bathroom dips to 50ºF (10°C). It also helps eliminate moisture problems, the need for ventilation systems, and mold growth.

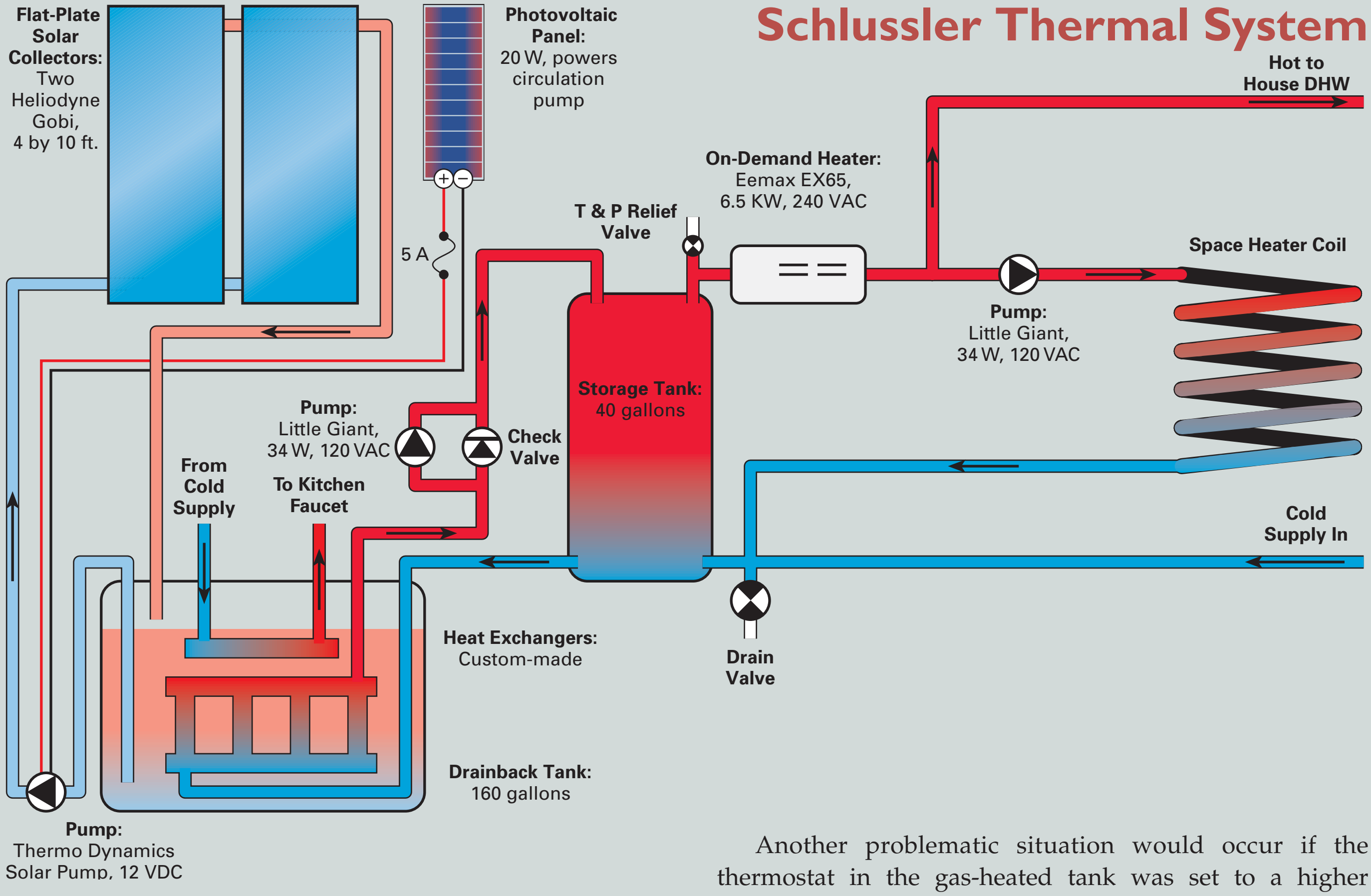
The house is fitted with a conventional flush toilet to meet building codes; however, I almost always use a composting toilet, located in the utility room. Composting toilets conserve water and turn a waste product into a valuable soil amendment. A well-designed composting toilet has very low odor and keeps pathogens at bay. This technology has a large potential for conserving water and resources, but has been generally overlooked. In areas that have been devastated by natural or human-made disasters, such as Louisiana or Iraq, composting toilets would be an ideal solution for sewage treatment.

Smarter Cooking

I've also managed to improve the efficiency in my kitchen by using what I term a "solar hybrid cooking system" and by recycling my food scraps. The cooking system incorporates water that is preheated by my solar thermal system, and insulated pots that are electrically heated and thermostatically controlled. Instead of using a garbage disposal, which uses water and energy, and increases the waste that needs to be disposed of at the local sewage treatment plant, I compost my food scraps.

This enclosed shower keeps heat in, allowing comfort at lower room temperatures. Other efficiency features include a solar-heated combination room heater and towel rack, and a tubular skylight for natural lighting.

Schlussler Thermal System



Wise Water Heating

I chose to use a drainback solar hot water system because the system uses no antifreeze, and it incorporates an unpressurized storage tank. Choosing an unpressurized storage tank allowed me to build my own tank and heat exchanger.

My hot water system consists of a 160-gallon (605 l) unpressurized tank and a 40-gallon (141 l) natural gas water heater; however, the gas was never turned on. The 40-gallon tank is located above the unpressurized tank. Heat is transferred from the unpressurized tank to the 40-gallon tank by a passive thermosiphon loop. Heavier cold water leaves the bottom of the 40-gallon tank, and then goes to a heat exchanger in the unpressurized tank, where it is warmed. It then rises to an entrance at the top of the 40-gallon tank.

Instead of using a long coil of copper tubing as a heat exchanger, I constructed one that uses several parallel paths to minimize flow resistance. I put a pump in this loop in case the thermosiphon loop was too slow, but I found that it is seldom necessary to turn it on.

If the gas was turned on to heat the 40-gallon tank, this particular system has two potential problems. After a long cloudy period, if I used a lot of hot water the morning of the first sunny day, the water would be heated before the sun could do its job, and the energy used to heat the water in the 40-gallon tank would essentially be wasted.

Another problematic situation would occur if the thermostat in the gas-heated tank was set to a higher temperature (say, 110°F; 43°C) than the water in the unpressurized solar tank (say, 100°F; 38°C). With colder water in the lower tank, the thermosiphon loop would make no contribution—even if the incoming water was at 50°F (10°C). I anticipated alleviating this problem by incorporating several valves in the system, which would allow incoming cold water to first go through the heat exchanger in the unpressurized tank. After leaving the heat exchanger, this warmed water would then enter the cold-water inlet at the bottom of the 40-gallon tank.

I later realized that these management problems could be eliminated by incorporating an inline (on-demand) water heater at the output of my 40-gallon tank and by not connecting the gas heater. Then, the question was: Should I go with a natural gas or electric inline heater? At the generating plant, three units of energy from natural gas are typically needed to produce a single unit of electrical energy—the 33 percent efficiency is a consequence of inefficiencies and the second law of thermodynamics, which states that all the heat energy in the gas cannot be turned into electrical energy.

My solar thermal system often warms the water to 100°F (38°C) during the winter. With the low flow rate of my energy efficient shower, I would only need 3,100 Btu per hour to boost the temperature of my hot water to 115°F (46°C). The lowest output I found on an inline gas water heater was 16,000 Btu per hour, which would mean wasting 80 percent of the heat. Since an electric heater can modulate its output so that a boost of only 5°F (3°C) or less can be made, I decided to use an electric water heater.

In the future I may split the output of my 40-gallon tank and use an instantaneous electric water heater for my domestic hot water, and an instantaneous gas heater to boost water temperature to my heating system. The larger output of the gas heater can be effectively used for space heat. This strategy would result in less carbon dioxide being generated; however, it would increase my utility bill because I'd be paying for gas.

The author with his 1,670 watts of utility-tied PV panels.

PV Power

My 1,670-watt solar-electric system consists of ten Sharp 167-watt PV modules and a Sunny Boy 1,800-watt inverter. During the darker part of the year, from September 21 to April 13, 2005, my net production equaled my consumption, and my PV system and solar thermal system supplied all my energy—no additional backups were required. During the summer months I contributed quite a few KWH to Pacific Gas and Electric (PG&E), my local utility company.

PG&E charges US$4.97 per month to be connected to the grid, and then sends a yearly bill based on net annual electrical use. If you generate more energy than you consume, you do not receive a refund for the extra KWH you produce. I would like to see an incentive program that would pay a bonus if your net annual electricity consumption was zero or less. A program based on net performance would encourage conservation and also encourage the homeowner to make sure their PV system continues working at peak efficiency.

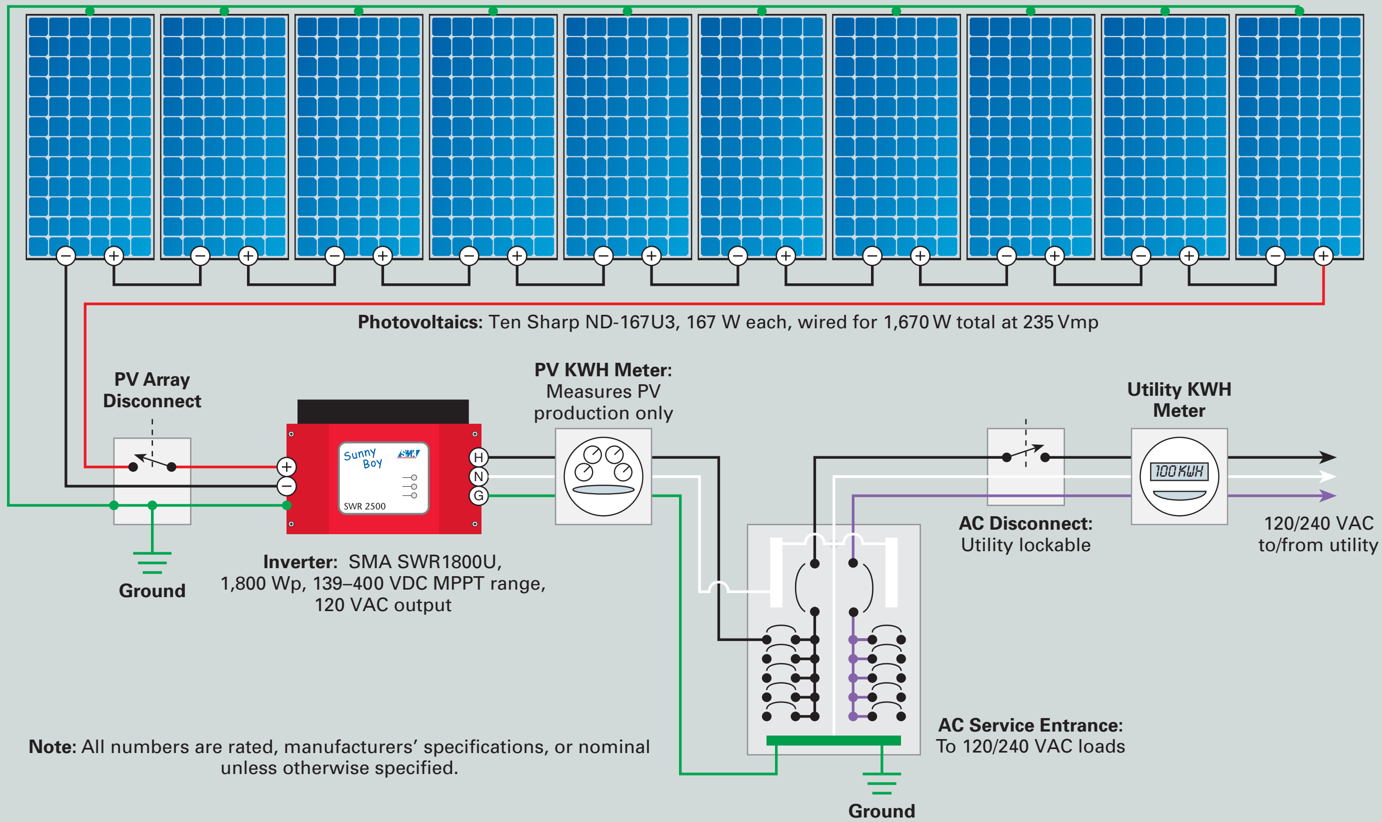
In Arcata, the average yearly insolation (incident sunlight) on a surface was a maximum at an angle of 26 degrees. This is the same as the angle of my roof, which has a 6-in-12 pitch. The average number of hours of full sun hitting my roof is 4.4 hours per day. To calculate the daily output of my PV array, both inverter losses and the losses of my PV panels were estimated. The Sunny Boy 1800 inverter is about 92 percent efficient. (I located my inverter in an interior space so I could readily keep track of its performance, and also capture the 8 percent waste heat it generates.)

The losses in the PV panels are primarily due to solar heating. For each degree Fahrenheit the panel temperature rises above 77°F (25°C), the output decreases 0.27 percent. A pole-mounted array will typically be about 40°F (22°C) above the ambient temperature. A roof-mounted array with a small clearance between the roof and the array could heat up to 65°F (36°C) or more above the ambient temperature. In

Left: The SMA Sunny Boy utility-interactive inverter, PV disconnect, and dedicated PV KWH meter are located inside the house.

Right: The service entrance, utility lockable disconnect, and utility KWH meter are mounted outside.

Schlussler Utility-Tied PV System



inland California where temperatures climb to the 90s, this loss alone could be more than 22 percent.

For aesthetics, I used a mount that placed the panels fairly close to the roof's surface (3 in.; 8 cm). The mount has a skirt in front of the panels that is only 1 3/4 inches (4.4 cm) from the roof surface. Using an infrared thermometer, I estimated that the cells were about 62°F (34°C) above the ambient temperature. With a mean daytime ambient temperature of 60°F (16°C), the average loss is then 12 percent. Because panel heating can influence the system's production, both PV panel and mount manufacturers should include information on how mounting configurations affect efficiency.

My calculations showed an overall efficiency of 81 percent. At this efficiency, and 4.4 peak sunlight hours per day, the output of my system should be 5.95 KWH per day, or 2,172 KWH per year. My measured output over twelve months was actually 2,130 KWH or 5.8 KWH per day. This was in excellent agreement with the calculated value; I was actually surprised these figures were so similar.

On a yearly basis, my solar-electric system produces 3.5 KWH per day for each KW of solar array. This figure is useful to see how large an array is needed to run an appliance. For example, my Sun Frost refrigerator consumes 0.27 KWH per day. Seventy-seven watts or a little less than half of one of my 167-watt modules can run the refrigerator.

The installed cost of a grid-tied system can range from US$6,500 to $11,000 per KW, depending on the ease of the installation, and the cost of the equipment and labor, as well as the size of the system (i.e., larger systems cost less per watt). Assuming the cost per KW is US$8,500 in Arcata with an average production of 3.5 KWH per KW of solar array, an investment of US$2,444 is required to produce one KWH per day.

In a stand-alone system, the investment required to produce 1 KWH per day is roughly double that, or US$5,000. The extra costs are due to a voltage mismatch between the

Tech Specs

Type: Batteryless, grid-tie PV

Location: Arcata, California

Solar resource: 4.4 average daily peak sun-hours

Production: 5.8 AC KWH/day

Utility electricity offset: 100 percent

Photovoltaic modules: Ten Sharp ND-167U3, 167 W STC, 23.5 Vmp

Array: One series string, 235 Vmp, 1,670 W STC

Inverter: SMA SWR1800U, 1,800 Wp, 139–400 VDC MPPT range, 120 VAC output

The Sun Frost Scrap Eater uses sunlight and heat to turn household food scraps into a valuable soil amendment.

PV panels and the batteries, the efficiency and limited storage capacity of the batteries, and the need for a backup system. During the summer, batteries are sometimes filled up by noon, and the output of the PV system for the remainder of the day is typically wasted. Charge controllers are currently available that minimize the voltage mismatch between the panels and batteries and increase the output of a PV system.

Conservation is a good investment if you can reduce your energy consumption 1 KWH for less than the cost of generating 1 KWH. For example, in a grid-tied system, if you purchase a product that consumes a KWH less than a competing product and its additional cost is less than US$2,444, it would be a good investment. The product should have the same life expectancy as the PV system. In an off-the-grid system, an investment up to US$5,000 would be worthwhile to save a KWH per day.

Going Extreme

More progress can be made in making a home's basic functions more efficient. Incorporating daylighting, implementing passive solar design strategies, installing a solar domestic hot water system, improving the energy efficiency of the cooking process, improving washers and dryers, recycling organic wastes like food scraps and human manure with composting systems, and using graywater systems to irrigate gardens are just a few changes that can substantially improve a home's energy efficiency. These potential improvements are a resource that is just barely tapped. Improvements in these areas will save energy more expeditiously and at a lower cost than will supply-side solutions.

Access

Larry Schlussler PhD, Sun Frost, PO Box 1101, Arcata, CA 95518 • 707-822-9095 • Fax: 707-822-6213 • info@sunfrost.com • www.sunfrost.com • Shower design, Scrap Eater outdoor composter, Human Humus Machine & Sun Frost refrigerator

Roger, The Little House, 1527 Buttermilk Ln., Arcata, CA 95521 • 707-826-9901 • Solar-electric system installer

Ben Scurfield, Scurfield Solar, PO Box 41, Arcata, CA 95521• 707-825-0759 • bscurfield@yahoo.com • Installer, solar domestic hot water system

Heliodyne, 4910 Seaport Ave., Richmond, CA 94804 • 510-237-9614 • Fax: 510-237-7018 • info@heliodyne.com • www.heliodyne.com • Gobi solar thermal collectors

Hunter Douglas • 800-789-0331 • consumer@hunterdouglas.com • www.hunterdouglas.com • Energy efficient window treatments (honeycomb cellular shades)

ODL Inc., 215 E. Roosevelt Ave., Zeeland, MI 49464 • 866-ODL-4YOU • info_west@odl.com • www.odl.com • Tubular skylights

Sharp Electronics Corp., 5901 Bolsa Ave., Huntington Beach, CA 92647 • 800-SOLAR-06 or 714-903-4600 • Fax: 714-903-4858 • sharpsolar@sharpsec.com • www.solar.sharpusa.com • PV panels

SMA America Inc., 12438 Loma Rica Dr., Unit C, Grass Valley, CA 95945 • 530-273-4895 • Fax: 530-274-7271 • info@sma-america.com • www.sma-america.com • Sunny Boy inverter


SUN~XTENDER® SERIES
...the heart of your solar system
• Designed For Alternate Energy Systems (PV/Wind)
• Maintenance Free - Never Add Water
• Absorbent Glass Mat Technology – Superior Cycle Life
• Sealed, Non-Spillable – Operates Upright on Its Side or End
• Low Impedance Design with Excellent Charge Acceptance
• Stand Alone and Grid Tied Systems
• Robust Military Aircraft Construction for Shock and Vibration
• Sun~Xtender® Series Batteries are Environmentally Friendly and Recyclable
• Underwriter's Laboratories Recognized Systems Component
• ISO 9001:2000 Certified
The Heart of Your Solar System
US MIL SPEC MANUFACTURER + SAFETY + "0" MAINTENANCE + LONG LIFE
=
SUN~XTENDER® SERIES BATTERIES
CONCORDE
2009 San Bernardino Road • West Covina, CA 91790 USA • Phone 626-813-1234 • Fax 626-813-1235
www.concordebattery.com

KEEP COOL

Install a Solar Attic Fan

John Patterson

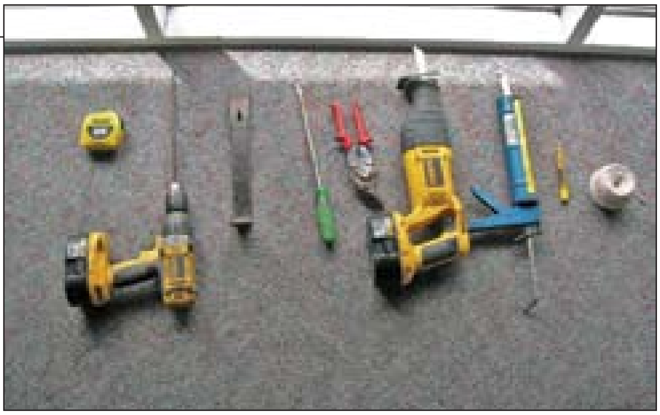
Solar-powered attic fans are cool! I've worked in attics for many years, running plumbing for solar water installations, and I know all too well how hot it can get up there. I've measured temperatures up to 140°F (60°C)! Most homes have manual roof vents, which allow some air movement, but they can't keep up with the sun pounding down all day.

A single solar attic fan can cool about 1,500 square feet (140 m^2) of attic area. The fan should be installed more or less in the middle of the attic to serve the entire space. The fan will draw outside air from the eaves and from other vents. The idea is to draw air from all outside sources equally.

Step by Step

Solar attic fans are very simple to install. My crews do them in an hour or two. The biggest challenge to the do-it-yourselfer is psychological—"Do I dare cut a 14-inch (36 cm) hole in my roof and trust that it won't leak?" If you have a tile, metal, or cedar shake roof, you may wish to defer to a professional. If you have a conventional composition shingle roof, it's not as scary as you think. You can do it!

1 First you need a few tools, which most do-it-yourselfers will have. Your attic toolbox should contain a measuring tape, drill with a 1/4-inch (6 mm) or smaller drill bit, and a light. On the roof, you'll need chalk or crayon, a short string, a flat pry bar, a caulk gun, a tube of clear silicone caulk, a cordless drill/driver, utility knife, and a reciprocating saw, saber saw, compass saw or keyhole saw.



2 Determine the general location of the fan. It should be installed in a sunny location, near the roof's peak, and in the middle of the attic space to be cooled. Next, determine the exact location of the attic fan. Measure 12 to 18 inches (30–46 cm) below the peak and make a mark centered between two rafters.

3 Drill a hole from the attic through the roof. Leave the drill bit in place so it can be easily found from the roof.

4 On the roof, locate your drill bit. Using a 7-inch (18 cm) string around the bit, draw a circle 14 inches (36 cm) in diameter. Always double-check the dimensions of the particular fan model you're using.

5 Drill a hole large enough to insert your saw blade, if necessary, and then cut around the circle's perimeter with your saw. Be sure to catch the cut-out plug rather than letting it fall in.

6 To allow the unit to slide all the way into place, you will have to trim away about a 2-inch-wide (5 cm) arc from the first course of shingles directly above the fan unit. Mark the roof at the centerline of the hole for the up-and-down axis to help determine the position of the fan when centered over the hole. You can go back into the attic to make sure.

7 Try to slide the solar attic fan into place, making sure the top edge of the unit slips under at least two or three courses (horizontal rows) of roofing. The opening of the fan should be directly over the hole in the roof.

8

Inevitably, you will hit nails or staples holding shingles in place as you attempt to place the unit. Do not force it! Instead, try to locate the obstacle by gently lifting shingles, and looking for the nail or staple in the way. If the obstacle is a nail, remove the nail with a flat pry bar. If a staple, drive a large, flat-head screwdriver under the staple and pry up. Repeat the process until all nails or staples in the way are pulled.

9

Now that the unit fits directly over the hole, you're ready to fix and caulk it into place. Lift the bottom edge of the base and caulk all the way up and a few inches beyond the point where the unit goes under the shingles.

10

Using gasketed roofing screws, fasten the base to the roof. The screws should pass through the caulked perimeter. Caulk over the screw heads and you're done.

Keep Your Cool

Now, that wasn't so nerve wracking, was it? Notice for yourself how much cooler the attic is with the fan working.

Standard, 120-volt AC attic fans have been around for a long time. They are often big and boisterous, and require an electrician or knowledgeable homeowner to do a hardwired hookup. Costs can easily exceed US$600.

For the same price or less (if you do it yourself), the more elegant solar-powered attic fan can do the job. Using a simple, 10-watt photovoltaic module directly powering a 12-volt DC fan, these self-contained units can quietly and effectively move 800 cubic feet (23 m^3) of air per minute. This is enough to cool a typical attic by 30 to 50°F (17–28°C).

Solar attic fans do not rely on batteries to get the job done. Instead, they simply operate when the sun is shining on the fan's PV module, and effectively cool the attic during the time of the day that heat would otherwise build up. In some places, it can eliminate the need for air conditioning.

No matter how well insulated your ceiling is, excessive heat in the attic will find its way into your living space. Insulation simply slows it down. By midday, an army of millions of Btu have marched through your insulation and are assaulting your living space. Solar attic fans reduce the air conditioning load in the living space below, and make hot summers more endurable for those who don't use air conditioning.

Success Stories

"Our house used to bake in the summer! We have a long, south-facing roof that would make the upstairs unbearable for months of the year. The temperature in the attic would build through the day and continue to radiate heat well into the evening. When we installed a solar-powered attic fan, it changed everything. Now, the upstairs temperature never exceeds the outside air temperature, and cools rapidly after sunset. I enthusiastically endorse solar attic fans. For such a tiny device, and such a small investment, it makes such a big difference. It's better than the conventional AC fan, which rumbles noise through the whole house. Mine does the job in total silence. I love my solar attic fan!"

—Jeff Michael, Portland, Oregon

Judith Ris proudly points to her new solar attic fan.

"We've had our solar attic fan installed for about a year. For years, our family has used air conditioning to maintain the home at the same comfortable level. We're on an equal pay program with the electric utility. Since the attic fan went in, our monthly payment has gone down US$10 per month. No other energy conservation measures were employed last year, so it appears that the attic fan deserves the credit. We love how it quietly and unobtrusively saves energy and money."

—Dr. Judith Ris, Vancouver, Washington

There are a handful of solar attic fan manufacturers. Most have fixed PV modules, which means that the unit has to be placed in the location most favoring the sun. One manufacturer offers a module that can be tilted. On a roof whose peak runs north and south, this unit can be placed near the peak on either side, with the module tilted up and oriented to the south. This is accomplished first by tilting the module, then spinning the base to face the module south before caulking and fixing to the roof. I've even placed these on north-sloped roofs, with the PV module tilted to face south.

Most solar attic fans have optional thermostats. The manufacturers claim that it's good to vent the roof year-round, which means no need for a thermostat. But, if you're worried that on cold winter days you may be expelling warmer air from the attic and increasing your heating load, a thermostat is advisable. Thermostats snap in place in the wiring between the module and the fan, and dangle freely into the attic space.

I've been asked about solar attic fans to cool upper level living areas finished to the rafters. Generally this is not an acceptable use, since in winter months the hole in the roof allows heat to escape even if the fan motor is disabled. If a well-insulated and sealed cover is used, however, it could work.

Few solar energy technologies are more simple, elegant, and cost effective than solar attic fans. The significant benefit for relatively low cost makes it an excellent investment both in terms of energy savings and personal comfort.

Access

John Patterson, Mr. Sun Solar, 3838 SW Macadam Ave., Portland, OR 97239 • 888-765-7359 or 503-222-2468 • Fax: 503-245-3722 • john@mrsunsolar.com • www.mrsunsolar.com

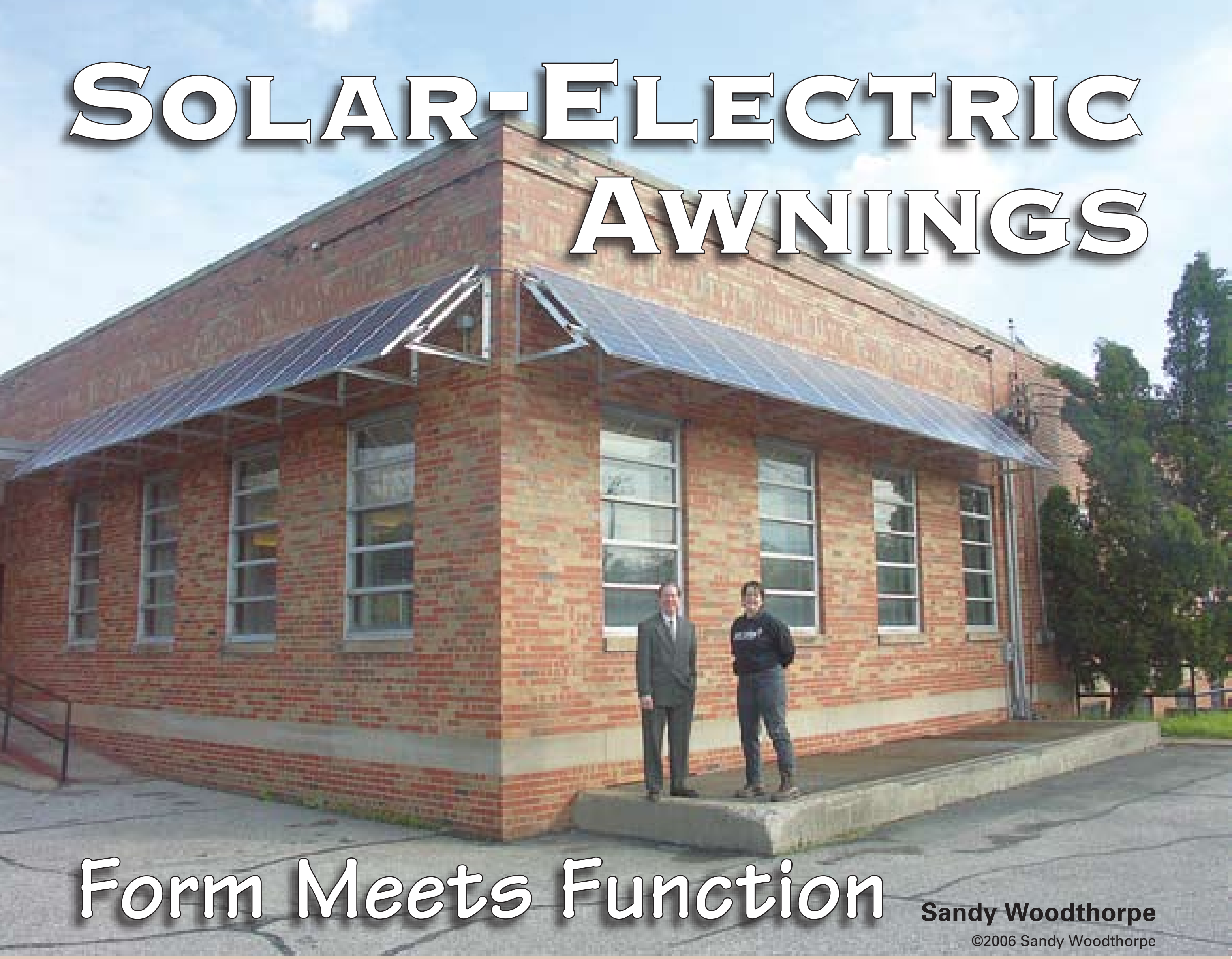
Solar Attic Fan Manufacturers:

Natural Light Energy Systems, 10821 N. 23rd Ave., Ste. #1, Phoenix, AZ 85029 • 800-363-9865 or 602-485-5984 • Fax: 602-485-4895 • elio@nltubular.com • www.solaratticfan.com

Nu-Light Solutions, 1900 Dobbin Dr., San Jose, CA 95133 • 408-254-6661 • Fax: 408-254-7908 • info@fan-attic.com • www.fan-attic.com

Solatube International Inc., 2210 Oak Ridge Way, Vista, CA 92081 • 800-966-7652 or 760-597-4400 • Fax: 760-599-5181 • info@solatube.com • www.solatube.com

Solar-Electric Awnings



Form Meets Function

Sandy Woodthorpe

Above: Architect Bill Doty and RE systems designer Erika Weliczko under the solar-electric awnings at the south corner of the Doty & Miller office.

Northeast Ohio receives an average of four peak sun hours daily. That might not seem like much to those of you living in the Sunbelt, but it's enough sunshine for solar electricity to work in Cleveland. In fact, two solar-electric awnings that a group of us Ohio solar-energy enthusiasts installed last summer are generating electricity for a small architectural firm. And we are busily planning more projects to demonstrate that solar electricity is a viable alternative to coal- and nuclear-generated electricity.

Below: Structural engineer Ed Gallagher and Bill Doty display one of the custom mounts.

The awning system was Green Energy Ohio's (GEO) first workshop project. This article describes the system, as well as how we used the project to turn one July weekend into a fun, educational, and publicity (and electricity!) generating event. The installation drew more than twenty participants from central and northeast Ohio, as well as Michigan, and was a big success.

Seed of an Idea

Our workshop and installation grew from an idea conceived by Bill Doty, solar energy advocate and partner of Doty & Miller Architects. In 2002, he applied for matching grant funds from the Ohio Department of Development's Office of Energy Efficiency to help finance a small, grid-intertied system at his firm's office building in Bedford, just south of Cleveland. Bill included an educational component—a workshop—in his proposal for the Energy Loan Fund (ELF) grant. The purpose of the workshop was to help promote solar energy to the community, provide a learning opportunity for budding solar-electric installers, and keep costs within budget. The total project cost was US$20,250. The ELF grant Bill received covered 50 percent of the cost; he matched it with US$10,125.

The project was promising right from the start. Doty & Miller is a 27-year-old firm, well known in the region for its commitment to using "green" design and materials. The firm's offices are located in a beautifully renovated 1930s-era U.S. Post Office building that showcases the firm's sustainable design expertise. Green construction materials were used for the flooring, walls, windows, paint, and trim. The heating, cooling, and ventilation system, as well as kitchen appliances, office equipment, and lighting were selected for their high efficiency ratings.

Doty & Miller Architects renovated this former post office to modern-day efficiency standards.

The Seed Is Planted

At the time funds were approved for his system, Bill was hosting meetings for the GEO's solar committee. This group of about ten volunteers was organizing GEO's annual tour of solar homes and businesses, held each October in conjunction with the American Solar Energy Society's National Solar Tour. When Bill happily informed the committee that money was on the way to install a solar-electric system, the members saw the potential for a high-profile renewable energy demonstration project. Doty & Miller's reputation for sustainable design, the firm's civic involvement, and the building's location in a recently revitalized part of town were elements for success.

In the past, GEO offered numerous seminars that provided overviews of various renewable energy technologies. The solar committee wanted to take learning to the next level by giving workshop participants hands-on installation experience.

Custom-made mounting brackets provide a stable platform for the PV arrays.

A Showcase System

Because of the demonstration nature of this project, Bill felt it was essential that the solar-electric panels be visible from the street, rather than hidden on the roof. He liked the idea of a solar-electric awning system for its aesthetic appeal and also because it combines active solar energy generation with passive shading of the building's windows during the summer.

With the Doty & Miller building, system designer Erika Weliczko had to take into account two different sun exposures—one on the southeast side and the other on the southwest side—

Workshop participant Jason Moore wires the panels.

and figure out how to deal with shading from nearby trees. Ultimately, she designed the system with two separate PV arrays—a southeast-facing array optimized for 9 AM to 2 PM, and a southwest-facing array optimized for 11 AM to 3 PM. Each array feeds DC electricity to a dedicated inverter that, in turn, outputs grid-synchronous AC electricity.

The next challenge was designing the support framework (mounting racks) for the solar-electric panels. Rather than ordering stock mounts and retrofitting them to form the awnings, Bill favored custom designing the framework. After calculating combined solar-electric panel weights, the optimum angle for capturing solar energy, weatherability, strength, and aesthetics, Doty & Miller's structural engineer Ed Gallagher came up with a design that used stock aluminum angle material, cut to size and bolted together.

The custom-designed and fabricated aluminum awning that supports the solar-electric panels consists of a series of triangles constructed out of lightweight, 3- by 3-inch, aluminum angle. Before the workshop, the mounts were pre-drilled and bolted together to form triangles using stainless steel bolts with stainless steel nylon locknuts. Next, the triangles were drilled and mounted to the building on previously installed, threaded epoxy stud anchors. After the mounts were fastened to the building, aluminum box beam rails were attached to them horizontally. With the rack and horizontal rails in place, the solar-electric panels were then fastened to the rails using UniRac low-profile mounting clips.

Tech Specs

System Overview

Type: Batteryless, grid-tie PV

Location: Bedford, Ohio

Solar resource: 3.9 average daily peak sun-hours

Production: About 300 AC KWH per month

Utility electricity offset: About 4 percent (due to significant HVAC loads)

Photovoltaics

Modules: 28 Kyocera KC-120, 120 W STC, 16.9 Vmp

Array: Two, 14-module series strings, 1,680 W STC each, 236.6 Vmp, 3,360 W STC total

DC array disconnect: Square D HU361

Array installation: Custom mounts installed on SE- and SW-facing facades, 45-degree tilt

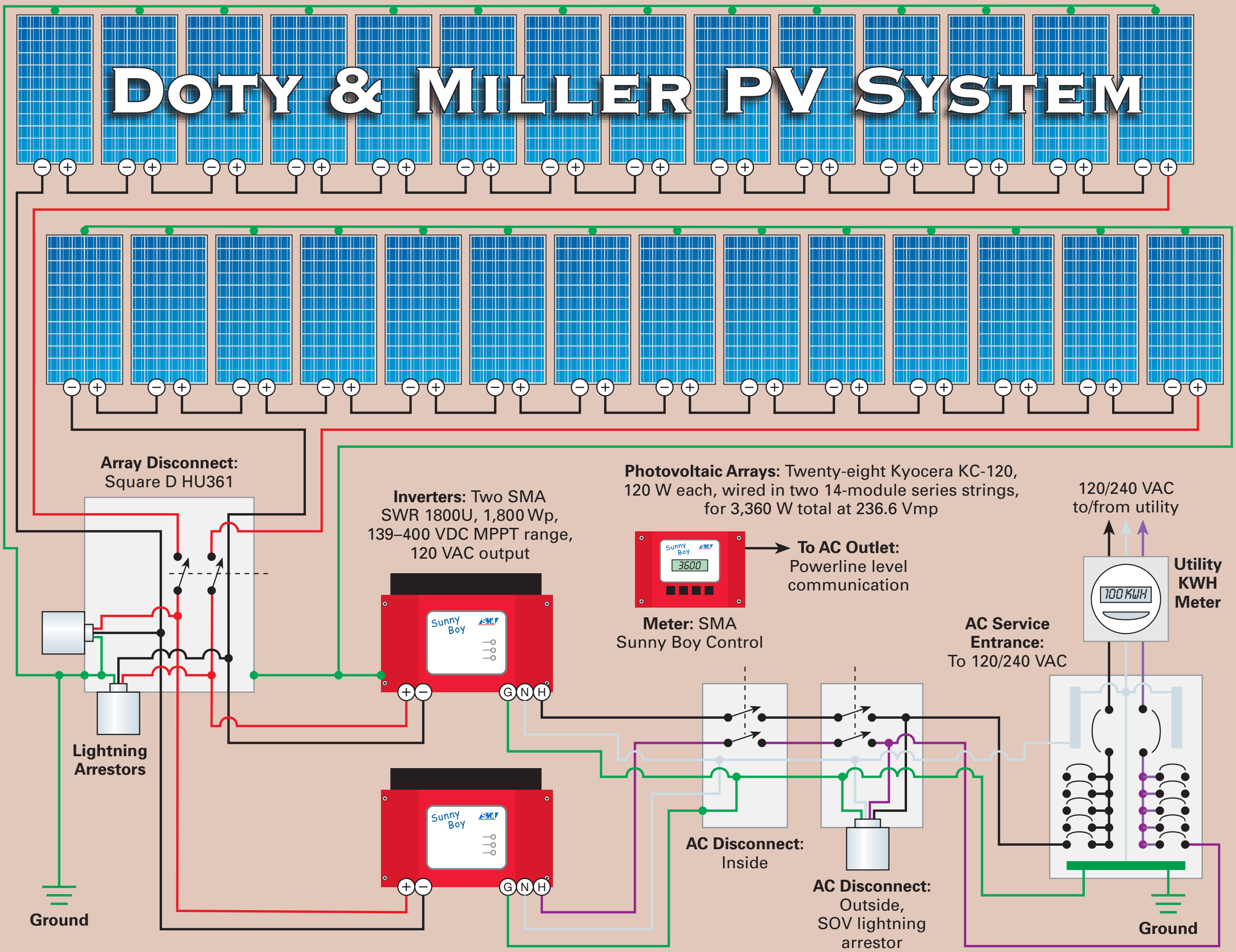
AC disconnect: GE TG3221

Balance of System

Inverters: Two, SMA SWR 1800U, 1,800 Wp, 139–400 VDC MPPT range, 120 VAC output

System performance metering: Sunny Boy Control

Installing the photovoltaic panels—participants were provided with hard hats and gloves, and given a briefing on safety before beginning the hands-on portion of the workshop.



Locating the balance of system components in the vestibule lets visitors see how they function.

System Components

At 15,000 square feet (1,394 m^2) of office space, the Doty & Miller building has significant loads due to office equipment, and space heating and cooling. To stay within their limited budget for this demonstration project, a relatively small PV system, which meets approximately 4 percent of their electricity needs, was designed and installed. Since the building's critical electrical loads, including the security system and building controls, already had battery backup and the local utility grid rarely experiences outages, a batteryless inverter system was chosen.

Each awning consists of fourteen Kyocera KC-120 (120 W) panels wired in series, feeding its own Sunny Boy 1800U inverter. The peak output rating for each awning is 1,680 W.

Workshop Design

The GEO solar committee agreed that registration would be higher if people did not need to lose standard work time to participate. After much discussion, we finally decided on a single weekend workshop. Once we defined our objectives, the workshop scope, registration logistics, project workflow, and many of the other planning details fell into place quickly.

After deciding on three to four hours for the morning lecture session, we tried to gauge the amount of time each activity would take during the hands-on portion. We figured that groups of four to five people could work simultaneously on each aspect of the installation. Each group would have access to a workshop volunteer for consultation and supervision.

Green Energy Ohio workshop participants expanded their own knowledge and helped expose the community to renewable energy with this high-visibility PV system.

Our workshop registration form asked participants to indicate their electrical experience level, any related certifications, and their reasons for attending. This helped Erika design the instruction to fit the students, as well as provide what they needed to know to work on the Doty & Miller project.

As it turned out, participant skill and knowledge levels varied. All indicated that they believed energy independence to be important for the future of America. Many said they were considering solar electricity for their own homes. A few attended to learn and have fun working on a "green" project. Several professional electricians, including two members of the International Brotherhood of Electrical Workers union, came to learn more about solar electricity and expand their expertise.

Two major learning objectives were important—to provide sufficient information about solar energy relevant to the Doty & Miller project and to give participants hands-on installation experience.

Workshop time was split into a morning classroom session and an afternoon hands-on installation session. The Saturday morning instruction featured a crash course in the fundamentals of solar electricity. Using the specifics of the Doty & Miller project, major topics included power and energy, budget considerations, electricity costs, solar-electric panel ratings, component selection, wire sizing, safety, resources, and system configuration comparisons.

After spending all morning sitting inside, participants were eager to get outside and start working with the real thing. Toward the end of the first afternoon, participants returned to the classroom for a debriefing with a question-and-answer period. Then, they were given a preview of the important installation elements that were scheduled for completion on Sunday.

The class was divided into four rotating work groups. While one group was mounting the inverters and disconnects, another was cutting pieces of flexible, weather-tight conduit for the panel-to-panel connections and assembling wires with spade terminals for installation between the panels. A third group was up on the scaffolding. Other participants were running conduit from an external junction box to the inside equipment and pulling the necessary wiring. Everyone had the opportunity to climb up on the scaffolding and get their hands in a wiring junction box on the back of a solar-electric panel, or work with the inverter electrical connection, as well as do some wire stripping or learn how to heat PVC conduit so it could be bent.

The combination workshop–installation undertaking proved successful, in large part, because of the collective talents, skills, and experience of the committee and volunteers. So far, the workshop–installation combo has gained us publicity in three magazines—*Home Power, Properties,* and *Solar Today.* Online, the project is described at the Green Energy Ohio Web site and Department of Energy's Million Solar Roofs Web site.

PV System Costs

Item	Cost (US$)
28 Kyocera 120 W panels	$12,320
2 Sunny Boy 1800U inverters	3,400
Custom aluminum frames	2,000
Sunny Boy Control	700
Scaffolding rental	500
Design & consultation	300
Misc. electrical, hardware, etc.	250
Permits & fees	200
DC disconnect	150
4 Lightning arrestors	112
4 Internal mounting clips	104
Hardware for frames	100
2 AC disconnects	84
2 External mounting clips	30
Installation labor donated ($7,600 value)	0
Total	$20,250
Ohio Office of Energy Efficiency matching grant	- $10,125
Out-of-Pocket Cost	$10,125

To consolidate system components and reduce cost, only one DC disconnect was installed on this system. Flipping the DC disconnect lever effectively shuts down both awnings by opening both the southeast and southwest array circuits. The same is true for the AC disconnect located near the inverters, as well as the external lockable AC disconnect. Electrical storms are common in northeast Ohio, so as an extra precaution, each awning has a lightning arrestor installed on both DC and AC sides of the inverter.

Solar-Electric Success

Volunteers and GEO committee members completed the installation in a weekend workshop led by Erika (see "Workshop Design"). And so far, says Bill, "The system is doing very well—even generating some electricity under cloudy conditions."

The Doty & Miller building was a featured attraction on the 2004 Green Energy Ohio–American Solar Energy Society tour. "Many [of our visitors] didn't realize that solar-electric systems could be so attractive," says Bill. "In fact, many people commented on how cool it looks. The awning and component panel provide an excellent demonstration of renewable energy—colorful, technically interesting, and aesthetically unique. The awning shows how a building can benefit from both active solar-electricity generation and passive shading."

"The system is great for public education and awareness," says Bill. "We located the controls in the rear entrance vestibule, so people who tour the building can easily see how the system is laid out and understand how it works. Eventually, we'll also add informative labeling of the components, much like the ones we have in the building to explain its energy efficiency measures."

Recently, they added a software program that allows them to track the system's output. This output will be integrated into their newly upgraded building automation and controls program. Both will be incorporated into a Web-based control system, which they can access via the Internet. This capability will give them the opportunity to monitor and adjust their operating systems online, as well as collect data on the solar-electric system's performance.

"Doty & Miller believes that renewables are the future," says Bill. "It's just not 'talk' to us—we are truly committed. Installing this small system on our building provides visitors and clients alike with tangible evidence of that commitment."

Access

Sandy Woodthorpe, Technical & Marketing Communications • 440-639-0819 • iwrite4you@earthlink.net • www.writeon4you.com

Bill Doty, Doty & Miller Architects, 600 Broadway Ave., Bedford, OH 44146 • 440-399-4100 • Fax: 440-399-4111 • wdoty@dotyandmiller.com • www.dotyandmiller.com

Green Energy Ohio, 7870 Olentangy River Rd., Ste. 209, Columbus, OH 43235 • 866-GREEN-OH or 614-985-6131 • Fax: 614-888-9716 • geo@greenenergyohio.com • www.greenenergyohio.org

Erika M. Weliczko, REpower Solutions, PO Box 91992, Cleveland, OH 44101 • 216-402-4458 • erika@repowersolutions.com • www.repowersolutions.com

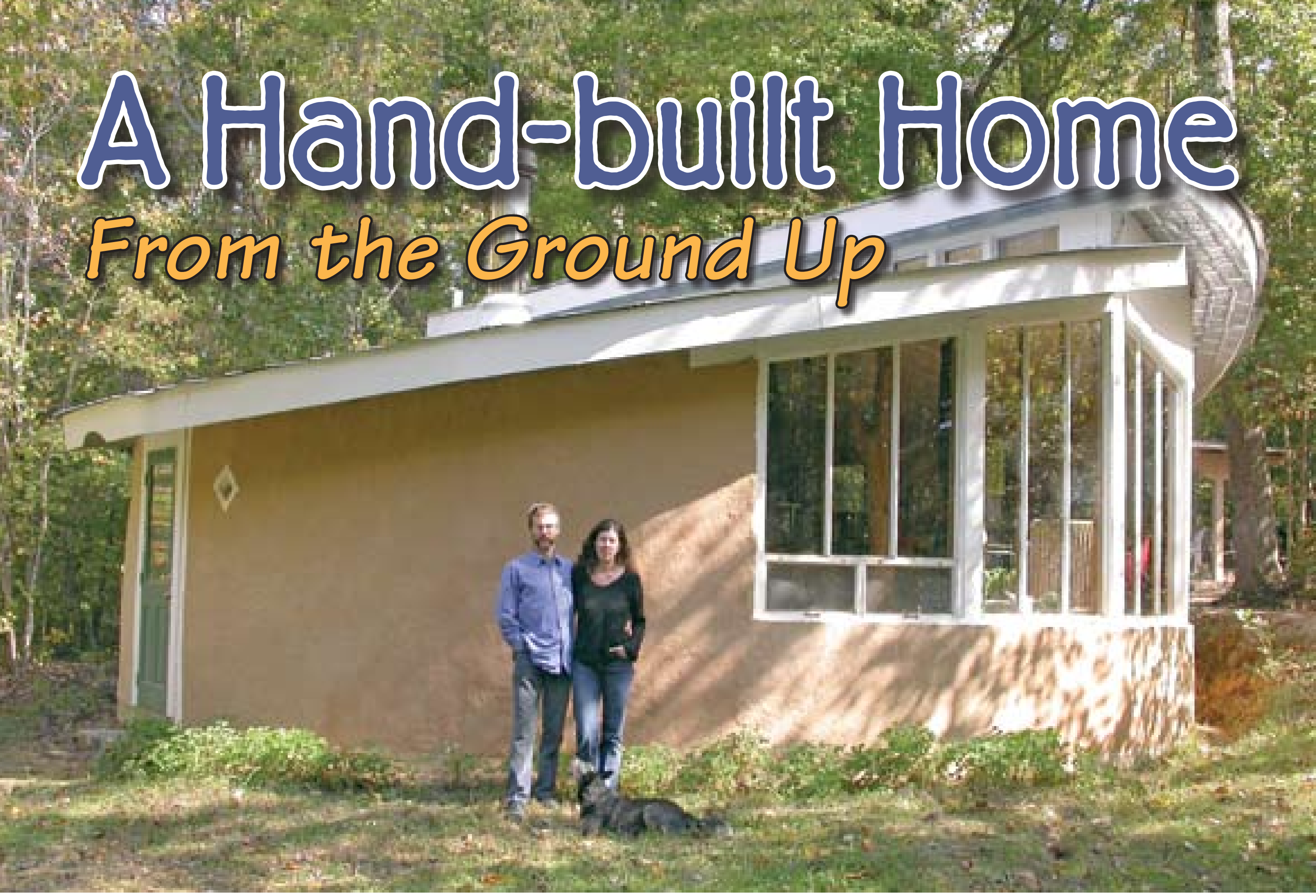
Kyocera Solar Inc., 7812 E. Acoma Dr., Scottsdale, AZ 85260 • 800-223-9580 or 480-948-8003 • Fax: 480-483-6431 • info@kyocerasolar.com • www.kyocerasolar.com • PV panels

SMA America Inc., 12438 Loma Rica Dr., Unit C, Grass Valley, CA 95945 • 530-273-4895 • Fax: 530-274-7271 • info@sma-america.com • www.sma-america.com • Inverter

Square D/Schneider Electric, 1415 S. Roselle Rd., Palatine, IL 60067• 888-778-2733 or 847-397-2600 • Fax: 847-925-7207 • www.squared.com • Square D breaker

UniRac Inc., 3201 University Boulevard SE, Ste. 110, Albuquerque, NM 87106 • 505-242-6411 • Fax: 505-242-6412 • info@unirac.com • www.unirac.com • Rack mounting system

A Hand-built Home
From the Ground Up



The author and his wife in front of their hand-built cob house in North Carolina.

Stephen Hren

When my wife Rebekah and I decided to build our own house, we began researching various alternative building techniques that would be appropriate for our climate and resources here in the Piedmont region of North Carolina, about 30 miles (48 km) north of Durham.

We briefly flirted with the idea of building a monolithic concrete dome, even going so far as to have a round, 800-square-foot (74 m^2) concrete slab poured. But our flirtation ended when we actually saw a dome home—it looked like a UFO had landed in the woods.

Now we had a large slab and a really big pile of clay from the excavation. We investigated other natural building methods, but after eyeing the mound of earth in our yard, we decided to build our house out of cob—a mixture of clay, sand, and straw (also called monolithic adobe).

Our completed cob house fits perfectly on the round slab, and blends beautifully with our surrounding landscape, having risen directly from it. The materials that weren't free were inexpensive (see the costs table), and we were able to build it ourselves—with a lot of help from our friends, of course. This energy efficient home also has a 310-watt PV system, which meets all of our electricity needs, including water pumping and refrigeration. We run as much as we can on DC power (including LEDs and fluorescent bulbs), which also is more efficient.

From the Ground Up

Cob is a very versatile and stable material, so the options for a home's design are numerous. Although our round cob house's curved walls have their advantages, they have one major drawback. With curved walls, integrating the roof, floors, and windows gets quite tricky, and using milled lumber results in lots of scraps. The construction could frustrate some carpenters—and if you're hiring the work out, could result in a poor job or add to the total cost. However, the advantages are many.

First of all, walls with substantial curves in them are self-bracing—they inherently distribute building stresses more evenly than rectangular structures. This can make a well-designed circular cob building very strong.

This gently sloped roof puts less weight on the cob walls while simultaneously providing enough of an angle to shed snow.

Round walls also help direct the wind flow *around* the house. This lessens the stress on the house during extreme weather. But keep in mind that a given building's design and engineering will ultimately determine how structurally sound it is.

While cob has tremendous compressive strength (it can hold up much more than it weighs), cob walls can fail due to vertical pressure or loading from the roof, especially in areas that experience heavy snowfall. For our project, we considered two design elements. First, steeper roof systems are somewhat heavier than low-pitched ones, but shed snow better. If you live where you receive heavy snowfalls like we do, your building design needs to take into account both roof structure and snow loading on the cob walls. Second, because we wanted a lower pitched roof, additional support in the center of the house was necessary to transfer a portion of the roof's load directly to the ground rather than outward on the walls.

Bulk Up & Add Mass

Plan to incorporate some kind of exterior insulation into your cob home. Near the end of our inspection process, our inspector questioned the insulation value of our 12- to 16-inch-thick (30–40 cm) cob walls. I had been sure they would be adequate, so I was shocked when I discovered their total R-value to be only R-3 or R-4 (about R-0.25 per inch). This was unacceptable, so we had to find a way to insulate the outside of our cob home if we wanted to get our final certificate of occupancy. To help boost the R-value of our home, we ended up painting the outside with a new-fangled coating called Nansulate, which uses itty-bitty ceramic tubes that effectively trap air to slow heat transfer.

Neither my wife nor I were thrilled with the idea of painting the gorgeous exterior of our home, but the practical results were eye-opening. The combination of our high thermal mass walls now surrounded with insulation remarkably improved the energy efficiency of our home.

Houses, due to their relative longevity compared to other fuel consumers, such as cars or household appliances, will be the last to adapt to the greater scarcity of fossil fuels. So considering energy use in designing and building new homes is of paramount importance. With fossil fuel availability likely on the edge of permanent decline, anything that reduces energy use in the day-to-day operation of a home is a good thing.

My wife and I are in the process of removing the insulation coating (although it stuck to the walls just fine) and are going to experiment with natural types of insulation, such as vermiculite or perlite mixed into cob. These natural insulations have the advantage of being much more permanent, while allowing the home's earthen walls to breathe better.

Additional support in the center of the house was necessary to transfer a portion of the roof's load directly to the ground rather than to the walls.

Insulation Ideas

Vermiculite or perlite mixed into the cob. Vermiculite and perlite have an insulation value of about R-2 to R-4 per inch; a 4- or 6-inch-thick (10–15 cm) application would be needed.

The author places the first rafters in the cob walls, after "keying" them to lock them into place.

Hybrid straw bale and cob. The cob provides the structure and thermal mass, while the straw provides the insulation.

A wattle-and-daub frame built around the exterior. This could be as simple as a 2-by-6-inch frame stuffed with straw. Wire mesh or some other lath (such as bamboo or strips of oak) is applied to the outside and is plastered as desired. The straw should be dipped in a clay slip (clay mixed with water) and allowed to dry to help improve its resistance to fire.

Besides insulation, another important design element incorporates interior cob walls, which add thermal mass to the structure. Alternatively, you may want to add an interior cob wall to an existing structure, or to a straw bale (or other well-insulated) house to help regulate interior temperatures. Since cob also is excellent for reducing noise, consider separating the sleeping quarters from the rest of the house with such a wall.

Cob Construction Tips

Cob loads must be distributed over door and window openings using either lintels or arches. Wood and stone lintels are common; they should extend at least 6 inches (15 cm) into the cob on either side of the opening. Use rot-resistant woods, such as oak or cedar, and treat with a natural preservative, like linseed oil.

Any wood that is incorporated into your cob structure for door and window framing should be keyed to help lock it in place. "Keying" refers to additional blocks of wood attached to the framing that give the cob something to "grab." This is especially important for rafters, because the ample roof overhangs (18–24 inches; 46–61 cm) needed to protect your cob walls are susceptible to uplift from strong wind gusts.

Try Your Hand at Cob

To get a feel for this material, start with a small project, such as a bread oven or greenhouse. You'll need a source of clay, sand, and straw. Often, clay and sand can be recovered from different layers of soil. Here in North Carolina, we have a subsoil of red clay, and sand can be found along stream banks. It's important to minimize the amount of organic matter in the mix; it can decay, leaving holes in the structure. If you need to purchase sand, masonry sand adheres best to clay.

For small projects, you can make cob by foot. On a tarp, add equal quantities of clay and sand. Roll the tarp back and forth until they are mixed evenly. Don't worry about small stones. Once there is a consistent mix, add water. Next comes the fun part. Squish this mixture with your feet. (Bare feet work best.) Keep adding water and stepping, occasionally rolling the tarp over to get a good mix, and throwing a few handfuls of straw in near the end. Be careful not to add too much water—the mixture needs to have some resilience so that it can be stacked, not poured. With an ideal mix you should be able to form a loaf like you would with bread dough.

You'll need a foundation to raise your cob structure off the ground—10 inches (25 cm) or more between graded earth and cob is recommended. For a foundation, stacked stone or brick will work in many cases. In general, you'll want a height-to-width ratio of 10:1 for load-bearing walls. (For example, a 10-foot-tall cob wall needs to be at least 1 foot thick.) Nonload-bearing walls need not be as thick—about 6 to 8 inches (15–20 cm). With materials at hand and some experience, one person can build about 25 linear feet (3.7 m) of wall, 12 inches (30 cm) thick and 4 inches (10 cm) high, in a day. We never achieved more than three layers in a week (about 1 foot; 30 cm in height).

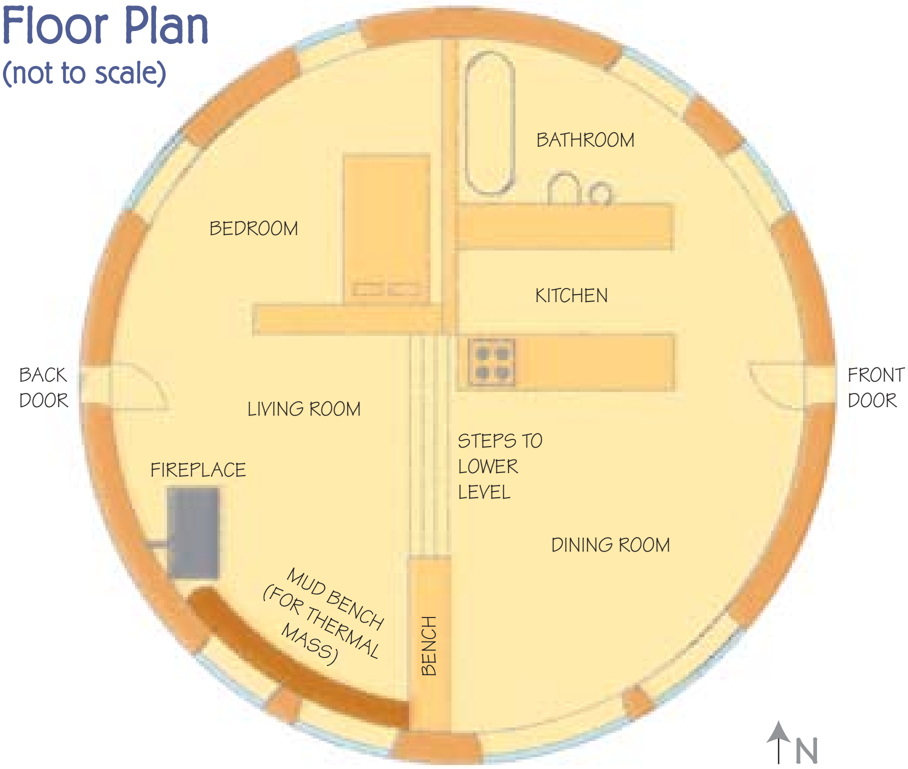
Depending on the weather, it takes a day or two before the cob hardens enough to add another layer. Keep the newly formed cob walls out of direct sunlight by placing a tarp over them; if the wall dries too fast it will crack. After three or four layers, we would even out the lumpy sides using an old handsaw and a level. Building with cob is slow but pleasant work, and is more enjoyable with friends.

Legit Permit

Somewhat reluctantly, we ended up going through the county inspection process for our home. Our inspector turned out to be reasonable and, instead of requiring us to have the plans stamped by a local engineer, allowed us to use Pima County, Arizona, building codes that detail "monolithic adobe." He also allowed us to live in our house while we were finishing it.

Although it was difficult and increased the length of the project, in the end it was well worth it. We have none of the constant worries that friends who live in uninspected houses have. By blazing a trail, we hope to have made it easier for others to build with natural materials. And we are able to get some publicity and host open houses, increasing our community's awareness of this inexpensive and beautiful building material.

Floor Plan
(not to scale)



Cob Home Costs

Construction	Cost (US$)
Poured slab foundation, 32 ft. diam.	$4,000
Lumber, roof & floor framing	2,000
Lumber, floors & cabinets	1,000
Misc. paint & hardware	1,000
Sand, 45 tons	750
Cement mixer	500
Roof tin	500
Kitchen & bath fixtures & plumbing	450
Tin ceiling, recycled, 400 sq. ft.	400
Sheetrock for ceiling, 400 sq. ft.	300
20 bales of straw	50
Clay (from excavation), equal parts to sand	0
Tarps (recycled)	0
Bead board for interior walls (salvage)	0
Labor, 2,000 hrs. (author, wife, friends)	0
Total Construction Costs	$10,950

Other	
PV system, 310 W (incl. appliances)	$6,000
Driveway & septic	2,000
Well	1,200
Total Other Costs	$9,200
Grand Total	$20,150

Access

Stephen Hren, 314 Street's Store Rd., Triple Springs, NC 27574 • 336-504-4452 • themudranch@yahoo.com

Industrial Nanotech Inc., 801 Laurel Oak Dr., Ste. 702, Naples, FL 34108 • 800-767-3998 or 951-324-7121 • Fax: 239-254-1381 • corporate@industrial-nanotech.com • www.industrial-nanotech.com • Nansulate insulative coating

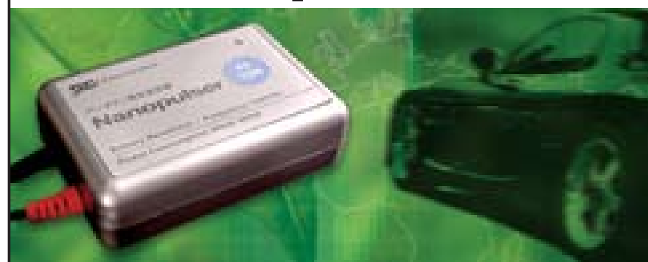
Adobe codes available through Southwest Solaradobe School, PO Box 153, Bosque, NM 87006 • 505-861-2287 • adobebuilder@juno.com • www.adobebuilder.com

The Cob Builders Handbook, by Becky Bee, 2000, Paperback, 178 pages, ISBN 0965908208, US$23.95 from Groundworks Publishing, PO Box 381, Murphy, OR 97533 • cobalot@cpros.com • www.beckybee.net

The Hand-Sculpted House, by Ianto Evans, Michael G. Smith & Linda Smiley, 2002, Paperback, 384 pages, ISBN 1890132349, US$35 from Chelsea Green Publishing Co., PO Box 428, White River Junction, VT 05001 • 800-639-4099 or 802-295-6300 • Fax: 802-295-6444 • info@chelseagreen.com • www.chelseagreen.com

Why Buildings Stand Up, by Mario Salvadori, 2002, Paperback, 328 pages, ISBN 0393306763, US$15.95 from Norton Publishing, W. W. Norton & Co. Inc., 500 Fifth Ave., New York, NY 10110 • 800-233-4830 or 212-354-5500 • Fax: 212-869-0856 • www.wwnorton.com

Discover
NEVER ADD WATER!
L16 Sealed AGM & Gel Battery Now Available
Sealed L16-AGM
Discover™ the difference:
Industry first
Discover Sealed L16 battery. Maintenance free design. Available in AGM and Gel.
Never add water
The Discover line of sealed maintenance-free advanced AGM or Gel commercial grade batteries never need water. Eliminates damage to equipment or work surfaces due to acid spills.
Recommended
Recommended for vacation homes, residential or commercial applications where normal maintenance may not be performed or location is critical.
Advanced design
We have designed our renewable energy batteries to withstand your extreme conditions, giving you a battery with maximum capacity and reliability.
CENTRICPOWER
centricpowergroup.com/solar
discoversolar@centricpowergroup.com
Dealer Inquiries




INTRODUCING...
The NEW!
SunKeeper-6 SOLAR CONTROLLER
MORNINGSTAR
6 amp or 12 amp
at 12 volts DC
SUNKEEPER™
Junction Box Mounted Solar Controller
• Provides regulated battery charging output directly from the solar module junction box
• 3 stage series PWM charging provides longer battery life
• Rated to 70°C ambient for highest reliability
• Ideal for oil/gas PV projects — certified for use in hazardous locations
• Weather-proof connection and rated for outdoor use
MORNINGSTAR corporation
Phone: +1-215-321-4457
www.morningstarcorp.com

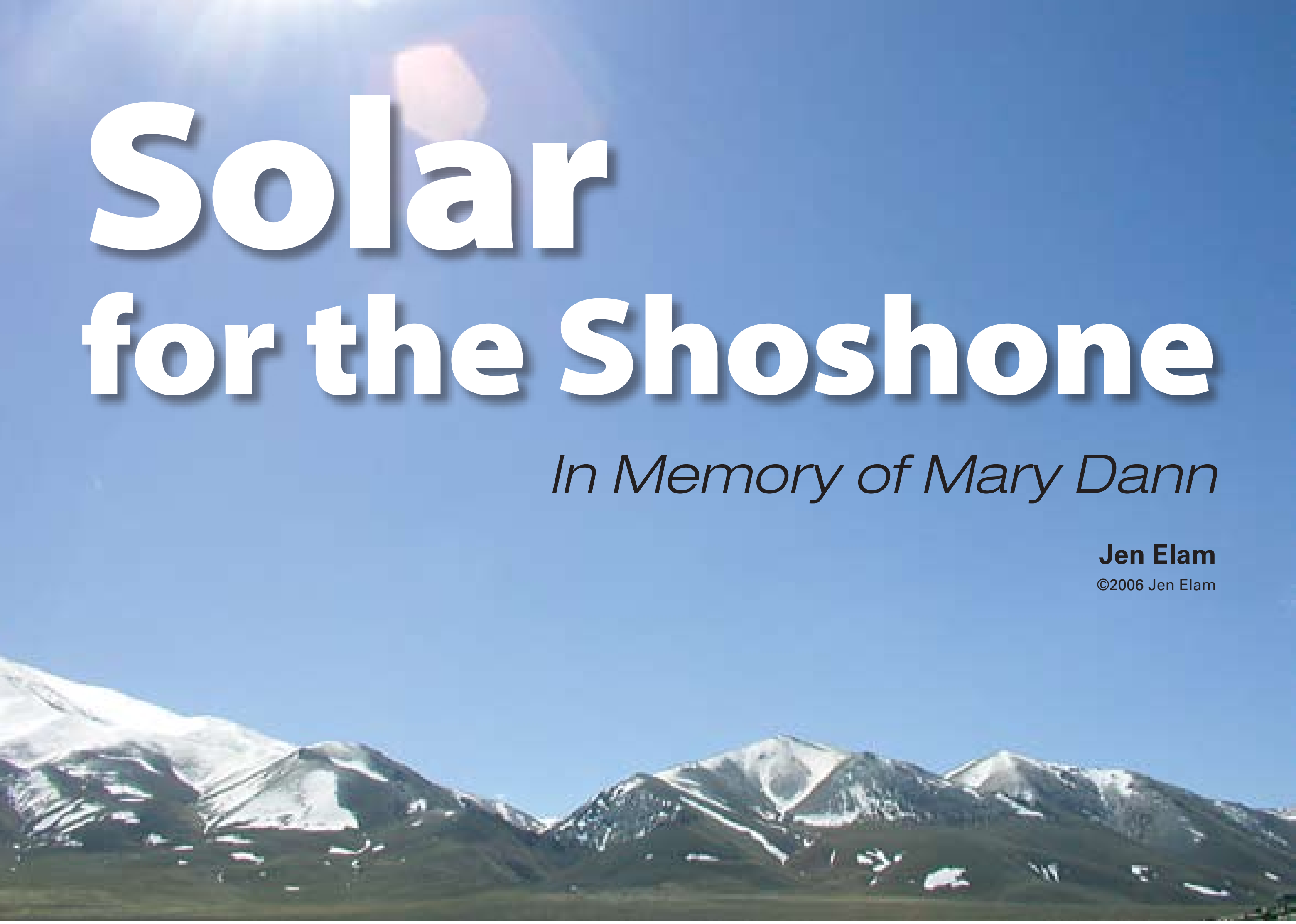

EZ Fill
Battery Filler
Easily controlled low pressure flow for perfect fill levels every time.
Includes six feet of hose for hard-to-reach batteries.
1.3 Gallon capacity.
Corrosion proof materials.
only $19.99
plus S & H
PATENT PENDING
"At last.....
an easy way to fill batteries!"
www.batteryfiller.com
Gravity Fill Systems, LLC
Southlake, Texas
(877) 679-3774
(817) 442-1344 (fax)


DP&W POWER-FAB
QUALITY HARDWARE FOR THE PV INDUSTRY
Designed for the Professional...
Top-of-Pole Mounts
Power-Rail Mounting System
Side-of-Pole Mounts
Power Tube Commercial Racking System
Power-Grid Racking System
Roof-Ground Mounts
Battery Boxes, Racks and Cabinets
Equipment Enclosures
Preferred by Experienced Installers
DIRECT POWER AND WATER CORP.
ALBUQUERQUE, NM USA
800-260-3792 or 505-889-3585
FAX: 505-889-3548
www.power-fab.com
info@power-fab.com

Solar for the Shoshone

In Memory of Mary Dann

Jen Elam



A clear, cold, winter's day on Western Shoshone lands—perfect conditions for collecting solar energy.

Many tribal members participated in the workshop to install the photovoltaic system.

Native Americans have a heritage of using natural resources and living with what nature has to offer. One of the first solar-electric systems on tribal lands in Nevada was installed on Newe Sogobia (Shoshone Land). A collaboration of people and companies from all over the country came together to help two grandmothers of the Shoshone tribe have electricity.

My involvement started about a year ago when I was flying to the Midwest Renewable Energy Fair for my company, Energy Outfitters. I was seated next to Johnny Weiss, one of the founders of Solar Energy International (SEI). He told me about a controversial project he was working on with the Western Shoshone tribe.

The project was controversial because it was the home of Mary and Carrie Dann, activists who have been fighting to keep their land and their livestock for more than 30 years. Yucca Mountain, where the government is planning to store nuclear waste, is right in these women's backyard.

We want our future as Western Shoshone people to be one that is in keeping with our cultural and spiritual respect for the environment, and sustainability for the future generations.

—Carrie Dann, Shoshone Elder

The Dann Sisters and the Western Shoshone Defense Project have been educating and organizing to protect the Western Shoshone tribal lands for 40 years. The Danns are being fined US$4 million by the Bureau of Land Management for trespassing on land that they claim as their own. For more information on the Danns' struggle for justice, visit the Western Shoshone Defense Project Web site at www.wsdp.org.

The Dann sisters had lived off grid their whole life, and were living with an engine-generator at the time. Johnny asked me if I thought I would be able to help with getting the equipment lined up for this project, and I said I would see what I could do.

Johnny mentioned that Honor the Earth, an organization that is headed by activist Winona LaDuke, which works on Native environmental issues, was going to be raising the money for the project. This meant we were on a tight budget, so I needed to get equipment donations for the system. The project received support from several generous renewable energy companies.

Honor the Earth and SEI put together a workshop that included the system installation, and offered it at no charge to all tribal members. The workshop consisted of two and a half days of training and two and a half days of installing the system. Twenty-eight tribal members came from as far away as 400 miles (640 km). Corbin Harney, Western Shoshone spiritual leader, came and did ceremonies and blessings the entire week. We had a beautiful sunrise ceremony on the morning of the beginning of the installation.

Two kilowatts of photovoltaic panels and some load efficiency measures significantly reduce the need for the diesel generator.

Site & System Design

The site, which has great solar access, is in the middle of Crescent Valley, Nevada. Because the house is located under a huge grove of old cottonwood trees, we chose to install the PVs on adjustable top-of-pole mounts away from the house. There is good wind on the site as well, and a wind-electric system is being considered for the future.

The Dann sisters were running a generator 24/7, and had three or four refrigerators or freezers. Once the loads were evaluated, areas where promising efficiency improvements could be made were identified. Using a Kill A Watt meter helped explain energy efficiency and how it can affect system size and operation. The simplicity of the push-button display makes it a breeze to check power draw of instantaneous loads, such as lights, as well as cycling loads, such as a freezer.

Activists Mary and Carrie Dann (front row, center) with workshop participants and instructors.

Tech Specs

System Overview

Type: Off-grid, battery-based PV

Location: Crescent Valley, Nevada

Solar resource: 5.5 average daily peak sun hours

Production: 330 AC KWH per month

Photovoltaics

Modules: Twenty Isofoton I-100, 100 W STC, 17.4 Vmp, 12 VDC nominal

Array: Four, 5-module series strings, 2,000 W STC total, 87 Vmp, 60 VDC nominal

Array combiner box: OutBack PSPV with 15 A breakers

Array installation: DP&W top-of-pole mounts, 45-degree tilt

Energy Storage

Batteries: Sixteen Surrette S-460, 6 VDC nominal, 350 AH at 20-hour rate, flooded lead-acid

Battery bank: 48 VDC nominal, 700 AH total

Balance of System

Charge controller: OutBack MX60, MPPT, 60 VDC nominal input, 48 VDC nominal output

Inverter: OutBack VFX3648, 3,600 Wp, 48 VDC nominal input, 120 VAC output

The OutBack Power Systems inverter, charge controller, system monitor, and AC and DC breaker panels.

More than ten, 75 W incandescent bulbs were replaced with 13 W compact fluorescent (CF) bulbs, resulting in a daily load reduction of approximately 3 KWH. This was a perfect example of how efficiency can dramatically reduce a home's energy use, and the system cost as well. It cost less than US$100 for these replacement lights, while PV panels to offset this load would have cost a few thousand dollars.

Two efficient Crosley freezers, provided at special discount by Backwoods Solar, were installed along with a new Energy Star refrigerator. Through these load reductions, generator run time will be reduced significantly, allowing the arrays to carry more of the load.

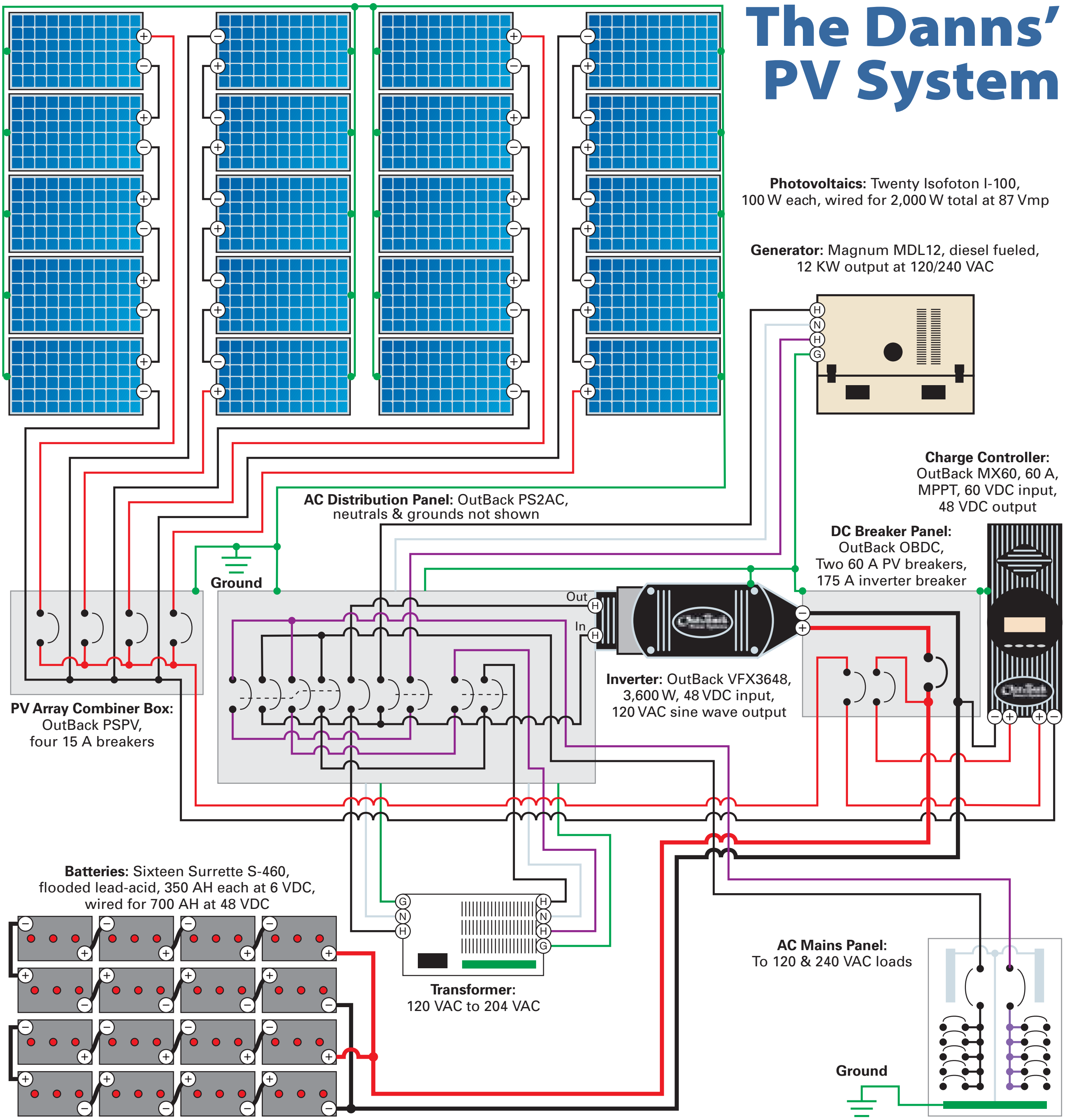
With SEI's help, we designed a 2 KW array of twenty, 100-watt Isofoton solar-electric (photovoltaic; PV) modules. Because the wire run from the solar arrays to the batteries was fairly long, we opted to wire the PVs at a higher nominal voltage than the battery bank to reduce transmission loss. The array voltage is stepped down at the battery bank by an OutBack charge controller. The stored energy is converted to 120 VAC by a 3,600-watt OutBack inverter. In addition, a 240 VAC step-up transformer was installed to power a 240 VAC well pump.

The AC breaker configuration.

System Loads

Computed Loads	Watts	Hrs. Per Day	Days Per Wk.	Avg. WH Per Day
10 CF lights	13	5	7	650
TV, 19 in. color	60	6	7	360
Well pump	4,800	2	7	9,600
Measured Loads				
Refrigerator, Energy Star	–	–	–	1,200
Crosley freezer	–	–	–	1,000
			Total	12,810

The Danns' PV System



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

My employers at Energy Outfitters generously let me use their expertise, tools, and facility to build the power center (which included the inverter, charge controller, disconnect panels, and metering). This gave me some wiring experience, and also kept the cost of the project down. They also provided the PV panels at cost—I really appreciated working for such a generous company during such a tight year.

Installation

During the workshop, we had two teams working on assembling the top-of-pole mounts and installing photovoltaic modules. The students had this part of the job wrapped up in no time. Another group was hard at work installing the power center and batteries in a small shed that had been built for this purpose on a nearby concrete pad.

Sixteen Surrette S-460 batteries store solar energy for silent nighttime power.

Each group devised a plan and schematic before beginning work. At the two pole-mounted arrays, Isofoton I-100 (12 V) modules were wired five in series for 60 V nominal. Each pole mount supports two series strings of five modules each. Quick-connecting MC cables made for speedy module wiring, and connections were taped with rubberized insulation tape and then covered with electrical tape to prevent unintended separation.

Each series string then passed through a 15 A breaker in an array combiner box. The home run wiring from the combiner box runs to the power shed, where an OutBack MX60 maximum power point tracking (MPPT) charge controller steps the voltage down to 48 VDC nominal. Maximum power point tracking increases the output of PV arrays, especially when weather is cold and the PV array is running at higher voltage.

Inside the power shed, sixteen Surrette deep-cycle batteries were wired eight in series and then paralleled for a 700 AH battery bank at 48 VDC nominal—35 KWH total, or about 18 KWH at 50 percent depth of discharge. We ran #2/0 (67 mm^2) cables in 2-inch Liquidtight flex conduit, from the batteries through a 175 A breaker to the inverter. The existing Magnum MDL12, 12 KW diesel generator was moved to a concrete pad just behind the power shed, and then interfaced with an automatic, two-wire generator start. An additional relay is required between the inverter auxiliary output and the generator remote start and control board.

Before this project, the Dann sisters had more than 400 feet (122 m) of hose everywhere they wanted to get water to the livestock in the corrals. Since we needed to ditch the trenches for the electrical lines anyway, we decided to bury all of the water lines too, even though it meant a lot more ditching.

Peaceful Energy

We had a closing ceremony, and Carrie and Mary shared their comments and appreciation for everyone and everything that was done for them. It was a wonderful collaboration of people coming together to really make a difference for two women who care so much for the earth and for the seven generations to come.

I wish I could end this article on a happy note, but two weeks after we returned from Mary and Carrie's land, Mary died in a farming accident. I like to think that she lived those last two weeks without the noise of that generator, and in the peaceful valley with that beautiful mountain range. I will miss her, and I am honored to have met her and shared experiences with her.

Access

Jen Elam, Solar Design Technician & Consultant, PO Box 2425, Durango, CO 81302 • 970-749-2416 • jenelam7@yahoo.com

Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • Fax: 970-963-8866 • sei@solarenergy.org • www.solarenergy.org

Honor the Earth, 2104 Stevens Ave. S, Minneapolis, MN 55404 • 612-879-7529 • honorearth@earthlink.net • www.honorearth.org

Western Shoshone Defense Project, PO Box 211308, Crescent Valley, NV 89821 • wsdp@igc.org • www.wsdp.org

Alternative Energy Engineering, PO Box 339, Redway, CA 95560 • 800-777-6609 or 707-923-2277 • Fax: 707-923-3009 • info@aeesolar.com • www.aeesolar.com • System components

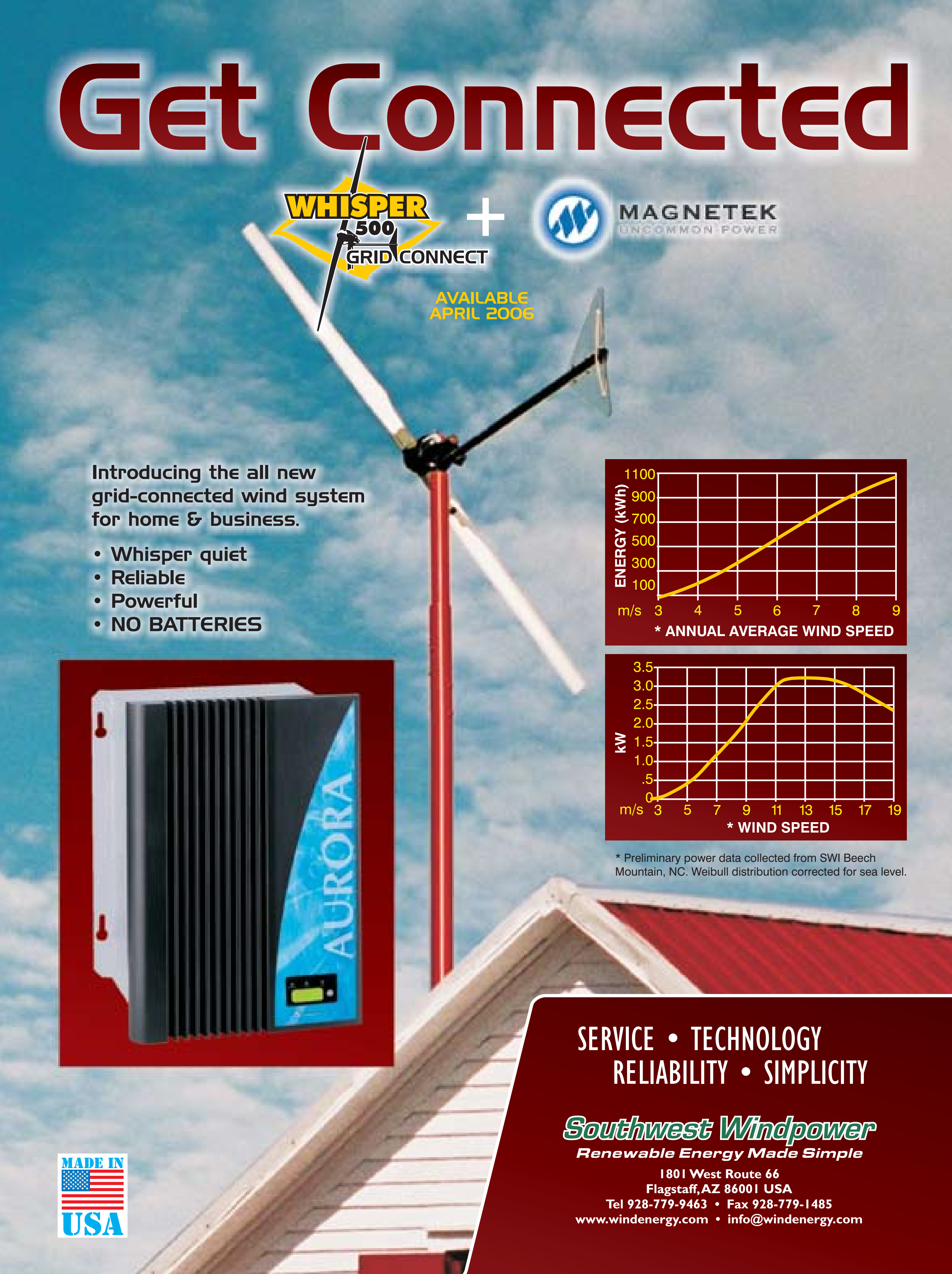
Backwoods Solar Electric Systems, 1589 Rapid Lightning Creek Rd., Sandpoint, ID 83864 • 208-263-4290 • Fax: 208-265-4788 • info@backwoodssolar.com • www.backwoodssolar.com

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

Isofoton, C/ Montalban, 9, 28014 Madrid, Spain • 34-91-531-26-25 • Fax: 34-91-531-10-07 • isofoton@isofoton.com • www.isofoton.com • PVs

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

Surrette Battery Company Ltd., PO Box 2020, Springhill, NS, Canada B0M 1X0 • 800-681-9914 or 902-597-3767 • Fax: 800-681-9915 or 902-597-8447 • sales@surrette.com • www.surrette.com • Batteries


Get Connected
WHISPER 500 GRID CONNECT
+
MAGNETEK
UNCOMMON POWER
AVAILABLE APRIL 2006
Introducing the all new grid-connected wind system for home & business.
• Whisper quiet
• Reliable
• Powerful
• NO BATTERIES
ENERGY (kWh)
1100 900 700 500 300 100
m/s 3 4 5 6 7 8 9
* ANNUAL AVERAGE WIND SPEED
kW
3.5 3.0 2.5 2.0 1.5 1.0 .5 0
m/s 3 5 7 9 11 13 15 17 19
* WIND SPEED
* Preliminary power data collected from SWI Beech Mountain, NC. Weibull distribution corrected for sea level.
AURORA
SERVICE • TECHNOLOGY
RELIABILITY • SIMPLICITY
Southwest Windpower
Renewable Energy Made Simple
1801 West Route 66
Flagstaff, AZ 86001 USA
Tel 928-779-9463 • Fax 928-779-1485
www.windenergy.com • info@windenergy.com
MADE IN USA

FINDING *Greener* WHEELS

Steve Boser

In pursuit of my lifelong dream to build a greener vehicle from the ground up, I have spent years looking at electric vehicle (EV) conversion books and catalogs, and have read every article Shari Prange has written for *Home Power*. I've built electric bicycles and scooters, and modified my kids' power wheels to the point that they performed too well for them to play with. I've even rebuilt a three-wheel scooter for my mother to use when she was ill. But although I had the skills, the one thing I did not have was the time to tackle another project.

Exploring EV Options

In July 2000, I decided to buy a Corbin Sparrow—a single-passenger, three-wheeled, all-electric vehicle. At that time, no other vehicle offered its sporty performance with an electric drive, and a range well within my daily commute. Money in hand, I contacted Corbin Motors and was put on a waiting list. When they were unable to fulfill my order, I figured it was time to move on.

During this time, I attended several National Electric Drag Racing Association events (if you believe electric cars are all overgrown golf carts, these events will change your mind) and DaVinci Days in Corvallis, Oregon, where I met several members of the Oregon Electric Vehicles Association—people with real-world experience with EVs. I also joined several EV newsgroups, and while redesigning my game plan, came up with another possibility.

There are certainly many converted EVs on the market, and seemingly no end to almost-completed projects that had been shelved for design problems, money problems, or dwindling interest. But after several months of looking, I convinced myself that project cars were best left to someone

Greener Car Choices

Best

Worst

Vehicle	Time	Cost
DIY EV conversion	Lots of time to build	Significant investment
Factory-new EV	Ready to drive immediately	Greater than gas cars (if available)
Unfinished EV conversion	Substantial time to complete	Cheap
Used, running EV (from kit)	Probably some time to install new batteries	Similar to used gas cars
Used, running EV (unique design)	Probably some time to install new batteries	Similar to used gas cars
Factory-new hybrid electric vehicle	Ready to drive immediately	Greater than gas cars
Biodiesel vehicle, used or new	Some time to find biodiesel source	Similar to used or new gas cars
Waste vegetable oil diesel vehicle, used or new	Some time to convert & find WVO source	Some extra cost for the conversion

else—a bargain to be had in many cases, but still nothing that fit my vision.

Next I considered completed, operating EVs. Many were built from kits advertised in *Home Power*. Usually the reason for sale was the owner had changed jobs and no longer had a practical commute. Most of these cars just needed battery packs, and there were some nice conversions available for reasonable prices. Unfortunately, by the time I would decide that the car was acceptable, it was sold. A sellers' market exists for well-running EVs—if you are shopping for one, be sure to do your homework quickly and thoroughly, and jump on the right chance as soon as you can.

Besides kit EVs, there were owner–builder conversions—the cars that were most entertaining to inspect. The designs varied from cars engineered well enough to win the Ansari X Prize for space travel if they had been pointed skyward, to designs that were unsafe at any speed.

Getting a turnkey electric car was looking bleak until one evening, when I spotted an electric truck for sale online. Although the truck was in need of new batteries, it was just what I needed for my entry into the EV world.

The first few months of commuting the 16 miles (26 km) to and from work with the truck were great. But soon I decided it was time to go back to work for myself, and resigned my job. Within weeks, the statement that many EV owners echo hit me—after I'd run down the charge in my batteries and was stranded in a grocery store parking lot. My EV was wonderful, but if and only if I drove a consistent route every day and didn't deviate much from those driven miles. I needed a car with a less limited range.

Alternatives to All-Electrics

Hybrid-electric vehicles, which pair an electric motor with an internal combustion engine, eliminate several drawbacks of all-electric vehicles, the obvious one being range limitation. These cars also tend to be highly reliable, mainly due to the fact that hundreds of people have participated in their engineering. They also offer the least amount of tinkering to get a greener ride—just get in and go. Many different makes and models are hitting the marketplace, some with better fuel economy than others. But I didn't want to spend the money on a new car, so I kept investigating other options for cheaper, "greener" wheels.

Using the Internet, I researched running a diesel car on waste vegetable oil (WVO). A common thread was the book *From the Fryer to the Fuel Tank*, so I purchased a copy (see Access). After reading this book, I decided that a veggie-oil-fueled diesel would meet my transportation needs, and replaced my truck with a 1982 Volkswagen Jetta diesel I bought on eBay.

Its owner-designed and installed WVO conversion is simple and works well. That's not to say any of the conversion kits on the market aren't good. But if you're handy with tools (and not afraid to experiment), there isn't any reason *you* can't do a conversion yourself. The downside is that you are your own technical support.

If you're not into tapping into your fuel lines and tinkering with your fuel tank, biodiesel, a chemically thinned vegetable oil fuel that you can make or buy (in some areas), is another green fuel option. Most newer diesel vehicles can run on biodiesel without any modifications—but be sure to check your car's warranty before you fuel up. In some cases, using biodiesel may void the vehicle manufacturer's warranty. Biodiesel is a powerful solvent that can weaken rubber components. In older diesels, you may need to replace rubber hoses and seals with synthetic ones.

Biodiesel and WVO can be low-cost fuels (if you source and process the oil yourself), and can be a boon to restaurant owners who benefit by not having to pay a rendering company to haul off their used cooking oil.

Availability	Build Quality	Pollution Reduction	Meets Needs
Conversion parts or kits readily available	As good as you want it to be	Excellent from grid power; even better on RE	Depends on consistency of driving style
None in production	Like any new vehicle	Excellent from grid power; even better on RE	Depends on consistency of driving style
Plenty for sale	Varies widely with builder	Excellent from grid power; even better on RE	Depends on consistency of driving style
Some for sale, but they go quickly	Generally proven designs	Excellent from grid power; even better on RE	Depends on consistency of driving style
Some for sale, not as many as unfinished projects	Varies widely with builder	Excellent from grid power; even better on RE	Depends on consistency of driving style
Several models available, may have waiting list	Like any new vehicle	Better than straight gas cars, but still burns gas	Most models: better than a gas car
Stock diesel vehicle	Like any new vehicle	Depends on biodiesel-to-diesel ratio used	As good as a diesel, as long as you have a fuel source
Conversion kits available for WVO	As good as you want it to be	Depends on WVO-to-diesel ratio used	As good as a diesel, as long as you have a fuel source

Both fuels are made from renewable resources (oil-seed crops) and burning them produces less pollution than their petroleum counterpart.

Finding the Right Wheels

Making the decision on what type of greener wheels suit your needs isn't difficult, but it does require some homework. First, keep track of your driving habits and mileage. Are you just using your car to commute to work or for infrequent, short trips to the store? Or do you spend most of your day behind the wheel?

If you're logging only a few miles on your car each week, your pocketbook and the environment might best benefit by keeping the car you're now driving tuned up, and by using a bike or walking. Keeping a perfectly good car, even if it isn't the greenest car on the block, may produce less pollution and use less energy than a new one, which has consumed vast amounts of energy and resources just in its manufacture. If you need a car infrequently, consider car sharing (see "Sharing the Road," in *HP109*), which allows you the benefit of using a car when you need it, without any of the hassles and expenses of ownership.

But if you are still in the market for good, green wheels to get you around town, take a look at the "Greener Cars—Pros & Cons" chart above. It will help you figure out what kind of car best meets your needs, and will help you get a jump start on finding a cleaner, more eco-friendly ride.

Access

Steve Boser, PO Box 5206, Aloha, OR 97006 • java@xprt.net

National Electric Drag Racing Assoc., 1018 Banner Ave., Fremont, CA 94537 • info@nedra.com • www.nedra.com

From the Fryer to the Fuel Tank, 3rd edition, by Josh Tickell, 2000, Paperback, 162 pages, ISBN 0970722702, US$24.95 from Biodiesel America, 8033 Sunset Blvd., #154, Hollywood, CA 90046 • Phone/Fax: 310-496-3292 • www.biodieselamerica.org

Find EVs at:

Electric Auto Association • www.eaaev.org

Electrifying Times magazine • www.electrifyingtimes.com

EV Finder • www.evfinder.com • Listing of EVs for sale

Electric Vehicle Photo Album • www.austinev.org/evalbum/ • View more than 600 different EVs

Hybrid electric car info:

HybridCars • www.hybridcars.com

Biodiesel/WVO info:

Boulder Biodiesel • www.boulderbiodiesel.com/john/SVO/index.jsp

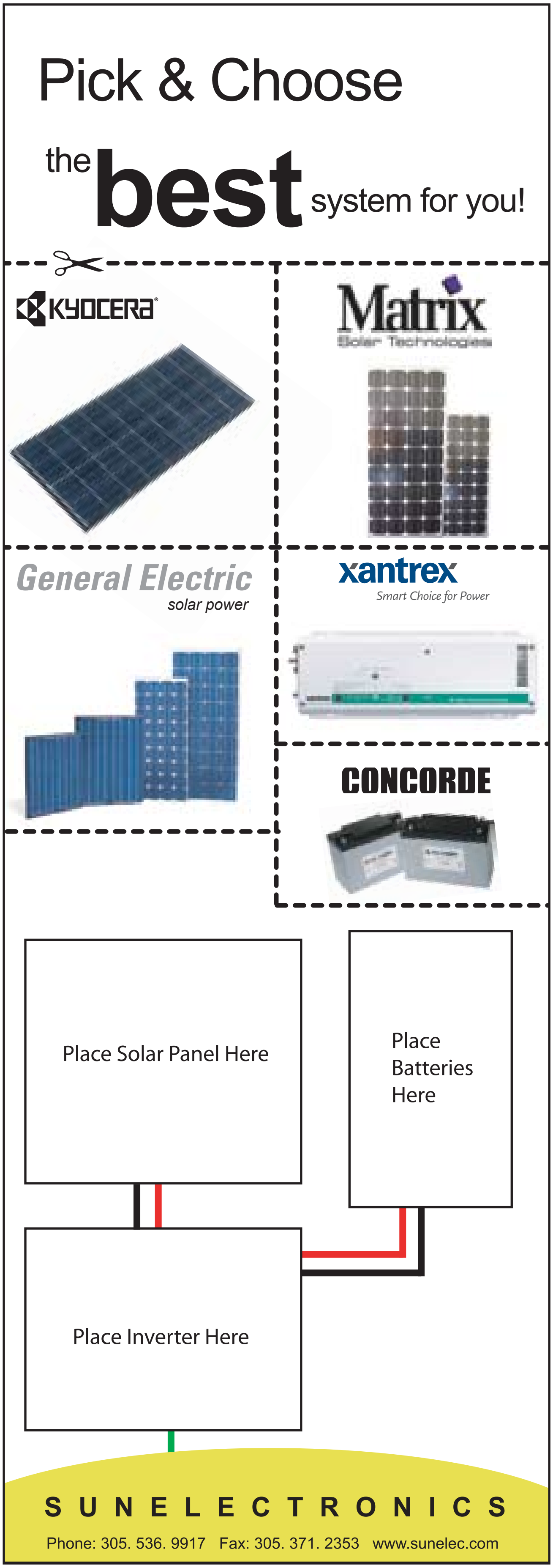
The Veggie Van Organization • www.veggievan.org

EARN A DEGREE IN
RENEWABLE ENERGY
$420 OUT-OF-STATE & $300 IN-STATE / SEMESTER
COMBINE SCIENCE & HANDS-ON TRAINING
FOCUS ON PHOTOVOLTAIC DESIGN AND INSTALLATION
TWO YEAR A.A.S. DEGREE OR
ONE YEAR CERTIFICATE PROGRAMS
BOTH EMPHASIZE FULL N.E.C. COMPLIANCE
PLEASE VISIT US ONLINE AT www.sanjuancollege.edu/reng
S J C
FOR ADDITIONAL INFORMATION ABOUT THE
RENEWABLE ENERGY PROGRAM AT
SAN JUAN COLLEGE, FARMINGTON, NM
PLEASE CONTACT: TOM MUNSON
(505) 566-3003 OR (800) 241-6327
munsont@sanjuancollege.edu

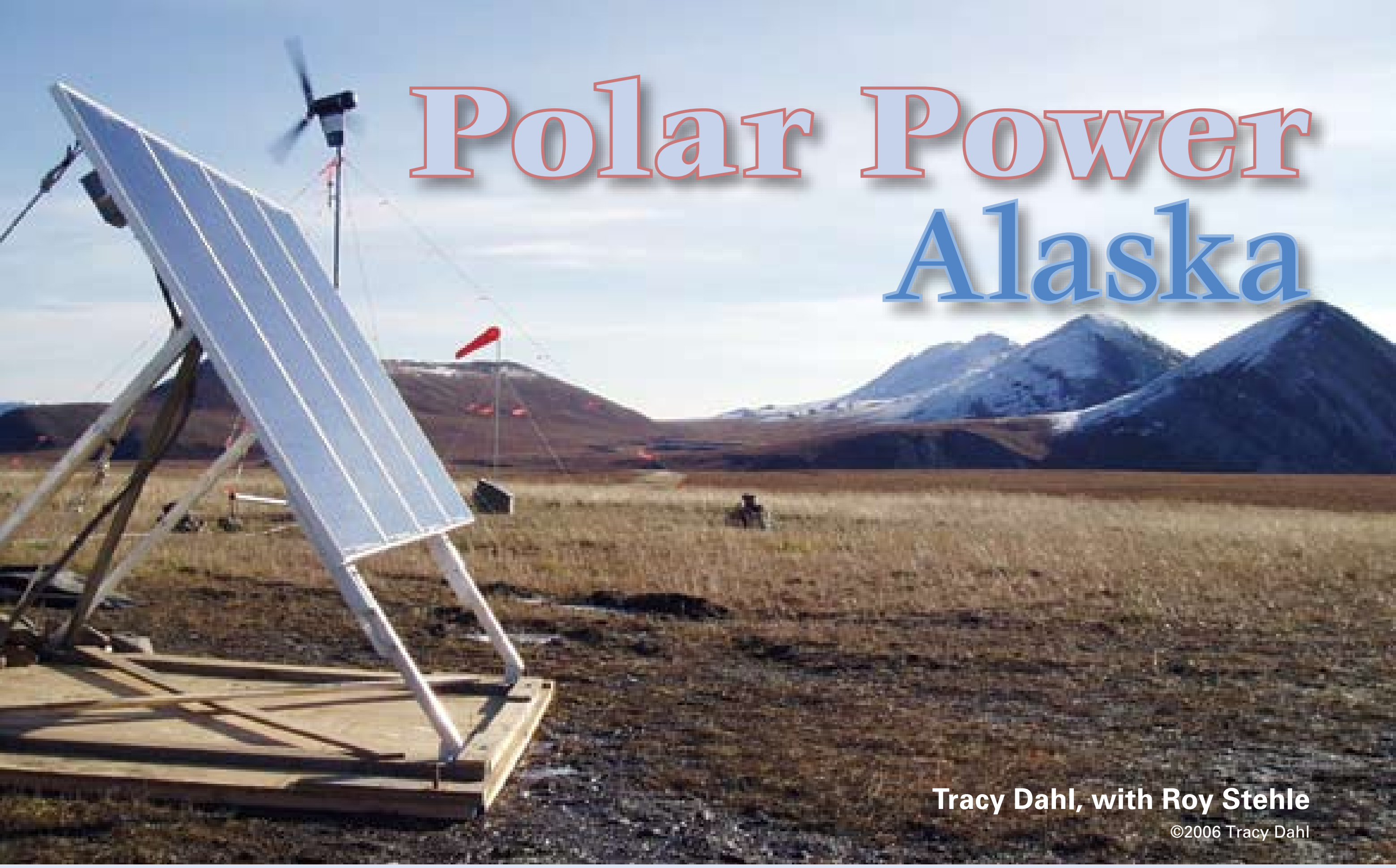
Quality First!
Sun Pumps Inc.
SOLAR PUMPING PRODUCTS
SCS SERIES
BRUSHLESS DC
SUBMERSIBLE PUMPS
Brushless DC Submersible Pumps up to 2 HP, heads up to 700 feet and flow rates up to 50 GPM.
SDS SERIES
SUBMERSIBLE PUMPS
Diaphragm Submersibles with heads up to 230 feet & flow rates up to 4.3 GPM.
SCB SERIES
BOOSTER PUMPS
Centrifugal Booster Pumps from 12 volt Home Pressure Systems to 180 volt High Pressure Booster Pump Systems.
PCA & PCB SERIES
PUMP CONTROLLERS
New Micro-processor based pump controllers up to 3 HP.
Current boosting and voltage boosting models available.
SC-P SERIES
POOL PUMPS
Pool Circulating Pumps from ½ to 2 HP.
We also manufacture:
Jet Pumps
Triplex Piston Pumps
Jack Pump Retrofit Kits
For free system sizing, technical support, or to place an order call:
Phone: 1-800-370-8115
(928) 348-9652
Fax: (928) 348-9653
www.sunpumps.com
SOLARJACK
SunPumps stocks all parts and will rebuild any original SolarJack pump or controller.

ZOMEWORKS
Passive Energy Products
Serving customers since 1969, Zomeworks has over 15,000 Trackers installed in different climates on nearly every continent in the world!
NEW
Custom shock for UTRK040, also available for older model Trackers!
Universal Roof / Ground Mounts & Top of Pole Fixed Mounts
California Building Code certification available for all racks
AND more......Battery Boxes, Cool Cells & Double Play
Alpine Elementary School-UTRF168 Installation by Mark Snyder Electric
WWW.ZOMEWORKS.COM
ZOMEWORK@ZOMEWORKS.COM
800-279-6342


LED LIGHT BULBS
Save Over 80% On Your Lighting Bill
60,000 Hour Bulb Life
2-year Warranty • UL Listed
CC Vivid
LED Spotlight
CC Vivid +
LED Light Bulb
CC Vivid 20
LED Floodlight
LED Spotlight
CC Vivid 30
LED Floodlight
C.CRANE
800-522-8863 • ccrane.com


Pick & Choose
the best system for you!
KYOCERA
Matrix
Solar Technologies
General Electric
solar power
xantrex
Smart Choice for Power
CONCORDE
Place Solar Panel Here
Place Batteries Here
Place Inverter Here
SUNELECTRONICS
Phone: 305. 536. 9917 Fax: 305. 371. 2353 www.sunelec.com


SunDanzer
Cool with Solar
Energy-Efficient
• Automatic operation
• Thick polyurethane insulation
• Lockable lid
• Interior light
• Corrosion resistant coated steel exterior
• Patented low-frost system
• Easy to clean interior
• Low maintenance
12/24 VDC Energy Efficient Refrigeration
(915) 821-0042
info@sundanzer.com
www.sundanzer.com



Polar Power Alaska

Tracy Dahl, with Roy Stehle

How do you supply reliable electricity 24 hours a day, 365 days a year, at an unmanned research site in one of the most remote locations on the planet? How do you transfer the scientific data to the researcher's home institution in near real-time? How do you monitor the status of the system so you know when there is a problem? How do you diagnose problems remotely, so you know what to bring with you to the site when weather conditions allow you to travel there?

The U.S. Arctic Program

I work for VECO Polar Resources, the civilian contractor to the National Science Foundation's Arctic program. The NSF Office of Polar Programs sponsors research in Antarctica and throughout the Arctic. I have had the privilege to work in both areas, and have faced the questions posed above many times. The answers are rarely the same, and are usually dependent on the environmental conditions and the type of research being supported.

My colleague Roy Stehle of SRI International and I are partners on the Ivotuk project, which is described in this article. Roy is an electrical engineer and communications expert with many years of experience. He is also extremely attentive to detail, and notices when anything is amiss. It is Roy who is responsible for most of the real brain work in this project. I'm more of the shovel and hammer man.

Ivotuk

Ivotuk, Alaska, is a tiny unmanned research site that lies at the southeastern edge of the National Petroleum Reserve on the North Slope. This is a classic Alaskan tundra environment. There are no trees, and few spots high enough to get out of the water table. The 5,500-foot (1,676 m) runway and a raised gravel pad remain from oil exploration days in the early 1970s, and have a lot to do with making this a great place to conduct research. During the summer, skies are frequently overcast. In the winter, solar energy is available for a few hours a day at best.

It was for this reason that a redundant diesel generator system was initially selected for the site. Northern Power

Systems (NPS) of Vermont was chosen to provide the autonomous power supply. A photovoltaic (PV) option was a possibility to include with the system, but due to the environmental conditions, it was originally determined that it would not be a cost-effective augmentation to the central power supply.

The NPS Module

The original system was built by NPS, and was intended to provide electricity for the operation of meteorological experiments and data acquisition instrumentation. It also powered the satellite communications system to transfer the data to the researcher's home institution in San Diego. Two Lister Petter 6.5 KW diesel generators are housed in a modular refrigeration-type enclosure, set on a rugged aluminum I-beam frame.

Roy Stehle and Todd Valentic, also of SRI International, worked together to create the electronics package and programming that allows us to see very detailed information on how the system is performing. Data is sent out via a StarBand satellite link to the server based in California. Archived data allows us to note any trends in system performance over time. That is how Roy first noticed deterioration of battery capacity after only a year of operation, and brought it to my attention. Anyone with Internet access can take a look at how the system is performing. The Web address is included at the end of this article.

NPS has used similar generator modules elsewhere, including the Arctic and Antarctica. The units have generally served well, but the bottom line is that the design requirements exceeded the actual performance of the unit.

The Issues

First and foremost is the fuel efficiency issue. The unit was designed to run unattended for a full year at a 200-watt rated output. The actual power requirement ended up at an average of 240 watts continuous. This doesn't sound like much, but add it up. That comes to 5,760 WH a day, or 2,100 KWH a year. That is a fair bit of energy, and it takes a large volume of diesel fuel to produce it. Also, the thermal inefficiency of the container resulted in a tremendous number of run cycles on the Espar heaters, which are run on diesel fuel to keep the electronics and generators warm enough to operate. We could only run the system for a bit longer than eight months before the two 175-gallon (660 l) fuel tanks were critically low.

Another problem that rather quickly became evident was a serious loss of battery capacity. The unit autonomy (period of time between charge cycles) became less and less, while the amount of fuel used became more and more. To understand why this happened, you have to take a look at the conflicting requirements of the generators and the battery bank.

Diesel generators like to run under full load. This is where their efficiency is greatest (still only about 30% conversion efficiency), and where the longevity of the engine is greatest. If a diesel generator is run at low load for extended periods of time, it is far less efficient in burning fuel. Incomplete combustion and dramatically increased emissions result in heavy deposits in the exhaust system, and often, premature cylinder wear, sticking piston rings, and a host of other problems. Cold weather exacerbates the condition markedly.

Batteries, on the other hand, demand long periods of low-current input at the end of a charge cycle. Generators are often run at maximum efficiency for a relatively brief period of time, and then are shut down to avoid excessive fuel consumption and possible engine damage.

A longer run cycle would be better for the batteries, but bad for the engine. A shorter run cycle would be better for the engine, but bad for the batteries. The compromise ultimately settled on in Ivotuk was fairly bad for both components. The fact that the battery bank was rather undersized—720 AH at 24 VDC—only made the problem worse. The generators had to cycle more frequently, and thus ran a greater percentage of the time under low load. Here was a system crying out for some renewable energy (RE) input.

The Plan

During my three-week stay at Ivotuk the first season, I noted that although the weather was often overcast, there was actually a fair bit of solar energy available. Also, the wind blew fairly consistently. I looked into it more and determined that while this was not a great site for renewable energy, there was enough to make the case for augmenting the system with a wind turbine and some PV.

The Ivotuk base camp with fresh snow on the mountains.

The author demonstrates that the PV tilt angle is to spec.

My trip report stated my concerns about system longevity, and recommended the installation of a wind/PV hybrid system to augment the existing diesel generator/battery system. By this time, deterioration in the performance of the system was fairly obvious, and the proposal received NSF approval.

The Equipment

Due to the environmental conditions at the site (common to much of interior Alaska), wind power was chosen as the primary renewable energy source. Unlike the lower 48 states, much of Alaska remains a mystery in terms of what RE resources are available. Fortunately, another research group had good wind records for this site that allowed me to determine that it was adequate to produce sufficient output to support the electrical loads much of the time.

Through various sources, including the pages of *Home Power* magazine, Proven wind turbines had come to my attention. This is a very robust turbine built in Scotland, known to have superior ability to stand up to severe icing conditions. Further, they can continue to put out close to full power right up to the rated survival wind speed of 155 mph (70 m/s)! Here was a turbine that looked like it could survive the ravages of the environment. I decided that having the turbine survive the Alaskan winters was the highest priority, and set about finding an appropriate vendor.

Fortunately, Greg Egan of Remote Power Inc. is located right in Fairbanks, and is the dealer for Proven in interior Alaska. Greg is also a licensed electrician, and has a lot of experience with installing systems in remote locations. Since my deployment to Ivotuk would have me performing a lot of functions aside from the RE installation, I asked Greg to join the team. Greg was intimately involved with all of the renewable energy aspects of this project, and really brought a lot to the table. Greg was on site for a significant part of the RE installation and did most of the wiring of the system and controls.

I decided that the addition of PV was also cost effective to this project, and Greg recommended using Evergreen PV panels. I had long been interested in this manufacturer, due to the innovative String Ribbon manufacturing process they use. It seemed quite serendipitous that Greg was also a dealer for Evergreen. I decided that four, 110-watt panels would make an adequately sized array for the project. The 440-watt PV array should be able to carry the system loads for much of the summer.

A tracking array was considered, but rejected due to reliability concerns in this extreme environment. The panels are mounted in a vertical orientation on an array mount

The Proven and the OutBack controllers regulate wind and PV charging.

The battery bank is made up of 24 industrial-quality, 2-volt cells.

pointing true south at approximately a 70-degree tilt. This angle gives up some production in the summer, but takes good advantage of the sun angles during the transitional seasons. It also gets a bit more reflected light from the snow-covered surface (8 months of the year), and sheds snow more readily than a flatter angle. The panels themselves are mounted 2 feet (0.6 m) above the ground, which allows snow to slide off without accumulating at the base of the panels.

The Deployment

Field deployments at Ivotuk have to be very carefully planned. The closest hardware store is hundreds of miles away, and to bring in an overlooked item would cost about US$2,000 for the flight. Many players were involved, and no one tends to have much wiggle room in their schedule. My colleague Jay Burnside and I worked through seven flight plans before we finally had one that everyone could live with.

In addition to my duties in relation to the technical aspects of the job, I also served as the camp manager for the length of the deployment. This meant that I was responsible for feeding, sheltering, and seeing to the welfare of all of the personnel on site. This is not an insignificant task in and of itself. Remember that this is the Alaskan bush. It is unforgiving wilderness all around. The nearest native village of Umiat is more than 90 miles (145 km) away.

In a field project like this, a lot of things can go wrong, with no immediate help to be had. The hundreds of caribou migrating through presented no immediately apparent hazard, but the several grizzly bears roaming the area definitely did. In addition to my normal tools, I added a 12-gauge pump shotgun and a comprehensive medical kit. Fortunately, on this deployment, all I needed was one Band-Aid.

Despite the significant natural hazards, the assembly and erection of the wind generator tower was my greatest concern, and I knew I would need some help. Brian "Buckwheat" Buckley is a veteran of the Antarctic and Arctic programs, and a very competent and experienced carpenter. Buck agreed to come in with me on what would prove to be some fairly tough camping conditions. We arrived on site on August 22 and immediately set to work putting up our camp. The weather took a nosedive by day two, with snow, sleet, and rain—sometimes all in the same hour.

We had hoped to use Manta Ray earth anchors for guying the wind turbine tower. Upon driving them into the gravel pad to the full depth of the cable, we found that we could lever them back out again to within a couple of feet of the surface. This did not give me a very satisfied feeling about the strength of the anchor. Fortunately, I experienced these doubts before leaving Fairbanks. While preparing for the deployment in town, I had Buck build up some 2- by 2-foot (0.6 x 0.6 m) plywood deadmen, just in case the Mantas didn't work out. The downside of using this approach was that it meant some serious excavation had to be done—by hand. We used the Manta anchors for the lower guy wires, where they will be adequate.

On day five, the weather broke. Nothing is as beautiful as a clear blue sky after days of heavy weather. We took advantage of the break to assemble the tower and wind turbine. Assembling the Proven is not particularly tricky, but a significant amount of time is required. By the end of the day, we were ready to raise the tower.

Raising the Tower

Flights to remote locations in the Alaskan bush are not cheap, so we must always minimize our cargo whenever possible. With this in mind, I decided that rather than bringing in a heavy winch system, I would raise this relatively short tower with a rope and pulley system. Using the base of the tower as my starting point, and the NPS container as the second anchor point, I set up a simple 3-to-1 reduction system.

The first time the tower was raised, I had several Bureau of Land Management (BLM) folks on hand to help out. As it turns out, the rope and pulley system is so effective that two people can handle the operation with relative ease. The fact that we had the tower built with a 20-foot (6 m) gin pole for a 20-foot mast gave us a 1-to-1 lever ratio. The 3-to-1 system on the rope made it fairly easy for two people to pivot the beefy Proven WT600 (155 pounds) into position. In fact, I even did the operation once by myself, just to see if it could

The 155-pound Proven wind turbine and its 20-foot tower were raised into place with a rope-and-pulley system.

PV-Powered Tower Light

We were limited to a 20-foot (6 m) tower height by the BLM, because of concerns about aircraft safety and migratory birds. The BLM also required us to add a strobe light to the tower for alerting aircraft of its presence. Unfortunately, I was unaware of this requirement until I arrived in Fairbanks. I felt that it would be a mistake to run another AC line out to the tower, and that it would use up some of the valuable energy we were trying to gain. With this in mind, I decided that an independent system would be the way to go. Since air operations only occur during the summer at this site, PV was the answer.

Two 20-watt, thin-film PV panels supply electricity to two beefy (1,200 CCA) starting batteries. I was replacing the starting batteries on the generators anyway, and given the nature of the application, felt that they would be perfectly adequate for this application. These batteries were only two years old, and showed no deterioration in performance, but in this type of application, we can leave little to chance.

A really efficient and bright 48 LED bulb was selected to minimize the electrical draw. This was enclosed in a weatherproof housing and mounted just below the top guy point on the mast. Buck whipped up an insulated plywood box with the top sloped at 45 degrees for maximizing the summer gain, and it was a done deal.

Experienced RE supplier ABS Alaskan prewired the strobe timer and the charge controller in a weatherproof box, which we mounted to the outside of the battery box. A simple toggle switch for turning the light on and off completed the package. The charging circuit is active all the time, although there will be little or no input for at least four months of the year.

The LED bulb is quite visible even in direct sun, and the whole system seems very efficient. The batteries should have ample capacity to sustain up to a few weeks of operation in overcast weather. It is a clean little system, and I really can't say enough about the quality of service I received from ABS.

Thin-film PV panels and two batteries (inside box) supply electricity to a safety strobe light mounted on the wind turbine tower.

be done. It can, but it is definitely a grunt. For safety, we will always make sure that two people are on hand for this operation.

System Description

The primary renewable energy component is the Proven WT600 wind turbine. It is a downwind turbine (blades are downwind of the tower), and really built to hold up to adverse conditions. The permanent magnet alternator puts out 3-phase wild AC, which travels about 100 feet (30 m) total before reaching the Proven controller. The controller box rectifies the 3-phase AC to a regulated 24 VDC nominal to charge the batteries.

The four, 110-watt Evergreen PV modules are wired in series for 48 volts nominal output. The array output is converted to 24 VDC nominal by an OutBack MX60 charge controller. This is an MPPT-type controller, which can significantly increase the real output of the PV array. The controller's power boost feature works especially well in cold climates, which Ivotuk definitely is. I have seen an output of 510 watts maximum from the 440-watt rated array, so the advantage of MPPT technology is pretty obvious.

Deteriorating Batteries

As stated above, we knew from monitoring the system over the course of the year that we had deteriorating battery performance. However, we didn't realize how critical the situation was, nor the extent of the damage to the battery bank. Progressive discharge testing performed on site by NPS personnel revealed that one cell was severely compromised, with fully half of the cells performing well below acceptable standards. Basically, the battery bank would reach a point in the discharge cycle where it would just collapse, and voltage would plummet.

Running several deep discharge/charge cycles restored a bit of capacity, but it was clear that we would have to address the problem more comprehensively. Unfortunately, despite many prior communications on the subject, NPS

The author standing proudly in front of the installed turbine.

was not prepared to address the battery problem to my satisfaction. Shipping out an entirely new battery bank within a few days was out of the question.

What we managed to do was to locate a single cell to replace the most severely compromised cell in the stack. We also reset the charge parameters to favor battery longevity over fuel efficiency and long-term generator performance. A major component of the field maintenance next year will be to replace the existing battery bank with a new and adequately sized stack, capable of handling the rigors of this application.

Take a Look

The renewable energy enhancements made on the Ivotuk electrical and telemetry system have dramatically increased system performance. So far, it appears that we may be able to stretch our fuel supply out to the extent that annual maintenance/fueling is achievable, even with the degraded battery bank. The replacement of the battery bank next year will definitely make a once per year visit possible. By adding renewable energy inputs, we have also enhanced the reliability of the system markedly.

Being able to see how the system is performing on a daily basis has allowed us to reach conclusions based on real data, rather than on assumptions, which has often been the case with autonomous systems in the past. This is cutting-edge technology, and there have admittedly been some painful lessons learned along the way.

I have absolutely no doubt that this system will continue to evolve, and point the way towards better, smaller, more easily deployed, and less costly systems in the future. In the interim, the Ivotuk system is on-line and doing its job, 24 hours a day, 365 days a year. Why not take a look and see how it's doing right now? See http://transport.sri.com/ivotuk.

Tech Specs

System Overview

Type: Off-grid, battery-based, PV-wind system

Location: North Slope of Alaska

Solar resource: 4 average daily peak sun-hours (March–August)

Wind resource: 6 mph (2.7 m/s) average

Photovoltaics

Modules: Four Evergreen EC-110, 110 W STC, 16.4 Vmp, modules configured for 12 VDC nominal

Array: One four-module series string, 440 W STC, 65.6 Vmp, 48 VDC nominal

Array installation: Stationary mount oriented toward true south, 70-degree tilt angle

Wind Turbine & Tower

Turbine: Proven WT600

Rotor diameter: 2.6 meters (8.4 feet)

Rated energy output: 124 KWH per month at 12 mph (5.4 m/s)

Rated output: 600 watts at 25 mph (11 m/s)

Tower: 20-foot (6 m), custom-built tilt-up

Energy Storage

Batteries: 24 Deka Unigy II, 2 VDC industrial cells, 360 AH per cell at 20-hour rate, AGM

Battery bank: Two 12-cell series strings, 24 VDC nominal, 720 AH total

Balance of System

PV charge controller: OutBack MX60, 60 A, MPPT, 48 VDC nominal input, 24 VDC nominal output

Wind turbine charge controller: Proven diversion controller with air heater, 24 VAC nominal wild 3-phase input, 24 VDC nominal output

Inverters: Two OutBack FX2024, wired for single unit operation (redundant) with relay actuated backup, 2,000 W each, 24 VDC nominal input, 120 VAC output. Transformer is used to step-up 120 VAC output to 240 VAC for transmission to instrument site.

System performance metering: NPS proprietary "Remote View" for original module. SRI developed data acquisition system (DAQ) for monitoring RE components. Near real-time status display via the Internet.

Wind- & Solar-Electric System Costs

Wind Turbine	Cost (US$)
Proven WT600 wind turbine, 24 VDC	$4,087
Freight, Scotland to Fairbanks, Alaska	1,450
Proven ECM 600/024/048 controller	753
Packing crate	343
Tower adapter for WT600	244
Diversion heater for turbine	225
Shorting switch, 3-pole	105
Total Wind Turbine	$7,207

Wind Generator Tower	
Tower	$800
Guy cables, turnbuckles, thimbles, etc.	250
8 Steel plates for anchors	200
Rope, pulleys, shackles	150
6 Manta Ray earth anchors	150
Plywood, lumber, etc.	100
Total Tower	$1,650

Solar-Electric System	
4 Evergreen EC-110 PV panels	$2,100
OutBack MX60 charge controller	649
DP&W module rack	485
3 OutBack OBPV circuit breakers	36
Total Solar	$3,270

Inverters	
2 OutBack FX2024 inverters	$3,590
OutBack Mate system monitor	295
2 OutBack FX-ACA adapters	70
Total Inverters	$3,955

Both Wind & PV	
Transport, Fairbanks-Ivotuk-Fairbanks	$3,300
Liquid Tite conduit & fittings	290
Miscellaneous wire	189
Miscellaneous electrical	173
Miscellaneous hardware	163
2 Lightning arrestors	100
Battery temperature sensor	29
Total Combo	$4,244

SRI Data Acquisition System	
Hardware (PLC, etc.), including spares	$2,700
Total Data Acquisition	$2,700
Grand Total	$23,026

Access

Tracy Dahl, Project Manager, VECO Polar Resources, 8392 S. Continental Divide Rd. #104, Littleton, CO 80127 • 719-859-4484 • polarsolar@direcway.com • www.vecopolar.com • Also see www.polarpower.com, a Web site providing resources for the polar research community in developing energy systems to enable remote scientific research

Roy Stehle, Senior Engineer, SRI International, 333 Ravenswood Ave., Menlo Park, CA 94025 • 650-859-2552 • roy.stehle@sri.com • www.sri.com

National Science Foundation, 4201 Wilson Blvd., Arlington, VA 22230 • 703-292-5111 • Fax: 703-292-9095 • info@nsf.gov • www.nsf.gov

Northern Power Systems, 182 Mad River Park, Waitsfield, VT 05673 • 877-496-2955 or 802-496-2955 • Fax: 802-496-2953 • info@northernpower.com • www.northernpower.com • Generator module

Greg Egan, Remote Power Inc. • 888-257-3639 or 907-457-4299 • Fax: 907-457-4290 • greg@remotepowerinc.com • www.remotepowerinc.com • Wind & solar-electric system components and design

Proven Energy Ltd., Wardhead Park, Stewarton, Ayrshire, UK KA3 5LH • 44-015-60-485-570 • Fax: 44-015-60-485-580 • info@provenenergy.com • www.provenenergy.com • Wind turbine manufacturer

Evergreen Solar Inc., 259 Cedar Hill St., Marlboro, MA 01752 • 508-357-2221 • Fax: 508-357-2279 • info@evergreensolar.com • www.evergreensolar.com • PV manufacturer

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

ABS Alaskan Inc., 2130 Van Horn Rd., Fairbanks AK 99701 • 800-235-0689 or 907-451-7145 • Fax: 907-451-1949 • jim@absak.com • www.absak.com • Strobe light PV system components

No Power? No Problem!

There is more to a working renewable energy system than a cheap deal on a pile of hardware.

We Provide:

Complete service. We do solar, wind, microhydro and pumping systems. Load analysis, site survey, system design, sales, installation, user training, and tech support long after the warranties expire. We live on renewable energy, have 20 years of experience, and have established over 500 systems. We specialize in NEC® compliant, safe systems that will make your Electrical Inspector smile!

Equipment for DIY. We offer reasonable deals and technical reality checks. Why settle for a packaged system when you can have yours custom designed by an expert?

Your best resource is a local pro. Tap into our network of qualified, competent Electron Connection associates across the country.

Going into the Biz? Why talk to a "sales technician" when you can talk to an electrician? We KNOW what works and how it works. We offer technical support, system design help, prompt shipment, fair pricing and NO BULL. Local referrals always. Electrical competence required.

Electron Connection

Bob-O Schultze
CA Electrical Lic #613554
OR CCB Lic #149724

IPP

Shell Solar Dealer

OutBack Power Systems

xantrex
Smart choice for power
Authorized Distributor

Mitsubishi Electric
Changes for the Better
Authorized Distributor

800-945-7587 toll free

www.electronconnection.com online catalog

PO Box 203, Hornbrook, CA 96044 USA
Voice / Fax: 530-475-3401 • E-mail: bob-o@electronconnection.com

Secondhand Solar

Choosing a Good Used Hot Water Collector

Chuck Marken

Used cars, bicycles, computers, and many other products have strong secondhand markets with known prices and values. Used solar heating collectors also can be a good value—but at what price? And what makes a used solar collector "good"? Follow along and I'll take the mystery out of this.

Solar Sleuthing

Used collectors are available for several reasons. The ugly truth is that many real estate salespeople advise their clients that their homes will sell easier without solar collectors on their roofs. Many times, used collectors also come available when big installations overlook budgeting for maintenance. The sad fact is that for lack of a thousand dollars to replace a pump, systems costing a hundred thousand dollars have been abandoned. And finally, poor installations are the third reason for used collectors being available. This is rarely the case today; most of those systems have been removed long ago.

Well-made solar collectors may have life spans between 30 and 50 years—perhaps more in some cases. I've serviced collectors that I know are at least 25 years old, and still going strong. The longevity depends on the materials used and if they've ever been abused.

Smart Shopping

In mild climates, good solar collectors can and do exceed temperatures of 300°F (149°C) under certain conditions. The transparent glazing and everything inside the collector should be able to withstand these temperatures on a daily basis and not break down. At the other extreme, collectors also must be able to take temperatures that dip well below 0°F (-18°C). Because expansion and contraction can be a problem, along with thermal and ultraviolet (UV) radiation, only a few materials make the grade. All well-made flat plate collectors have a few materials in common. Let's look at these first.

Glazing material. Tempered glass is a must for the transparent material that the sun shines through. This is the same type of glass required for use in patio and shower doors. It's tough stuff. Low-iron glass is desirable but not required for longevity. It improves the heat production of a solar collector by 6 or 7 percent because the glass itself absorbs less light and allows more to be transmitted to the absorber plate inside the collector.

I've never seen a plastic that stacks up to tempered glass. Plastics suffer from both the harmful effects of UV radiation and the thermal degradation produced by the collector. All the types of plastics that have been used on solar collectors in the past two decades have needed replacement.

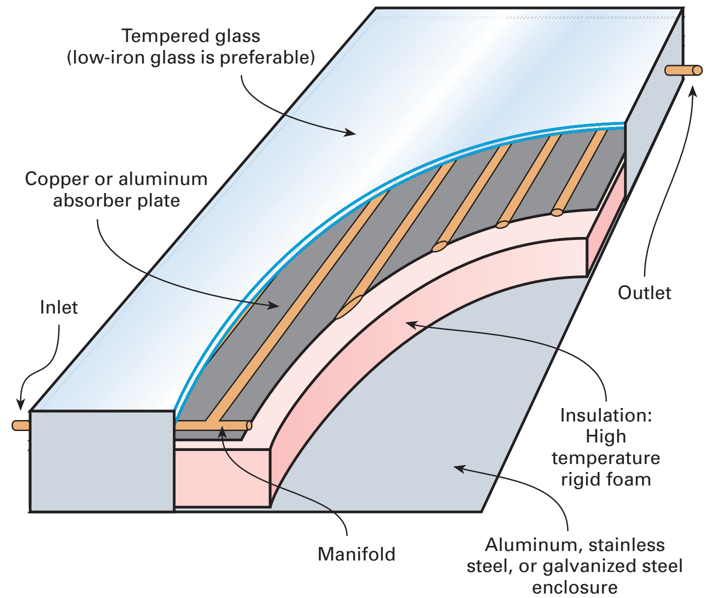
Absorber plate. The absorber is the hottest part of the collector, and it has to withstand temperature swings in the hundreds of degrees, for decades. Copper or aluminum is the best material for absorbers. In arid climates, steel is a possible substitute, but humid climates will call for increased maintenance with anything but copper or aluminum.

Waterways. Copper is the only common metal that I would trust to carry fluids reliably inside a solar collector for years or decades. Other than a freeze burst, degradation from a corrosive fluid is the only thing I have seen that will cause premature failure in copper tubing. Silicone and Teflon tubing have been used successfully in collectors, but I don't know of any used ones that are available. (Silicone has an upper temperature limit in excess of 400°F; 204°C and Teflon, a limit of about 425°F; 218°C.) Steer clear of other plastics and rubber compounds—I've never seen any that will hold up. Watch out for waterways made of aluminum. Many collectors were built with aluminum tubing and patterned aluminum absorbers, but these were specifically made to be used in loops without copper or steel, and with heat transfer oils—not with water or water–glycol mixes.

Insulation. Only high-temperature insulation is suitable—this leaves out many common types of insulation. Fiberglass and a rigid board insulation called polyisocyanurate ("polyiso") are the best choices here. Most collectors built today use polyiso, such as Thermax. Many polyiso products are foil-faced, which adds to the collector heating by reflecting radiant heat back to the absorber plate.

Enclosure. To my knowledge, all the collectors made in the United States today use an aluminum framework. I've seen steel- and fiberglass-framed collectors last for twenty years or more, but they need regular maintenance, such as keeping them painted. Steel enclosures are OK in arid climates but for most of the country, aluminum is best. Collectors with stainless steel and galvanized steel are suitable too, but very few of these are available.

Collector Anatomy



Before You Buy

Don't install any used collector without pressure testing it or having the assurance of the seller that it has been tested and is leak free. Collectors in closed-loop systems will have maximum system pressures of about 50 psi. Open loops will have less.

I always test collectors with 40 psi air. Collectors with classic manifolds need to have three ports plugged temporarily—I use standard wing nut test plugs similar to bottle plugs. A radiator hose with an appropriately sized pipe

A temporary compression plug used to seal a header pipe port so the collector can be pressure tested.

Pressure testing a collector to 40 psi.

Collector Checklist

In general, a "good" used solar collector is constructed with:

- ❑ Tempered glass
- ❑ An aluminum or copper absorber plate
- ❑ Copper waterways
- ❑ Fiberglass or polyisocyanurate insulation
- ❑ An aluminum enclosure

A stack of used liquid collectors waiting for adoption.

plug and hose clamp on one end works well. (A worst-case scenario is that you have to solder caps on the openings.)

Use a spray bottle of soap solution on your temporary plugs to ensure they are not leaking. Pressurize the collector, leave it for about 10 to 15 minutes, and then check the pressure. Any drop in pressure makes the collector suspect—monitor it for a few hours to see if the drop in pressure continues. Repeat spraying the collector with soap solution while carefully observing each joint to ensure the leak is not in your temporary plugs.

A leaking solar collector can be fixed, but the cost of the cure is usually not worth the effort and expense. For now, consider a leaky collector a poor choice.

Besides checking for leaks, it's beneficial to know what fluid was flowing through a collector in its previous home. As a general rule, synthetic oils pose no harm to collectors. Water can be a problem in areas with hard water (which contains lots of minerals). But if a collector is clogged with calcium or other deposits, and has been in service in a freezing climate, its pipes have probably frozen and burst—it will not pass the pressure test. Overheated antifreeze solutions and excessive chlorine pose the biggest threat to copper waterways, and will cause pitting in the metal.

Collectors that have been used to heat swimming pool water directly can easily become corroded, and the copper components may be damaged if the pool water's pH was too low. There aren't many of these used collectors around, but you should be extra cautious if you encounter what looks like a good deal on collectors that have been used for pools and hot tubs.

For collectors that use propylene glycol as a heat exchange liquid, be aware that buffers, such as aluminum hydroxide, which keep the glycol's pH above 7, break down at about 280°F (138°C). When the buffers disintegrate, the glycol solution can turn acidic (pH less than 7). At a pH of 6 to 6.5, the glycol solution will slowly eat away at the inside of the copper tubes in the collectors, and a lower pH will accelerate the corrosion. Pitting will normally be noticeable inside the header tubing of a collector before it starts leaking. A careful visual inspection of the inside of the headers and running your finger inside to feel for pitting will help to find any signs of corrosion.

Read the Fine Print

If you can find one on the collector, a manufacturer's label can give you a lot of information. Most labels seem to disappear or are unreadable after a few years. If you can find a readable label, it can tell you a good deal about the used collector. Here are some good, bad, and ugly flat-plate liquid collector models. This list is by no means complete, and it reflects my opinion and experience only. I have personally experienced the good and bad with every model and brand mentioned.

Good. AER, Energia, Grumman, Heliodyne, ITT Grinnell, MorFlo, Morningstar, Novan, Solar Industries, Suncatcher, SunEarth, U.S. Solar.

Maybes. American Solar King, Colt, Gulf Thermal, Radco, Solaron, Sunland.

A collector's label can provide you with a lot of good information.

Bad. All of the "maybes" above can be bad depending on many factors. "Maybes" mean be careful—it is difficult to determine the condition of the collector without taking the glass off and carefully inspecting the absorber. Colt is a good example. Although they made many good collectors, they also made some with a copper-coated aluminum tube that tends to corrode and leak.

Other "maybe" brands have absorbers that debond (separate) from the copper tubes under certain conditions. Perhaps the solder was too low a temperature and the collector stagnated too long at very high temperatures. A collector with bonding problems between the tubes and absorber is bad news, rendering the collector unworkable and very hard to repair. Some Sunland collectors exhibit "creeping" absorbers. The bent absorber can be seen through the glass. In some cases, the absorber has "crept" so much that it will break the tempered glass from the inside. Mounting these collectors horizontally can lead to creeping absorbers—but why this occurs remains a mystery.

The Bad & Ugly. Avoid any collector that leaks. Also steer clear of tracking collectors for general residential use—they're too complex and you'll have to make your own tracking electronics if the tracker malfunctions. And be sure to reject any collector with plastic glazing, whether it's Filon, Lexan, or whatever.

Other Collectors

Air Collectors. In general, you can evaluate air collectors just like liquid collectors. The only difference is that the absorber has no tubing. There are very few well-made glass air collectors on the market. I've encountered only four in the last year. I snapped up one to heat my garage–shop, and the other three were sold the first day they were advertised. People just don't abandon good air collector systems. Since they have no fluids in them and are normally very simple systems, they seem to be too popular to appear in the secondhand marketplace.

Evacuated Tube Collectors. Evacuated tube collector technology has come a long way in the last 25 years. My first experience with them was in 1981. General Electric made a model called a TC-100. My company bought a half dozen to try out. Half of them arrived broken, because the glass tube was not tempered. Many evacuated tube collectors suffered from the same problem. All collectors, regardless of type, should be made with tempered glass if they are going to last.

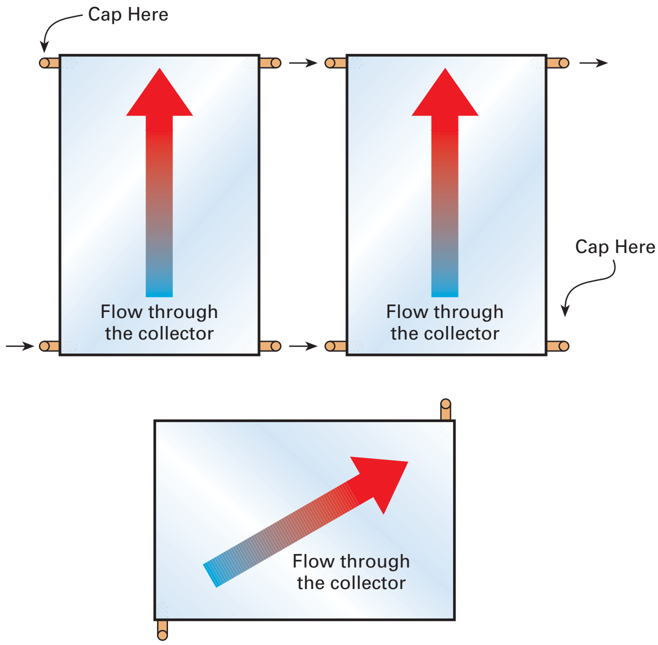
Another problem with older evacuated tube collectors was a loss of vacuum. If the tubes lose their vacuum over time, for any reason, it leaves them without any insulation to keep the heat in the collector. Just as a thermos effectively uses a vacuum to keep beverages hot or cold, a vacuum is superior to all the insulation types in flat-plate collectors. But older evacuated tube collectors are very questionable because the seals commonly don't last; plus there are very few used ones available.

Batch Water Heaters. Here, *caveat emptor*—buyer beware. The condition of the tank in classic batch water heaters is a big unknown. Always think "worst case" and plan to replace the tank if you consider buying one of these used. If the collector is only a couple of hundred dollars and in reasonably good condition, you can afford to replace the tank and have a water heater that will last another couple of decades or so before it needs another new tank.

Progressive tube batch heaters can be evaluated just like liquid collectors if they have copper waterways (large tubes are the tanks) and glass glazing. Check for pitting and pressure test—no leaks, good; leaks, bad.

Tracking–concentrating collectors. Unless you love to tinker endlessly, forget these Rube Goldbergs—get a Harley instead and enjoy yourself.

Used Collector Manifold



Prior to about 1980, many collectors were built with a single inlet and outlet. After 1980, internal manifolded collectors became more popular, because they saved a great deal of time and materials on multiple collector installations.

The aluminum enclosure, aluminum absorber, Type-M copper tube waterways, high temperature insulation, and low-iron tempered glass make it a good bet that this collector will be around for the next 30 years.

Money Matters

Collector size, more than the collector's condition, sets its price. Don't be afraid of older collectors if they appear to be in good cosmetic condition and pass a pressure test—they can still have twenty years or more left of service.

Used collectors usually need to be bought locally because of freight costs and the hassle most people have in crating collectors so that freight companies will accept the shipment. Also consider this from an installation standpoint—some larger collectors can tip the scales at more than 200 pounds (91 kg), making it difficult for even three or four people to hoist onto a roof.

"Good" Used Collector Prices

Size (ft.)	Price (US$)
3 x 6	$150
3 x 8	150–200
4 x 8	225–300
4 x 10	275–350
> 40 sq. ft.	300–400

When you're ready to start your secondhand solar search, first check the Yellow Pages under "Solar," or read the ads in your local newspaper and *Home Power* reader's marketplace. Once you've found your collector, make sure to check it out thoroughly before parting with your hard-earned dollars.

Access

Chuck Marken, AAA Solar Supply Inc., 2021 Zearing NW, Albuquerque, NM 87104 • 800-245-0311 or 505-243-4900 • Fax: 505-243-0885 • solarstuff@aaasolar.com • www.aaasolar.com

Multichannel Metering

Beta-Testing a New System Monitor

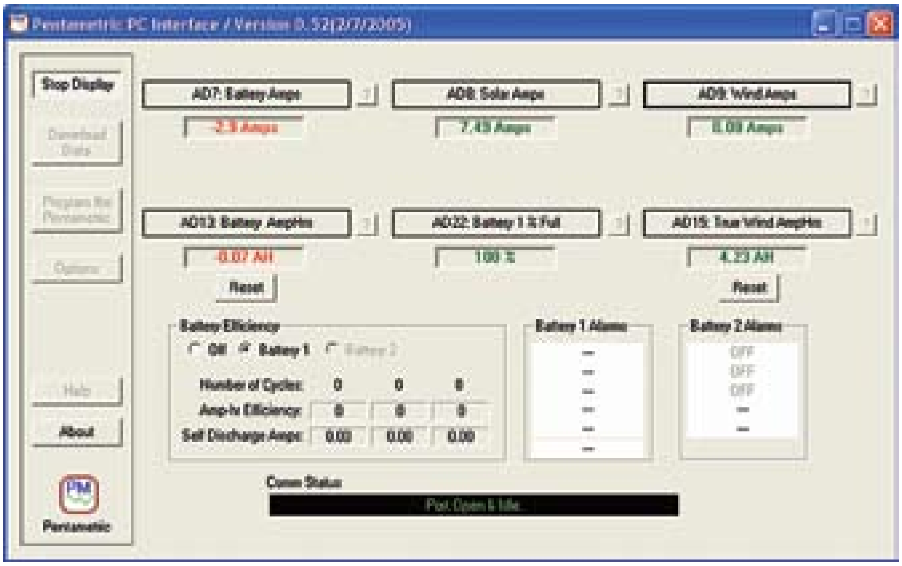
Stephen Dodd

After a year of getting great service at monitoring electrical input and output with my Bogart Engineering TriMetric meter, I was thrilled to have Ralph Hiesey accept me in his beta testing program for their new PentaMetric model. This new product is now in production and available, and the beta version has been giving me great results. What thrilled me most was discovering important new things about the dynamics of my renewable energy (RE) system.

Bogart Engineering produces metering devices that yield very precise data about electrical inputs and outputs of RE systems. These metering devices can be configured to monitor various inputs, such as solar-, wind-, or hydro-electricity.

The original TriMetric allows monitoring of volts, amps, amp-hours, and additional data for battery-based systems. Data is presented via an LED display. The meter combines data for all charging sources. This allows you to monitor the overall charging status of your system, which is great! But what if you have multiple charging sources and want to see how much energy each is contributing to your system?

The PentaMetric's display screen on a Windows-based computer.



Multiple Channels

The new PentaMetric carries all the functionality of the TriMetric, and can also measure three inputs or outputs at the same time. It can display these inputs and outputs on its two-line LCD display and on a Windows-based computer.

In addition, you can download relevant current data, as sampled over time, to an output file. This file is compatible with Microsoft Excel. You can then use Excel to manipulate or graph the data, allowing easy visualization of the relative value of various inputs and loads on the system (see the graph on the facing page).

With the addition of appropriate remote computer access software, PentaMetric users can also monitor their systems over the Internet from distant locations (though this would require an always-on computer, which could be a significant load). An installer could monitor many systems from a central location. A researcher could compile data from systems distributed over any area. User groups could compare their individual data. The data accumulated by the PentaMetric can be used to:

- Let you know when to start a generator
- Produce charge input and load data
- Display efficiency analysis

Rather than going into a lot of detail about the meter, I want to mention a few examples of how I have used it to monitor and manage my own system.

Contributors

I have a modest amount of solar-electric input (700 rated watts). I also have a very small wind turbine. For bulk charging, I have an 8.5-kilowatt diesel generator. I often wonder how much relative value I am getting from each of these inputs.

On any given day, I may have had weak or strong solar input, or lots of wind or no wind. One may be up while the other is down. I may be watching TV and reading, or I might be sawing lumber for construction. How can I best understand the state of charge of my system at any particular time, and identify which charging sources are most effective at my site? The only way is to measure each source of input and weigh it against each output. The PentaMetric can do this.

My system does pretty well with solar electricity. I have 400 amp-hours of battery capacity at 48 volts nominal (20 KWH total), and I like to keep the bank above 80 percent (4 KWH usable). I don't have a lot of loads because I'm not a very demanding guy. When I have large demands for construction, I start the diesel generator. I only occasionally need to resort to my diesel generator for bulk charging. I sometimes go months without the generator, beyond very occasional use to run my table saw.

The meter helped me conclude that the contribution from the wind generator at my site is small in comparison to the solar input. For one windy, five-day period in late March, the solar-electric array produced about 7 KWH, while the wind generator produced 0.55 KWH. Overall, for the initial month of meter use, the solar-electric array produced about 57 KWH and the poorly sited wind generator about 1.25 KWH. The PentaMetric makes all these elements much more quantifiable, and greatly simplifies analysis. It certainly allows improved battery maintenance policy.

I have also noticed that on a bright sunny day, as battery voltage increases to 54 volts and the batteries became full, my solar charge controller regulates the solar-electric charging into the batteries much of the day. As evening approaches and the battery voltage begins to fall off, it allows more energy into the batteries. The PentaMetric helps me see when my system is regulating, and when I might as well use the energy for something instead of having the potential energy from the arrays lost to regulation.

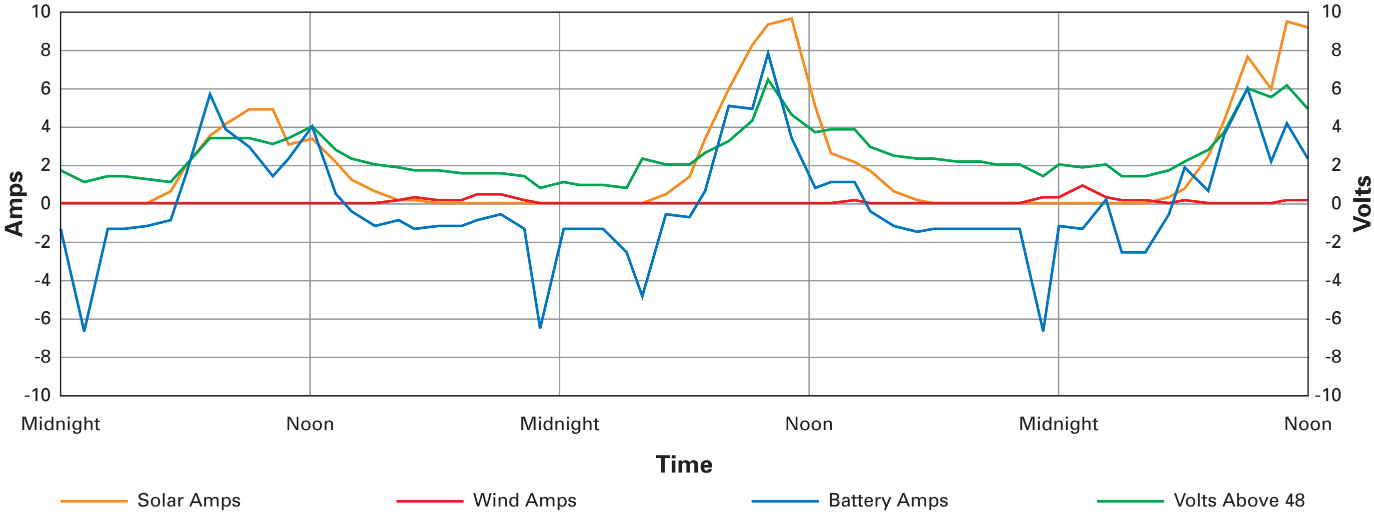
Recently, I noticed a complete failure of solar charging for a day and discovered a fuse was not well-seated in its socket. The PentaMetric alerted me to the problem, so I could fix it and restore my system to full operation.

The PentaMetric can monitor amps and amp-hours on three input/output shunt channels, as well as battery amps, amp-hours, and system voltage.

System Awareness

So how does it work? An appropriately sized shunt is placed between the sources or loads and the batteries (see shunt sidebar, next page). The PentaMetric reads the information from the shunts, calculates the amperage, and relays the information to the LCD display unit and the serial input

Graph from PentaMetric Data



What's a Shunt?

A shunt is basically a calibrated resistor made of special metals that keep the same level of resistance over a very wide range of temperatures, and that can also carry high current. By measuring the amount of voltage drop that occurs across this special material, we can estimate the level of current through the connected part of the system. To keep the losses as low as possible, shunts are usually designed to give extremely low voltage signals, as little as tenths of a millivolt (1/10,000 of a volt) per amp.

Two common shunts are used in renewable energy (RE) systems. The small ones are designed to handle up to about 100 amps DC and provide an output signal that has a ratio of 1 millivolt per amp. This makes reading the output easy with a digital meter that has a "mV" selection on it—each millivolt equals one amp. Often these are marked as "50 A/50 mV" or "100 A/100 mV" on the side. Temporarily passing currents above 100 amps for less than a minute is acceptable for units of this size.

The larger shunts are able to handle up to 500 amps DC continuously and provide an output signal that has a ratio of 1 millivolt per 10 amps. This is a little harder to read with a digital voltmeter, since you need to multiply the reading by a factor of 10 when using the "mV" scale. System meters such as the TriMetric and PentaMetric take care of doing the multiplication for you. Typically, these shunts are marked as "500 A/50 mV" on the side. Temporarily handling currents above 500 amps for up to several minutes is acceptable for these shunts.

Shunts with other values are available—often from old equipment or surplus catalogs. These may have values such as "100 A/50 mV" or "200 A/100 mV." These can be used, but the math always ends up making my head hurt too much.

In the old days, shunts were pretty uncommon in RE systems. We often used the actual system wires as a temporary shunt by measuring off a known distance of wire and connecting the leads of the meter to the wire at these points. We determined, for instance, that 20 inches (51 cm) of #4/0 (107 mm^2) cable is the same as a 500 amp/50 millivolt shunt.

A shunt is one of those little magical devices that make understanding a renewable energy system easier. Shunts give your system's meters a handle on the energy flow through your system. Then your meters can tell you what's going on, so you can use your system intelligently.

—Christopher Freitas

Shunts are located in the negative wire of their respective circuits, and as close as possible to the main negative battery terminal.

to a computer. The device reports the state of all measured values as often as every couple of seconds. You can watch as energy comes in from each source and as it goes out to loads from the battery.

For instance, I can see solar and wind amp-hours going in while the batteries are supplying lights, TV, microwave, and other loads. I was recently watching my laptop at my desk when its cooling fan came on, and I actually saw the increased amperage out of the battery bank show up on the display.

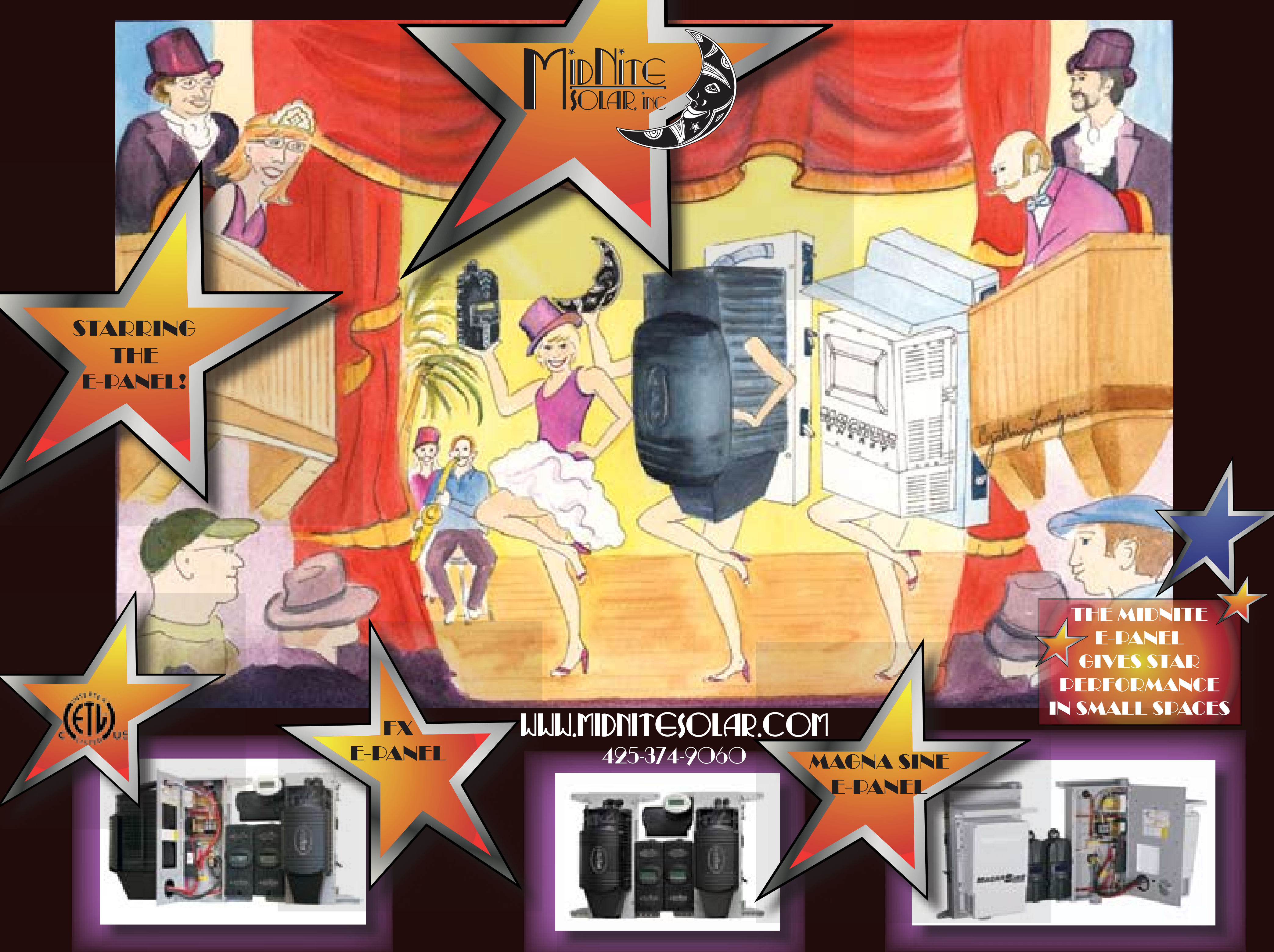
Turn on a light—see its load. Turn on all the lights and see their entire load. See the sun come up and watch it balance the existing load. See the PV input drop as the sun goes behind a cloud. See the sun go down and watch evening wind come up to take over supplementing the batteries. How cool! Now I have a way to know how my system is performing, and how it's likely to perform in the future. Not only that, but I can configure several devices to produce this information. I'm in data heaven!

Access

Stephen M. Dodd, 2089 Monroe St., North Bend, OR 97459 • sdodd@sdodd.com

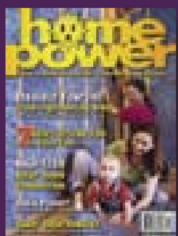
Christopher Freitas, OutBack Power Systems, 19009 62nd Ave. NE, Arlington, WA 98223 • 360-435-6030 • Fax: 360-435-6019 • cfreitas@outbackpower.com • www.outbackpower.com

Bogart Engineering, 19020 Two Bar Rd., Boulder Creek, CA 95006 • 831-338-0616 • Fax: 831-338-2337 • bogart@bogartengineering.com • www.bogartengineering.com • PentaMetric battery monitor


MidNite Solar, inc
STARRING
THE
E-PANEL!
THE MIDNITE
E-PANEL
GIVES STAR
PERFORMANCE
IN SMALL SPACES
FX
E-PANEL
WWW.MIDNITESOLAR.COM
425-374-9060
MAGNA SINE
E-PANEL

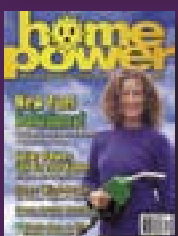
Missing Something?

Get all available back issues (75) for $100!
Or, #1–99: $5.95 ea. • #100–present: $8.95 ea.
All prices include shipping charges to all destinations.



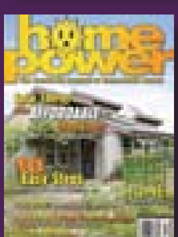
Issue 111
Feb/Mar 2006

Insulation Options • Driving Tips • Homebuilding Competition • Rebate Programs • Snow Power • Solar Home Office • Nigeria Projects • And more!



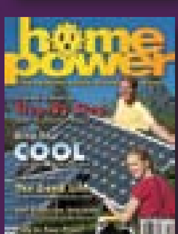
Issue 110
Dec/Jan 2006

New Fuel Solutions • Wind Power Basics • Natural Building Materials • Home Efficiency • Multimeters • Solar Car Race • Tax Credit Retrospective • And more!



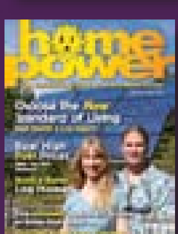
Issue 109
Oct/Nov 2005

Green Dream Home • PV Cost Estimate • PV Installation–Part 2 • DIY Passive Solar Heat • Natural Lighting • MPPT • Car Sharing • And more!



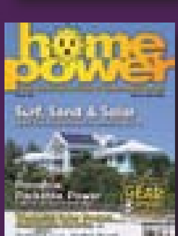
Issue 108
Aug/Sep 2005

Passive Cooling Strategies • Pole Mount Installation–Part 1 • The Good Life • Prius+ • Solar Hot Water Batch Heater • Passive Solar Earthship • And more!



Issue 107
Jun/Jul 2005

Zero Energy Home • Cordwood Building • Making Biodiesel • Solar Hot Water for Beginners • Rainwater Catchment • Solar RV • And more!



Issue 106
Apr/May 2005

Island Getaway • Grid-Tie Inverter Showcase • PV Design Choices • Ram Pump • DIY Solar Fountain • SIP Building • And more!

Browse our back issues at www.homepower.com/archive
Order online or call 800-707-6585 or 541-512-0201

HP Digital— The Perfect Paperless Alternative

$15 /year

Our digital subscription option is here! Download a full year of *Home Power*—six issues in PDF for just $15.*

- Identical to our print edition
- Easy, on-screen navigation
- Built-in bookmarks and links
- Searchable and printable

To learn more or to get started, visit...

www.homepower.com/digital

* Requires Adobe Acrobat Reader 5.0 or later and an e-mail address.

Your New Favorite Shirt Is Here.

in 100% organic cotton

$10 Sizes: S, M, L, XL, XX
S&H: US–$2, Can–$3, Other–$5

[Tank Tops - $12, Color: Natural, Sizes: S, M, L]

Also Available in Tank Top

www.homepower.com/shirts
800-707-6585 or 541-512-0201


Quality never goes out of style
Pioneers of the deep-cycle battery
Trojan has delivered decades of performance to renewable energy practitioners across the globe.
Made to last
Our deep-cycle batteries, made in the USA, have the best repution for long life, durability, and reliability.
Live technical support
Visit our website for technical information or call for live technical support.
Recycle your used batteries through our distributor network.
Trojan
BATTERY COMPANY
Clean energy for life™
1925
1950
1990
Trojan
The Better Battery
T-105
Available from Trojan Master Distributors Worldwide • 800-423-6569 • www.trojanbattery.com


Searching for a Canadian renewable energy company?
ENERGY ALTERNATIVES has provided thousands of reliable, long lasting and expandable power systems in some of the most remote areas of Canada during our
21 YEARS OF OPERATION.
Choose from our DIY packaged systems or turn-key professional installation.
DEALERS WANTED Energy Alternatives offers a comprehensive dealer training program, fast delivery, excellent pricing and superior technical support.
FREE
Buyers Guide
(for Canadian customers)
BC Electrical contractor
86683
ENERGY ALTERNATIVES
www.EnergyAlternatives.ca
TOLL FREE (800)265-8898


Sun Frost
Energy Efficient
Refrigerators & Freezers
Customized To Fit Your Needs
Available in DC or AC
Select From Over 10 Models
Choose from 1000's of Colors, Finishes & Woods
We also Manufacture Composting Toilets!
Please Contact Us For More Info
P.O. Box 1101, Arcata, CA 95518
tel: (707)822-9095 ▪ fax: (707)822-6213
info@sunfrost.com ▪ www.sunfrost.com

STRETCH Your Energy Dollars

With a Life Cycle Cost Analysis

Joel Davidson & Fran Orner

Are you paying too much to own and operate your lights and appliances? Businesses use life cycle cost (LCC) analyses to make equipment purchase decisions, reduce energy consumption, and improve their bottom line. You can use the same strategy.

An LCC analysis will help you compare energy use between appliances and save money over the long term, as well as reduce your energy consumption, your contribution to pollution, and the depletion of nonrenewable resources. For example, if every U.S. family replaced four incandescent bulbs with four compact fluorescent lightbulbs (CFLs) of equal brightness, the six largest nuclear power plants could be shut down. While the environmental benefits are obvious, how does this strategy measure up using an LCC analysis?

Plan & Save

If you're at all concerned with energy efficiency and how it will impact your wallet, an appliance's initial purchase price shouldn't be your only consideration. You should also examine the appliance's operating costs over its lifetime. Often, the energy expenses of running an appliance can be two to three times more than its initial purchase price. The simple formula below can help you calculate the total cost of an appliance over its useful life.

Life Cycle Cost = Purchase Price + (Annual Energy Cost x Equipment Lifetime x Discount Factor)

Purchase Price & Annual Energy Cost. Purchase price should include sales tax, delivery, and installation charges. Use the yellow EnergyGuide label that new appliances are required to display as an estimate of the annual energy cost (see "Read the Label First " sidebar). You can easily calculate the appliance's actual operating expense—just multiply its energy consumption rate (in kilowatts) times its daily operating hours. Multiply this by 365 days, and then multiply the result by your electric utility rate.

Annual Energy Cost = Energy Consumption Rate x Daily Operating Hours x 365 Days x Utility Rate

The yellow EnergyGuide label offers shoppers useful information on an appliance's annual energy consumption.

If there's no EnergyGuide label, you can find voltage, amperage, and operating wattage data on a sticker or plate on the appliance's bottom or back. Sometimes the nameplate will just list voltage and current, and leave off the watts (W). Current is expressed as amperage, and appears in a number of forms: 0.5 amps, 0.5 A, or 500 mA. To calculate watts, just multiply the volts and amps (V x A = W), and take that amount times 0.001 to convert it into kilowatts (KW).

Your electric utility rate is your total electric bill divided by your monthly kilowatt-hour (KWH) consumption. For example, our last electric bill was US$50, and we consumed 400 KWH in that month, for a per KWH charge of US$0.125 ($50 ÷ 400 KWH = $0.125/KWH).

Calculations in this article are based on the 2004 U.S. average retail electricity rate of US$0.09 per KWH. (See "How Much Do You Pay?" sidebar for more information.)

Once you have determined the energy consumption rate and your utility rate, the rest is just as easy. Suppose that you use a 100 W (0.1 KW) lightbulb three hours each night. Its annual operating expense would be US$9.86 per year (0.1 KW x 3 hours x 365 days x $0.09 = $9.86).

Equipment Lifetime. Appliance quality, power quality, and how the appliance is operated and maintained all affect how long an appliance will last. The table on page 85 lists some average appliance lifetimes.

Discount Factor. Using a discount factor provides a simple way to express the time value of money. First, you calculate the "real discount rate" by starting with the nominal discount rate, which is the interest rate applied to future payments, and then adjust it for inflation and the increase in annual energy prices above inflation. Plug in your own numbers for interest rates and inflation (expressed as decimal fractions) into the formula below:

Real Discount Rate = [(1 + Nominal Discount Rate) ÷ (1 + Annual Energy Increase Rate + Inflation Rate)] -1

Next, determine the discount factor using the formula below, and plugging in the Real Discount Rate you figured above (expressed as a decimal fraction), and the expected lifetime of the appliance in years as the power the denominator is raised to:

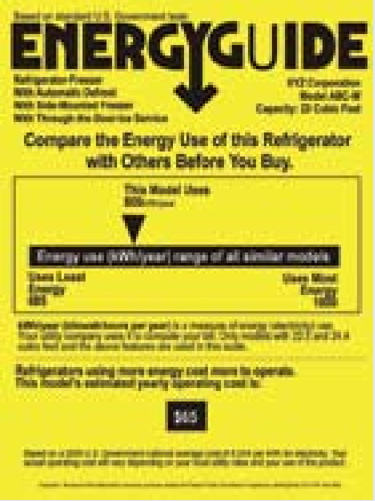
Discount Factor = 1 ÷ (1 + Real Discount Rate)$^{\textbf{Years}}$

Multiplying costs by the discount factor converts those costs into the "present value" of money. If you are not an accountant, discount rates and factors can be heady stuff.

The tables and the examples on this and the following page use 5 percent nominal discount or interest rate for the cost of money, a 2 percent inflation rate, and 1 percent increase in annual energy prices above inflation for a 1.942 percent real discount rate. You can use the discount factors in the Lifetime Cost Comparison table (below) as a shortcut.

Read the Label First

Look to the yellow and black EnergyGuide label when you're ready to purchase a new appliance. You'll find these helpful stickers on refrigerators, freezers, dishwashers, clothes washers, room air conditioners, and water heaters, to name a few. By law, appliance manufacturers are required to affix the labels to these products. The labels provide information about a particular appliance's capacity, estimated annual energy consumption, and energy efficiency rating, as compared to similar appliances.



Comparing Costs

Now that you know how to determine all the variables in the life cycle cost formula, you are ready to compare real costs of appliances. For example, let's compare the life cycle costs for two refrigerators that are equivalent in capacity and features. The price of Refrigerator A is US$750, and it costs US$75 per year to operate at US$0.09 per KWH. The price of Refrigerator B is US$100 less, but it consumes an estimated US$24 more in electricity per year.

Although Refrigerator A is more expensive initially, you can see from the table below that over its lifetime, Refrigerator A's energy savings make up for its higher upfront cost. If you live on the grid, the energy efficient refrigerator consumes less utility electricity, shaving dollars and cents off your electric bill. Using less energy also means reducing air pollution and conserving natural resources. If you're off grid, the energy efficient appliance

Lifetime Cost Comparison

Appliance	Price +	(Energy Cost x	Estimated Lifetime x	Discount Factor) =	Life Cycle Cost
Refrigerator A	$750.00	$75.00	20	0.69	$1,785
Refrigerator B	650.00	99.00	20	0.69	2,016
1 Compact fluorescent bulb (15 W)	$10.00	$1.48	10	0.83	$22
13 Incandescent bulbs (60 W each)	4.29	5.91	10	0.83	53

LCC Analysis for Two Refrigerators

Assumptions & Factors

Electricity cost (US$ per KWH)	$0.09
Annual energy increase rate	1%
Inflation rate	2%
Nominal discount rate*	5%
Real discount rate**	1.942%

* Interest rate applied to future payments
** Includes inflation to discount future dollars to present value. RDR = [(1 + nominal discount rate) ÷ (1 + energy rate increase + inflation rate)] -1

	Refrigerator A	Refrigerator B
Price	$750	$650
Energy consumption (W)	190	250
Daily operation (Hrs.)	12	12
Annual operation (Hrs.)	4,380	4,380
Annual energy consumption (KWH)	833	1,095
Annual energy cost (US$)	$75	$99

		Refrigerator A		Refrigerator B		
Yr.	Discount Factor[1]	Lifetime Energy Cost (US$)	Life Cycle Cost (US$)	Lifetime Energy Cost (US$)	Life Cycle Cost (US$)	Lifetime Savings B - A
1	0.99	$75	$825	$99	$749	-$76
2	0.97	146	896	193	843	-53
3	0.95	214	964	283	933	-31
4	0.93	279	1,029	369	1,019	-10
5	0.91	342	1,092	451	1,101	9
6	0.90	405	1,155	535	1,185	30
7	0.88	462	1,212	610	1,260	48
8	0.86	516	1,266	682	1,332	66
9	0.85	574	1,324	758	1,408	84
10	0.83	623	1,373	822	1,472	99
11	0.81	669	1,419	883	1,533	114
12	0.80	720	1,470	951	1,601	131
13	0.78	761	1,511	1,004	1,654	143
14	0.77	809	1,559	1,068	1,718	159
15	0.75	844	1,594	1,114	1,764	170
16	0.74	888	1,638	1,173	1,823	185
17	0.73	931	1,681	1,229	1,879	198
18	0.71	959	1,709	1,266	1,916	207
19	0.70	998	1,748	1,317	1,967	219
20	0.69	1,035	1,785	1,367	2,017	232

[1] Expresses the time value of money. DF = 1 ÷ (1 + real discount rate) ^{year}

When to Replace an Appliance

Consider these four factors when you're trying to make a decision to repair or replace an appliance:

- Years left in the appliance's expected lifetime
- Replacement cost
- Energy savings of the new appliance
- Maintenance and repair costs of the old appliance

Remember that even simple replacement parts, such as a refrigerator door gasket, can cost US$30 to US$100. Adding the cost of maintenance or repairs may tip the scales in favor of replacement.

If your 12-year-old refrigerator consumes 1,400 KWH per year and a new one would consume 700 KWH per year, at energy costs of US$0.09 per KWH you would recover US$63 per year in energy savings. If the old refrigerator would have lasted for eight more years, the simple dollar value of the energy savings of upgrading to a new refrigerator would be US$504, or US$432 when the discount factor is applied.

While you are figuring dollar and cents savings, don't forget to factor in environmental savings. Investing in more energy efficient appliances also cuts your contribution to pollution. Comparing the two refrigerators from the previous example, if your home is powered by the utility grid, operating the newer model produces 2.1 fewer pounds of nitrogen oxides, 4 fewer pounds of sulfur dioxide, and 1,061 fewer pounds of carbon dioxide per year. These numbers reflect the national average for all power plants in the United States. Use the Power Profiler provided by the Environmental Protection Agency (www.epa.gov/cleanenergy/powerprofiler.htm) to check how the electricity you use compares to the national average.

consumes less energy, which would allow you to install a smaller PV or wind-electric system.

Now compare CFLs and incandescent lightbulbs. Per watt, some compact fluorescent bulbs put out four times as much light (lumens) as incandescent bulbs. So why don't more people switch to fluorescents? One reason is sticker shock—compact fluorescent bulbs range in price from US$3 to $10 or more, compared to incandescent bulbs, which cost about US$0.33 apiece.

Even at US$10, is a CFL a better deal than a 33-cent incandescent lightbulb? Does it make economic sense to replace four 60 W lightbulbs used 3 hours per night with four 15 W CFLs?

For a 15 W CFL, the annual operating expense turns out to be US$1.48 per year (0.015 KW x 3 hours x 365 days x $0.09 = $1.48). For a 60 W incandescent lightbulb, the annual operating expense is US$5.91 per year (0.06 KW x 3 hours x 365 days x $0.09 = $5.91).

Incandescents have a lifespan of about 750 hours, compared to compact fluorescents, which last about thirteen times as long. Since incandescents are inexpensive, we will "buy" 10 years of 60-watt bulbs for US$4.29 (13 x US$0.33) and compare the 10-year life cycle cost for both types of bulbs. (See the Lifetime Cost Comparison table on page 83.) The life cycle cost savings (US$28) of the compact fluorescent bulb more than compensates for its additional upfront cost.

The Bottom Line

Life cycle cost analyses can help you make the most out of your energy dollars, while minimizing environmental impacts. The American Council for an Energy-Efficient Economy publishes a list of the most energy efficient appliances and the *Consumer Guide to Home Energy Savings,* a 247-page book loaded with practical tips (see Access). The *Guide*, which lists appliance brand names and model numbers, pays for itself in savings the first time you use it to shop for appliances.

How Much Do You Pay?

The cost per kilowatt-hour used for the calculations in this article is US$0.09, which reflects the 2004 U.S. national average retail electric rate. Individual state averages for residential electric utility rates range from US$0.0588 to US$0.1869 per KWH.

Your electricity costs include the basic utility rate per KWH and additional charges, such as transmission charges, rate adjustments, public purpose charges, nuclear decommissioning charges, competition transition charges, energy cost recovery fees, fixed transition amounts, bond fees, service cost adjustments, and more. All of these charges may be based on consumption per KWH, and are shown on your bill as either "bundled" or "unbundled" (itemized) charges. Additional charges on your bill may be billed per utility meter, and your bill could also include state and local taxes.

The simplest method to determine your total rate is to divide the total amount of your monthly bill by the number of KWH consumed during that month. Some utilities use a tiered rate, charging a baseline rate for an initial amount of power and progressively higher KWH rates for more consumption. Here's where efficiency can really pay off. For example, using actual utility rates, a single California household pays US$0.22 per KWH for the portion of their monthly consumption over 711 KWH per month. Replacing a few incandescent lightbulbs with compact fluorescent ones could drop their usage below 711 KWH per month into a "lower" tier, so they're only paying US$0.18 per KWH. As the family continues to invest in efficiency measures that reduce their electricity use, their consumption falls below 355 KWH per month, dropping their rate to the baseline of US$0.12 per KWH.

Average Appliance Life

Appliance	Lifetime Years	Lifetime Hours
Incandescent lightbulbs*	-	750
Compact fluorescent lightbulbs*	-	10,000
Dishwashers	12	-
Water heaters	13	-
Room air conditioners	15	-
Clothes washers	18	-
Refrigerators & freezers	20	-

*Lightbulb usage is typically 1,000 hours per year.

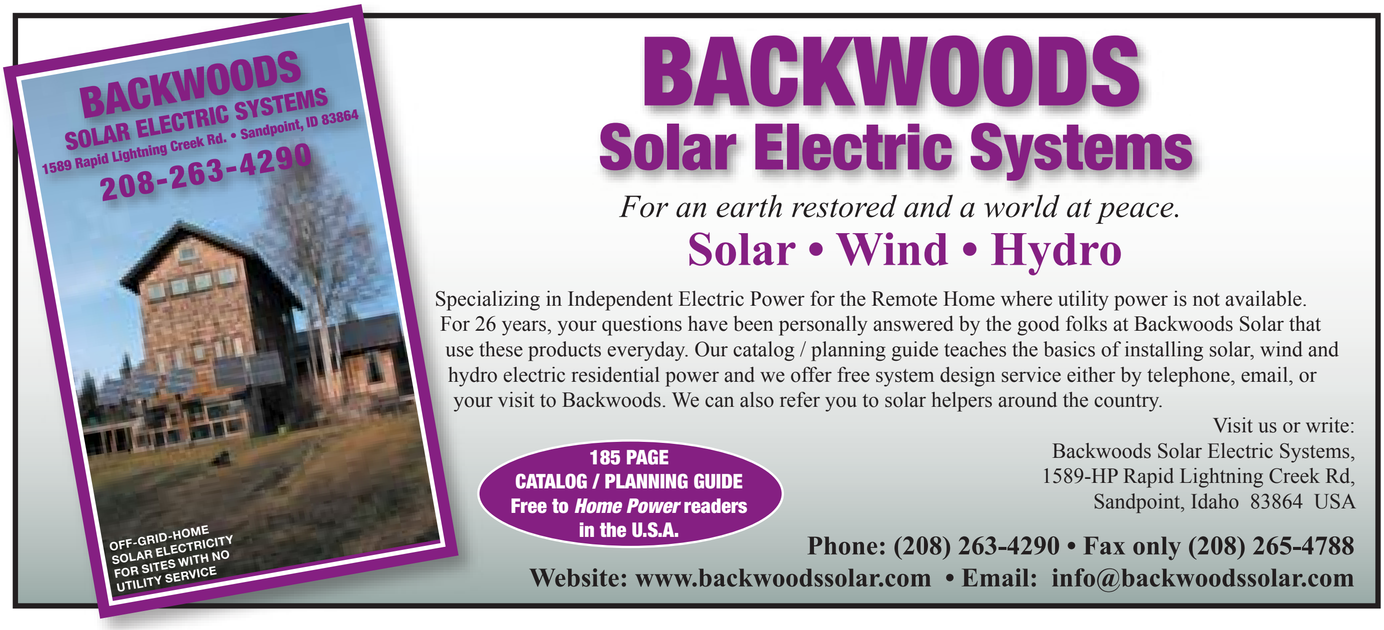
Access

Joel Davidson & Fran Orner, SOLutions in Solar Electricity, PO Box 5089, Culver City, CA 90231 • 310-202-7882 • Fax: 310-202-1399 • joeldavidson@earthlink.net • www.solarsolar.com

Consumer Guide to Home Energy Savings, 8th Edition, 2003, Paperback, 247 pages, ISBN 0918249465, US$8.95 and *The Most Energy Efficient Appliances, 2004*, Paperback, 46 pages, US$5 from American Council for an Energy-Efficient Economy, 1001 Connecticut Ave. NW, Ste. 801, Washington, DC 20036 • 202-429-0063 • Fax: 202-429-0193 • info@aceee.org • www.aceee.org


SANYO
Think Solar, for Life and the Earth
www.Sanyo.com
To ensure that children of the future will have a beautiful planet to live on, SANYO treats the Earth as a single living organism, and redefines conventional ideas to take advantage of unique technological resources to create global solutions for life and the Earth.
For more information visit www.Sanyo.com
SANYO EVOLUTION PROJECT


www.solren.com
hp@solren.com
SOLECTRIA
RENEWABLES
Grid-Tied PV Inverters
PVI2500 Residential
PVI1800 Residential
Lightweight & Efficient
Plug 'n Play Installation
Unsurpassed Quality
Breakthrough Price
360 Merrimack St. Lawrence, MA 01843 tel: 978-683-9700 fax: 978-683-9702


BACKWOODS
SOLAR ELECTRIC SYSTEMS
1589 Rapid Lightning Creek Rd. • Sandpoint, ID 83864
208-263-4290
OFF-GRID-HOME SOLAR ELECTRICITY FOR SITES WITH NO UTILITY SERVICE
BACKWOODS
Solar Electric Systems
For an earth restored and a world at peace.
Solar • Wind • Hydro
Specializing in Independent Electric Power for the Remote Home where utility power is not available. For 26 years, your questions have been personally answered by the good folks at Backwoods Solar that use these products everyday. Our catalog / planning guide teaches the basics of installing solar, wind and hydro electric residential power and we offer free system design service either by telephone, email, or your visit to Backwoods. We can also refer you to solar helpers around the country.
185 PAGE CATALOG / PLANNING GUIDE Free to Home Power readers in the U.S.A.
Visit us or write:
Backwoods Solar Electric Systems,
1589-HP Rapid Lightning Creek Rd,
Sandpoint, Idaho 83864 USA
Phone: (208) 263-4290 • Fax only (208) 265-4788
Website: www.backwoodssolar.com • Email: info@backwoodssolar.com

New Energy Tax Credits

Douglas L. Faulkner

Acting Assistant Secretary for Energy Efficiency & Renewable Energy

On January 1, a set of federal energy efficiency tax credits went into effect, making it easier for American families and businesses to reduce energy costs at home, at work, and on the road. These credits are designed to improve our nation's energy efficiency, while helping you offset the costs of purchasing and installing energy efficient appliances, renewable energy systems, and fuel-efficient vehicles, such as hybrid electric cars and trucks.

So how can you better your bottom line while investing in energy efficiency and renewable energy? Let's look at these new tax credits that are being provided, and discuss how you can use them to your advantage.

Tax Credits Vs. Deductions

As part of the Energy Policy Act of 2005, tax credits for energy efficiency will give consumers many happy returns when filing their 2006 and 2007 tax forms.

Tax credits are not the same thing as deductions—they're better. Deductions only reduce the amount of income that is taxed, *before* the tax amount is calculated. The result? Only a percentage of the deducted amount reduces the calculated tax.

A tax *credit*, however, is a direct, dollar-for-dollar reduction of the tax you owe. For example, consumers who purchase the most fuel-efficient vehicles could reduce their tax liabilities by up to US$3,400. Those who install certain products, such as energy efficient windows, insulation, doors, roofs, or heating and cooling equipment in their homes can subtract up to US$500 from their tax returns.

Although a tax credit won't cover the entire cost of these purchases or installations, the money saved through energy efficiency will help compensate for that upfront expense over the lifetime of the improvements. And given a few years, the improvements will likely pay for themselves in energy savings and reduced utility bills.

Credit Checklist

Now that you know a bit about tax credits and what sorts of things might qualify, you may be asking yourself, "How does this help me?" These tax credits can help if:

- You need to replace one or more major appliances or home fixtures (such as windows)
- Your home is in need of renovation, major repair, or upgrading for efficiency
- You're thinking about adding a renewable energy source to your home
- You're going to buy a new car

Think about what you need first. Do you have high gas or electric bills? Are there rooms in your home that are too hot, or too cold and drafty? Do you need to replace your furnace or air conditioning equipment? Make a checklist

Tax Breaks for Businesses

Businesses are also eligible for several tax credits, which include buying hybrid vehicles, constructing energy efficient buildings, improving the energy efficiency of commercial buildings, and investing in solar energy technologies, such as PV and solar hot water systems. Builders may be eligible for tax credits for constructing homes that meet stringent energy efficiency qualifications, and take advantage of a business tax deduction of US$1.80 per square foot for newly constructed buildings that use half as much energy as those that meet current energy code standards.

The energy bill also substantially increases the business investment tax credit from 10 to 30 percent. This tax credit is available to businesses that purchase solar thermal and PV systems during calendar years 2006 and 2007. The business investment tax credit for solar equipment does not have a maximum credit limit.

of what you'd like to do from the eligible improvements list and see if one or more apply to you. Even small home improvements, like adding insulation and weather-stripping around doors and windows, can shave a little bit off your taxes, while saving energy and cutting your utility bills.

A certified home energy auditor can determine which improvements will provide you with the largest savings and verify that the work done by contractors has been done correctly. The Residential Energy Service Network (RESNET; www.resnet.us) has a network of auditors that provide services in all states. However, having an audit is not a prerequisite for receiving the tax credits.

Advantages at Home

Specific tax benefits for the home are listed in the table. Possibly the best credits the new energy bill offers are for homeowners who invest in residential solar energy systems, such as solar-electric (photovoltaic; PV) and solar hot water systems. Taxpayers are allowed one credit equal to 30 percent of the qualified investment in a solar-electric system, up to a maximum credit of US$2,000, and another equivalent credit for investing in a solar water heating system. (The credit does not apply to equipment used to heat swimming pools or hot tubs.)

Solar hot water systems must be certified by the Solar Rating and Certification Corporation (SRCC) and produce 50 percent or more of the home's hot water needs. PV systems don't require a qualification, except in Florida, where systems must be rated and certified by the Florida Solar Energy Center to receive the tax credit.

All improvements must be installed in or on the taxpayer's principal residence in the United States. Home improvement tax credits apply to improvements made between January 1, 2006 and December 31, 2007. With an annual cap of US$500 (except for solar hot water and solar-electric systems), consider timing improvements to take full advantage of the available credits.

On the Road

The new tax credits also include help for auto buyers shopping for fuel-efficient vehicles. Depending on the vehicle's fuel economy and weight, tax credits range from US$250 to $3,400. Businesses that invest in heavy-duty hybrid trucks can receive larger tax credits (see the sidebar on facing page).

The new tax credit is for vehicles placed in service *beginning* January 1, 2006. But because there is a waiting list for many hybrids, note that you can still take advantage of the tax credit even if you arranged to purchase the vehicle in

Federal Tax Credits

Solar Energy	Tax Credit
Solar domestic hot water systems (must provide at least 50% of hot water needs)	30% of cost, up to $2,000
Solar-electric systems	30% of cost, up to $2,000
Cars	
Hybrid, diesel, EV, alternative fuel & fuel cell	Determined by vehicle weight, technology & fuel economy
Home Construction/Renovation	
Exterior windows	10% of cost; not to exceed $200
Skylights	10% of cost; not to exceed $200
Exterior doors	10% of cost; not to exceed $500
Metal roofing	10% of cost; not to exceed $500
Insulation	10% of cost; not to exceed $500
Home Heating & Cooling Systems	
Central air conditioning	$300
Air-source heat pumps	$300
Geothermal heat pump	$300
Gas, oil, or propane water heater	$300
Electric heat-pump water heater	$300
Gas, oil, or propane furnace or boiler	$150
Advanced main air circulating fan	$50

Source: www.energystar.gov; see Web site for specific requirements

Get the Star

When it comes to energy efficient upgrades, think Energy Star for your home appliances and heating and cooling equipment. This program, administered by the U.S. Department of Energy and the U.S. Environmental Protection Agency, helps identify energy smart products. Appliance and fixture manufacturers submit their products and, if they meet the program's standards, earn the right to use the label on their products and in their advertising. Energy Star appliances and fixtures will help you save energy—they are made to use less energy to do the same amount of work as an average appliance. For more information and a list of qualifying products, visit the Energy Star Web site at www.energystar.gov.

2005—as long as you did not take possession of it until after January 1 of this year.

The vehicle tax credit will be phased out for each vehicle manufacturer once that company has sold 60,000 eligible vehicles. At that point, the tax credit for that company's vehicles will be gradually reduced over the course of another year. In other words, the full benefit of the tax credit is a limited-time offer. If you're in the market for a new car, consider shopping (and buying) as soon as you can.

Save Even More

Federal tax credits are only part of the picture. You also may be eligible for utility or state rebates, and may be able to take advantage of state tax incentives for energy efficient homes, vehicles, and equipment. Check out your state's energy tax breaks and other incentives at www.dsireusa.org. Also, be sure to ask your tax preparer or seek advice online for ways to find these additional tax breaks—you may spend some extra time filling out your tax forms, but you and your bank account will be happier for it.

Don't forget: These tax credits will be available starting with *next* spring's tax preparation. They won't be available for tax forms filed this year. To get help figuring out which home improvements and purchases qualify, consult a professional tax preparer or go online to www.irs.gov. But start preparing now, and you'll be money—and energy—ahead when next tax season rolls around.

Access

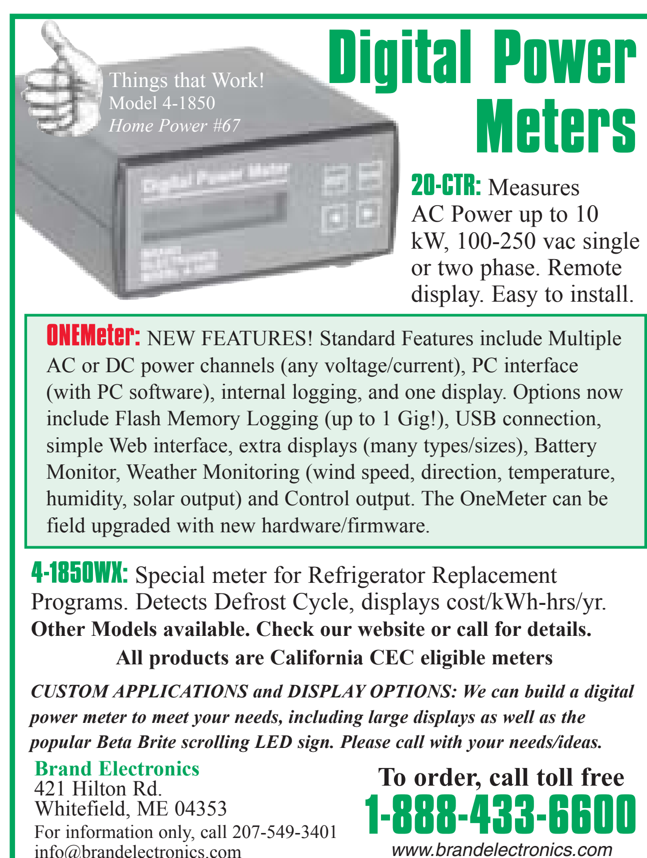
Douglas L. Faulkner, Acting Assistant Secretary for Energy Efficiency & Renewable Energy, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, 1000 Independence Ave. SW, EE-12, Washington, DC 20585 • 877-337-3463 • www.eere.energy.gov

To learn more about ways to improve your home's energy efficiency, check out: www.energysavers.gov • www.energystar.gov • www.fuelefficiency.gov


EVs That Work™
Clean Quiet Powerful
GORILLA TOUGH
WARNING: NOT TOYS !
6 years of satisfied customers.
Made in the USA
See our new webpage about
SOLAR CHARGING
GORILLAs
and other
Electric Vehicles
• Electric Power and Torque
• Almost Zero Maintenance
• No Oil, Gas, or Fumes
• 110v Charging or DC Direct
• Silent Utility and Mobility
CHIMP™
Our new stand-up security vehicle.
see website
info@GorillaVehicles.com
PLEASE SEE OUR WEBSITE
or call for a brochure package
Gorilla Vehicles
Doran Motor Company, Inc.
16121 Saint Croix Circle
Huntington Beach, CA 92649
(714) 377-7776
www.GorillaVehicles.com


WATSUN™
SOLAR TRACKERS
• A diverse line of quality trackers for: Grid-Intertie, Commercial Applications, Remote Homes and Water Pumping.
• Trackers from 150 W to 15 kW.
• Complete pre-engineered TracKits™ available.
• Patented technology.
• 15 years of solar tracking experience.
Array Technologies, Inc
505-881-7567
www.wattsun.com


Battery Filling Systems
Put the fun back in watering your batteries!
• One Connection
• One Minute
• Accurately Fills Each Cell, Every Time!
See Product Review, Home Power Magazine Issue 100, Page 82
Master Distributor for BFS, deep cycle & industrial batteries
All Battery Sales & Service
1-800-562-3212
Fax: 425 742-1739
vern@allbatterysalesandservice.com
SALES AND SERVICE
All Battery


Things that Work!
Model 4-1850
Home Power #67
Digital Power Meters
20-CTR: Measures AC Power up to 10 kW, 100-250 vac single or two phase. Remote display. Easy to install.
ONEMeter: NEW FEATURES! Standard Features include Multiple AC or DC power channels (any voltage/current), PC interface (with PC software), internal logging, and one display. Options now include Flash Memory Logging (up to 1 Gig!), USB connection, simple Web interface, extra displays (many types/sizes), Battery Monitor, Weather Monitoring (wind speed, direction, temperature, humidity, solar output) and Control output. The OneMeter can be field upgraded with new hardware/firmware.
4-1850WX: Special meter for Refrigerator Replacement Programs. Detects Defrost Cycle, displays cost/kWh-hrs/yr.
Other Models available. Check our website or call for details.
All products are California CEC eligible meters
CUSTOM APPLICATIONS and DISPLAY OPTIONS: We can build a digital power meter to meet your needs, including large displays as well as the popular Beta Brite scrolling LED sign. Please call with your needs/ideas.
Brand Electronics
421 Hilton Rd.
Whitefield, ME 04353
For information only, call 207-549-3401
info@brandelectronics.com
To order, call toll free
1-888-433-6600
www.brandelectronics.com

Making the Utility Connection for Larger Systems

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

This 30 KW PV system requires a supply-side utility connection.

As state and federal incentives continue and proliferate, larger photovoltaic (PV) systems are being installed on residences. The *National Electrical Code (NEC)* establishes how and where a utility-interactive PV system may be connected to the utility system. The point of connection for these systems may be either on the *load* (structure) side of the service disconnect or the *supply* (utility) side of the service disconnect.

Often, larger PV systems cannot be conveniently installed on the load side by using backfed circuit breakers in an existing load center. In many cases, the complex requirements for load-side connections [Section 690.64(B)(2)] are impractical and dictate that the utility-interactive inverter be connected on the supply side of the service disconnect.

This column concentrates on the requirements of the 2005 *NEC*, Section 690.64(A), Point of Connection, which allows residential PV installations to be connected to the *supply* side of the service disconnect. Making code-compliant *load* side connections to the utility grid for smaller PV systems was covered in *Code Corner, HP111.* Here are some, but not all, of the major code sections that address supply side connections. They apply to either a residential or commercial installation.

Supply Side Connections Allowed

Section 690.64(A) allows a supply (utility) side connection, as permitted in Section 230.82(6). In that section, photovoltaic systems are listed as equipment that is *permitted* for connection to the supply side of the service disconnect. The word "permitted" indicates an optional requirement.

The connection of a utility-interactive inverter to the supply side of a service disconnect is essentially connecting a second service-entrance disconnect to the existing service. Many, if not all, of the rules for service-entrance equipment must be followed.

Rules for Service-Entrance Conductors

Section 240.21(D) allows the service conductors to be tapped and refers to Section 230.91. These service-entrance tap requirements are not the same as the general feeder tap rules found elsewhere in the code. Section 230.91 requires that the service overcurrent device be co-located with the service disconnect. A circuit breaker or a fused disconnect would meet these requirements. A utility-accessible, visible break, lockable (open), fused disconnect (safety switch), if used, may also meet utility requirements for an external PV AC disconnect.

Section 230.71 specifies that the service disconnecting means for each set of service-entrance conductors shall be a combination of no more than six switches and sets of circuit breakers mounted in a single enclosure or in a group of enclosures. The addition of the photovoltaic equipment disconnect would be counted as one of the six.

Section 230.70(A) establishes the location requirements for the service disconnect. These are similar to the requirements for locating the PV DC disconnect. The disconnect must be in a readily accessible location, near the point of entrance of the service conductors. The local jurisdiction will determine if it is to be inside or outside the building.

Section 705.10 requires that a directory be placed showing the location of all power sources for a building. Locating the PV service disconnect adjacent or near the existing service disconnect may facilitate the installation, inspection, and operation of the system.

Disconnects Rated at 60 Amps

Section 230.79(D) requires that the disconnect must have a minimum rating of 60 amps. This would apply to a service-entrance-rated circuit breaker or fused disconnect.

Section 230.42 requires that the service-entrance conductors be sized at 125 percent of the continuous loads. (All currents in a PV system are worst-case continuous.) The actual rating should be based on 125 percent of the rated output current for the utility-interactive PV inverter [690.8]. The disconnect must have a 60-amp minimum rating. Larger conductors may be required after temperature and conduit fill factors have been applied.

For a small PV system (for example, a 2,500-watt, 240-volt inverter requiring a 15-amp circuit and overcurrent protection), these requirements would appear to specify a minimum 60-amp rated disconnect, but 15-amp fuses could be used; fuse adapters would be required. While 15-amp conductors could be used between the inverter and the 15-amp fuses in the disconnect, Section 230.42(B) requires that the conductors between the service tap and the disconnect be rated not less than the rating of the disconnect—in this case, 60 amps.

How to deal with the 60-amp disconnect, 15-amp overcurrent requirements using circuit breakers is not as straightforward. A circuit breaker rated at 60 amps would serve as a disconnect, and it could be connected in series with a 15-amp circuit breaker to meet the inverter overcurrent device requirements. In this case, the requirements of 690.64(B)(2) should be applied for the series connection. See *Code Corner*, *HP111* for details.

Check Available Fault Currents

Section 110.9 requires that the interrupt capability of the equipment be equal to the available fault current. The interrupt rating of the new disconnect–overcurrent device should at least equal the interrupt rating of the existing service equipment. The utility service should be checked to ensure that the available fault currents have not been increased above the rating of the existing equipment. Fused disconnects with RK-5 fuses are available with interrupt ratings up to 200,000 amps.

Section 230.43 allows a number of different service-entrance wiring systems. However, considering that the tap conductors are unprotected from faults, the conductors should be as short as possible, with the new PV service disconnect mounted adjacent to the tap point. Conductors installed in rigid metal conduit would provide the highest level of fault protection. All equipment must be properly grounded per Article 250 requirements.

Where to Make the Tap

The actual location of the tap will depend on the configuration and location of the existing service entrance equipment. The following connection locations have been used on various systems throughout the country.

On smaller residential and commercial systems, there is sometimes room in the main load center to tap the service conductors just before they are connected to the existing service disconnect. In other installations, the meter socket has lugs that are listed for two conductors per lug. Combined meter–service, disconnects–load centers frequently have significant amounts of interior space where the tap can be made between the meter socket and the service disconnect. Of course, adding a new pull box between the meter socket and the service disconnect is always an option. In larger commercial installations, the main service-entrance equipment will frequently have bus bars that have provisions for tap conductors.

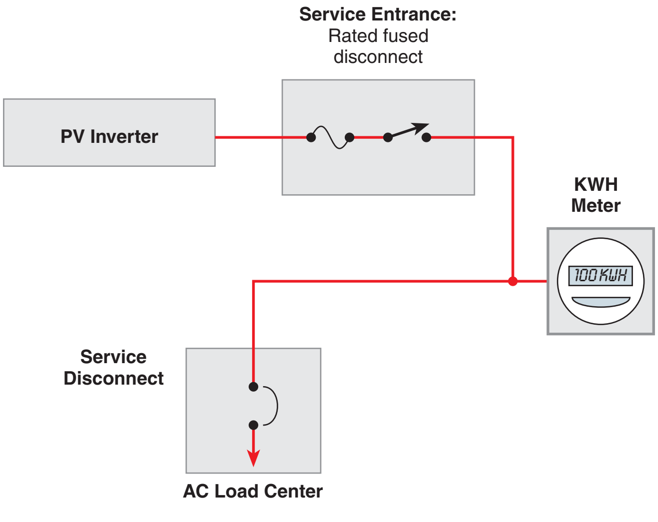
Be Safe

In all cases, safe working practices dictate that the utility service be de-energized before any tap connections are made. The utility company will have to disconnect and de-energize the electrical service to the house. In most cases, the meter will be pulled from the socket.

Additional service-entrance disconnect requirements in Article 230 and other articles of the *NEC* apply to this connection. An electrician with experience in installing service-entrance equipment should make these types of PV–utility interconnections.

The requirements of *NEC* Section 690.64 can be met in nearly all installations. While the requirements, at first glance, are somewhat complex and sometimes overlooked, attention to these details in the design, installation, and inspection of these systems should help to ensure a safe, durable, and code-compliant installation.

Supply Side of Service Disconnect



Questions or Comments?

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

Access

John C. Wiles, Southwest Technology Development Institute, New Mexico State University, Box 30,001/ MSC 3 SOLAR, Las Cruces, NM 88003 • 505-646-6105 • Fax: 505-646-3841 • jwiles@nmsu.edu • www.nmsu.edu/~tdi

Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices, a downloadable 144-page PDF manual • www.nmsu.edu/Research/tdi/public_html/Photovoltaics/Codes-Stds/PVnecSugPract.html

2008 *NEC* proposals PDF • www.nmsu.edu/~tdi/pdf-resources/2008NECproposals2.pdf

Sandia National Laboratories, Ward Bower, Sandia National Laboratories, Dept. 6218, MS 0753, Albuquerque, NM 87185 • 505-844-5206 • Fax: 505-844-6541 • wibower@sandia.gov • www.sandia.gov/pv

The 2005 *NEC* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA), 11 Tracy Dr., Avon, MA 02322 • 800-344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301 • custserv@nfpa.org • www.nfpa.org

Putting PV Modules *to the Test*

Don Loweburg

Photovoltaic (PV) system performance is a topic of crucial importance. From an installer's perspective, it is important to clearly communicate to the prospective customer what they can expect for their money. Also, most grid-connected solar-electric systems these days receive state assistance in the form of rebates, performance incentives, or tax credits. For state agencies administering these programs, it is imperative that they make sure the state is receiving full value for the funds expended. Understandably, they too have an interest in system performance.

There are many ways to represent system performance—for example, power output, efficiency, or tons of carbon dioxide (CO_2) avoided. Though these perspectives may have value, they are not fundamental quantities. Fundamentally, PV systems produce electricity. Electrical energy consumption and production is measured in kilowatt-hours (KWH). The KWH production of any given solar-electric system varies considerably from month to month over the course of a year. However, because the total annual amount of sunlight (solar energy) is nearly constant for a given location, the total yearly energy produced by a PV system varies little from year to year. Hence, the annual total KWH produced by a PV system is a good measure of its performance.

Have Data, Will Analyze

Many factors influence system performance. To better understand the issues affecting system performance, it is revealing to review the data now available that has been derived from a number of sources and installed systems. One comprehensive project by the International Energy Agency (IEA) is the "IEA PVPS Task 2 Analysis." Both the IEA's reports and raw data for more than 431 systems worldwide is available on the Internet (see Access). In addition to drawing from the data and conclusions of that study, two other systems in existence for ten or more years have been independently examined in detail.

The Arcata Study

The first system reviewed in detail was installed at a test site in Trinidad, California, in 1990 by the Schatz Energy Research Center, which is located at Humboldt State University in Arcata, California. Before installation of the PV modules in 1990, every module was tested. The initial testing revealed a problem that will be consistently exposed in most systems tested.

The study, titled "Comparison of PV Module Performance Before and After 11 Years of Field Exposure," shows that each module's actual power output, new and out of the box, was significantly lower than its nameplate rating. During individual testing of the 192 modules, the mean value of the maximum power (P_{max}) produced at normal operating cell temperature (NOCT) was about "14 percent below the manufacturer's nameplate rating." Though no initial performance figures measuring yearly energy output for the system were reported, it is clear that this array underperformed from day one.

When all modules in the system were retested in 2001, the average P_{max} at NOCT for the modules had decreased by 4.39 percent—an average of 0.4 percent per year, assuming a gradual decrease. This level of degradation over time is within acceptable limits for individual PV modules. There is, however, another issue that is revealed when the 1990 data is compared to the 2001 data. Though the decline of the average P_{max} at NOCT for all modules is acceptable, the variability or "spread" of values is not. This increased variability of module output decreases the overall performance of the system. The authors of the Arcata study state, "The histogram [on the facing page] showing the distribution of P_{max} at NOCT, indicates that the maximum power has decreased since 1990. The variability in maximum power within the modules has significantly increased as can be seen by the larger range of P_{max} values."

Significant variability of module P_{max} has a disproportionately negative effect on system output, well beyond expectations based simply on the reduced average value of P_{max}. The reason for this is that modules are wired in series, and in a series circuit, the weakest element predominates. Generally, the weaker modules end up being distributed randomly in the multiple strings of series-connected modules. One weak module in a string will reduce the entire string's output, and thus disproportionately reduce the system's output.

A System in Toledo, Spain

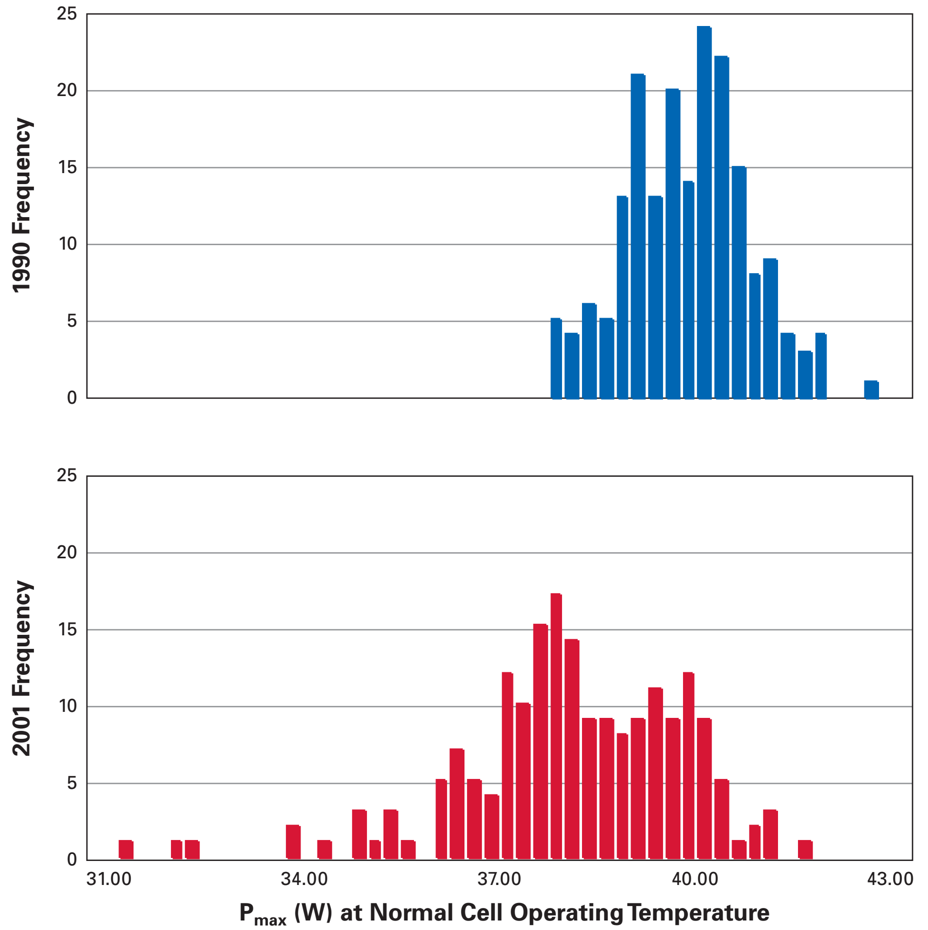
The second system to be examined in detail was reviewed in the November–December 2005 issue of *Renewable Energy World.* Titled, "Toledo, Ten Years On," the article examines the ten-year performance history of a 1-megawatt PV system installed in central Spain. Completed in 1994 and retested in 2004, module data and system performance were evaluated.

A total of 7,936 PV modules were incorporated in the array. The expected design output of the system was 980 KW. The authors state, "The first PV array peak installed power measurement taken in July 1994 showed 17.14 percent less power compared with the manufacturers' catalogue nominal values." Unlike the Arcata system, the modules were not initially evaluated individually. However, the poor system performance indicates less-than-specified module performance. In fact, earlier in the article, the authors, referring to the less-than-anticipated array output, report, "The difference can be explained by differences between manufacturer nominal PV peak power and the one supplied."

Ten years later, in 2004, the Toledo system was again evaluated. The array power output had declined 23.26 percent compared with the nominal design power, or 7.3 percent when compared to the initial installed power measurements. The 7.3 percent loss over the ten years in service is considered acceptable based on an assumed module power degradation of 0.5 to 1 percent per year.

Individual module testing also occurred during the period of retesting from 2002 to 2004. The project used modules manufactured by two companies. The PV modules were tested for P_{max}, and the power distributions obtained revealed that the average module power loss (as compared to the manufacturers' rated values) was 21 percent for one group and 15 percent for the other. Hence, module losses account for most of the 23.26 percent decline in total plant output power. Of course, there are other factors that can reduce system power. Dust, wiring losses, inverter efficiencies, and diode losses contribute to diminished system power over time. However, these issues are small when compared to the much greater effects of low module power.

Comparison of P_{max} Distribution 1990 & 2001



Data courtesy of Schatz Energy Research Center, Humboldt State Univ.

The IEA Study

The IEA study also supports these findings regarding module performance, as detailed in the Arcata and Toledo reports. From the IEA study, the author concludes, "There is a systematic deviation of minus 5 points to minus 15 points of the measured PV nominal power from the rated power specified in the data sheets by the manufacturer." To be fair, this conclusion is based on modules manufactured in the early to mid-1990s. The author adds in the conclusion, "As a consequence of these results, the manufacturers of PV modules have improved the accuracy of their module quoting with respect to STC performance during the last years."

The Results Are In

Today module ratings are tighter. The old standard of plus or minus 10 percent has been improved. Some examples of STC power ratings by several module manufacturers show a significant improvement (Evergreen, -2%; BP Solar, +/- 5%; Shell Solar, +/-5%; Sanyo, -10%; Kyocera, +10%/-5%). Two issues should be kept in mind.

1. The minimum rating is primary, since module string performance is dependent on the minimum, as discussed earlier.
2. System power estimates should be based on these minimums rather than the published average value of P_{max}.

System performance is dependent on many factors. Module performance is one of many technical and design–installation factors influencing system performance. The yearly energy output of a system depends on the complex interaction of these many factors. Maximizing system performance must be the goal of the PV industry. Studies such as those reviewed, especially the generous data presented by the IEA, allow us to constantly improve our understanding of system performance and correspondingly get more energy from every square meter of sunshine.

Access

Don Loweburg, IPP, PO Box 231, North Fork, CA 93643 • 559-877-7080 • i2p@aol.com • www.i2p.org

IEA PVPS Task 2 reports • www.iea-pvps-task2.org/public/index.htm

Downloadable data on hundreds of systems • www.iea-pvps-task2.org/database/

Schatz Energy Research Center, Humboldt State Univ., Arcata, CA 95521 • 707-826-4345 • Fax: 707-826-4347 • serc@humboldt.edu • www.humboldt.edu/~serc/ • www.humboldt.edu/~serc/papers/29thIEEEPVSC.pdf • “Comparison of PV Module Performance Before and After 11 Years of Field Exposure”

“Toledo, Ten Years On,” *Renewable Energy World*, November–December 2005 • www.renewable-energy-world.com

Nuclear Energy & Climate Change

Just Smoke & Mirrors?

Michael Welch

April 26 marks the twentieth anniversary of the catastrophic explosion of Reactor #4 at the Chornobyl Atomic Energy Station in northern Ukraine, and the effects of the disaster continue today. The accident was caused by human errors, made while working with one of, if not *the* most dangerous technologies ever invented.

We humans can be counted upon to make mistakes—but with nuclear plants, such errors can suddenly turn into giant catastrophes. People are still dying from the Chornobyl accident, and the greatest numbers of deaths still may be to come, as cancer from radiation exposure can take two decades or more to develop. But the impacts are not all human-centered—more than 17,000 square miles (27,359 km) of productive land was contaminated, and as tainted groundwater reaches the Dnipro River in the coming years, water supplies for millions will be at risk.

The event marked the decline of nuclear power plant construction in developed nations, due to increased public awareness and the resulting resistance to the dangers of this technology. In addition to power plant accidents and huge cost overruns, public concern also has centered on waste storage and transportation issues. More recently, fears have surfaced regarding terrorism and nuclear weapons proliferation. But as I reported a year ago, the nuclear power industry is pushing with all of its might for a resurgence—under the guise of slowing climate change, despite the fact that we do not need more nuclear power plants built. Further, if we (meaning us, our politicians, and our government) do a good job in making our homes and industries more energy efficient, we won't need to build more fossil-fueled power plants either.

Clouding the Issue

Once and for all, there is no longer any question about whether or not human activities are contributing to global warming. Even the current U.S. administration, which had previously denied the reality of climate change, has admitted that there is a problem. This seems out of character for politicians who have otherwise so staunchly supported the fossil fuel industry. So why the change of heart? I believe that the change in position is intended to help the administration's other friend, the nuclear power industry.

The global warming issue, combined with the questionable notion that we need more power plants, plays into the nuclear power industry's resurgence plans perfectly. U.S. Secretary of Energy Bodman fostered this impression, saying, "Another important way to meet our growing energy needs without depending on fossil fuels is expanding our use of nuclear power…nuclear energy is the only technology we currently have to reliably produce large amounts of electricity with no pollution or greenhouse gas emissions at all."

The nuclear energy industry would like you to believe theirs is the best solution, but what's the *real* deal with nuclear energy and global warming? According to the preface of a November 2005 report from the Heinrich Böll Foundation, an international nonprofit that promotes democracy, human rights, and a healthy environment:

> *Investing in nuclear energy carries not only considerable health, financial, and security risks, it may also prove to be a dangerous lock-in and dead end. Twenty years after the nuclear disaster of Chornobyl, any attempts by the nuclear industry to celebrate its revival and to paint itself as the solution to climate change should be rejected. Policy makers around the world should learn from its people, who largely resist the use of nuclear energy.*
>
> *…nuclear energy is no answer to climate change. A shortsighted renaissance of nuclear energy would require considerable amounts of public money, which should rather be invested in the development and deployment of renewable energy technologies and energy efficiency measures.*

The Böll Foundation report, based on respected studies, says that temperature increases caused by human activities should not exceed a total of 2°C (4.2°F) over pre-industrial levels, an amount which is "increasingly seen as a threshold for a magnitude of global warming which will lead to unacceptable consequences and risks for nature and human societies." The report also agrees with other studies, which state that global temperature increases should not exceed an average of 0.2°C (0.4°F) per decade. The Earth has already undergone a temperature increase of 0.6°C (1.2°F) since 1900, which leaves merely 1.4°C (3°F) until the threshold is hit.

Implausible Number of Nuke Plants

According to the possible scenarios examined in the report, and assuming "business as usual" with regard to global carbon dioxide (CO_2) emissions from fossil fuel combustion, it would take a three- to six-fold increase in nuclear power use over the next 50 years to avoid unacceptable global temperature increases.

Considering that existing, aging nuke plants will need to be replaced, the report states that three to four large nuclear power plants would need to be built every year to meet the goal of temperature mitigation. But the plants themselves are not the only required elements of such a plan. They won't run without fuel, and such an aggressive construction campaign would need to rely on finding uranium resources within a few decades. Past experience with extending uranium-mining capabilities makes that seem unlikely. It can take 20 to 30 years between uranium exploration and the start of production. And fifteen new fuel-enrichment plants would need to be built to provide enough fuel—triple the 70,000 tons (63,503 metric tons) of uranium now used annually.

The United States would not be the only country to increase capacity. The figures apply worldwide, which means that most small- to moderate-sized countries would need to use nuclear power, as well. That radically increases the possibility of nuclear weapons proliferation—which might add many countries to the "nuclear club" of atomic bomb ownership. It also greatly increases the possibility that other groups or individuals could either get their hands on "the bomb," or have the capability of using a dirty bomb against their enemies.

Beyond Nuclear—Efficiency First

The report states, "…the economics of nuclear power generation are decisive for the future role of nuclear power in the framework of an ambitious climate strategy. Without a price on CO_2 (either with a carbon tax or within the framework of an emissions trading scheme), it is unlikely that nuclear power could compete in competitive markets." In other words, for nuclear power to become affordable, it has to become very expensive for industries to emit greenhouse gases. Of course, giving huge subsidies to nuclear energy could make up for its high cost, if that is what our politicians support.

The Böll Foundation report compares other scenarios and their capabilities of decreasing CO_2 emissions. Energy efficiency is high on the list, including increases in manufacturing and building efficiencies, and efficiencies for power plants and end users. For example,

> *In total, a reduction potential of up to 16,000 Mt [million tons] CO_2 could be estimated for 2050 if comprehensive measures for the improvement of energy efficiency in the end-use sector were to be implemented. This is…40 to 60% of the gap between BAU ["business-as-usual"] and ambitious emissions reductions to enable a stabilization of CO_2 concentrations in the range between 400 and 450 ppm [parts per million].*

The report identifies the key problems with implementing energy efficiency on such a large scale as "the necessity of a steady phase-in and permanent efforts. Especially in the field of energy efficiency improvements, the step-by-step approach and an early start will be of much higher importance than certain technological breakthroughs. The long-living capital stock, e.g. in the building sector, will require early action to use the existing windows of opportunity."

End-user awareness and motivations are important factors in achieving significant reductions in energy use. These are largely social, rather than economic issues. Relying on market-based motivations to improve energy efficiency will create large delays in implementation. The government must step in to give efficiency and conservation the boost it needs to slow global warming—a very difficult task in the current political climate.

States Take the Reins

The report is clear that renewable energy can play a big role in avoiding an unacceptable global warming scenario. But it also makes it apparent that impending advances are still needed to implement utility-scale renewable energy:

> *…the key barrier for a broader use of renewables is their economic competitiveness. Besides hydropower and some options of biomass use, most technologies for power generation from renewable energies are in an early stage of development. If research and development is intensified and early market introduction is continued, a significant cut in costs is assumed.*

Once again, government must step in to make sure the advances happen soon—the economy-based market incentives that motivate businesses to step up to the plate will probably not materialize until the situation has passed the crisis stage—possibly too late.

In the United States, states are stepping up where the feds are not, though the 2006 federal tax credits are a nice incentive. The California Public Utilities Commission approved an ambitious, ten-year, US$2.8 billion rebate program for the installation of residential and commercial solar energy systems. Hawaii is moving forward with a comprehensive energy bill that will radically reduce its dependence on imported oil and take advantage of island-based resources, while promoting conservation and efficiency measures.

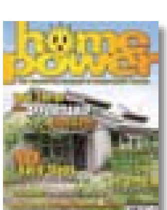
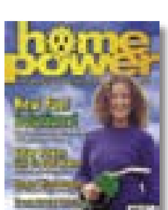
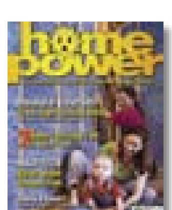
These are only two examples out of many that show how state governments are stepping up to meet pressing energy issues. Efficiency, paired with current and developing renewable technologies, can and must be an important part of our energy production. We, as citizens, must also step up. That means addressing our own energy use habits, and saying, "Yes!" to renewable energy. And, just as importantly, it means saying, "No," to nukes. Nuclear energy cannot contribute significantly to help with climate change—not now, not ever.

Access

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

Heinrich Böll Foundation, Heinrich Böll Foundation, Hackesche Höfe, Rosenthaler Str. 40/41, 10178 Berlin, Germany • 30-285-34-0 • 30-285-34-109 • info@boell.de • www.boell.de • A PDF of "Nuclear Energy and Climate Change" can be downloaded from the Promised Files section of www.homepower.com

"Chornobyl+20: Remembrance for the Future" conference in Kyiv, Ukraine, April 23–25, 2006, will commemorate the twentieth anniversary of the Chornobyl catastrophe, bringing together independent scientists, environmentalists, sustainable energy experts, and a public audience for a new examination of the 1986 Chornobyl accident's continuing health, social, and economic consequences, and drawing new attention to the promise and need to implement sustainable energy technologies. Info: Tetyana Murza, Ecoclub • 380-362-237-024 • tanyam@nirs.org • www.ch20.org


+

+


Photons

Packets of Energy from the Sun

Ian Woofenden

Derivation: From Greek photo-, *"light," and* on, *"unit." The word "photon" was proposed by chemist Gilbert N. Lewis in a letter to* Nature *magazine in 1926.*

One of the long-standing debates in science is whether light is a particle or a wave. Isaac Newton theorized that light traveling from the sun is particles. Dutch astronomer Christiaan Huygens believed that light is made up of waves.

Albert Einstein and other scientists' conclusions combined Newton's and Huygens' theories, proposing that light comes in small packets of energy that share characteristics of both particles and waves. He showed that each of these characteristics may be observed depending on the context. While energy appears to be transmitted from the sun via electromagnetic waves, when it comes to phenomena like light, those waves seem to be made of particles.

Trying to visualize this is the same as trying to visualize any physical process—our mental models may help or hinder us. *Home Power* publisher and renewable energy guru Richard Perez says, "In reality, neither explanation represents 'truth.' Both are merely descriptions based on our limited point of view. All particles—protons, electrons, photons, gravitons, mesons, bosons, magetrons, and the remaining huge list—are fictional entities that we use to describe disturbances or anomalies in space and time. While we can manipulate energy, we really don't have a clue as to what it really is."

Fortunately, the sun works, whether we understand the physics behind it or not. On Earth, the energy we use on a daily basis comes from the sun, and photons, these mysterious light particle–wave entities, are the delivery vehicle. How they are received on Earth affects us and how we use the energy.

Even fossil fuels are the result of photon energy from the sun. The process of photosynthesis (from the Greek words for "light" and "bringing together") uses the sun's energy to combine carbon dioxide from the air, and water from the soil into food to grow plants. Ancient plants received solar energy, just as today's plants do. As these plants decayed and were trapped under layers of sediment, the pressure and heat of overlying layers of earth transformed them into fossil fuels. When we use these fuels, we're tapping this stored solar energy. But these resources are limited because they take eons to form, and using them results in air, soil, and water pollution.

Using renewable energy technologies is a much cleaner way to use the sun. With photovoltaic (PV) panels, photons bump electrons in a solar cell into an electrical circuit, satisfying our need for electricity. With solar hot water panels, the sun's energy is absorbed by dark materials, increasing the vibration of the molecules, which we experience as heat. This same process can heat our homes directly through passive solar design or through solar air collectors. Solar heat energy in the earth is also used by ground-source heat pumps—a very efficient home heating system.

The same reception of photons and conversion to heat drives a couple of other energy forms here on Earth—wind and hydropower. The sun's energy heats the land, which in turn heats the atmosphere. This heating is uneven, due in part to the unevenness of the Earth's surface. So some places are hotter than others, and this creates differences in air density. In the end, this causes wind, which can be tapped for electrical and mechanical energy.

The sun also drives the hydrological cycle, evaporating water from oceans and lakes, where it rises into the sky and condenses to form clouds. Clouds then drop the water as rain or snow, creating streams and rivers, which eventually return to the ocean to be evaporated again. This falling water is a particularly potent and reliable source of energy, and renews itself continually.

The sun's energy travels 92.9 million miles in about 8.3 minutes (186,282 miles per second). About half the energy aimed at the Earth reaches its surface, with the rest being reflected, blocked, or absorbed by the atmosphere. According to a July 1999 article in *Science* magazine, a square of PVs about 100 miles (161 km) on a side could have satisfied the electrical energy needs of United States that year.

Although this is a large area (roughly the size of Massachusetts), it is less than one-quarter of the land that is covered by impervious surfaces like roads and parking lots. If wind energy is part of the mix, the needed space for PV shrinks. If geothermal energy is also tapped, the space needed for PV shrinks again, and shrinks even further if hydroelectric energy becomes part of the equation. The point is clear—we can gather more than enough renewable energy to power our society. The sun is doing the hard work, and we just need to be clever about collecting a few packets of energy from it.

Access

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

Thanks to Bill Beaty, John Perlin, David Sweetman, and others for inspiration and assistance on this column.

Reefer Madness

Kathleen Jarschke-Schultze

Bob-O and I bought my Sun Frost RF16 around the end of 1991. It replaced a small, old Servel propane refrigerator named Harold. Harold came from our previous home on the Salmon River. He resided on the enclosed porch with his mate, Sylvia. They were perfect together. His door was hinged on the right and her door was hinged on the left.

Harold did not take the move to our present home on the creek very well at all. We had to turn him upside down on his head for a couple of hours and burp him before he would work at all. He had what we laughingly called an "icebox." Only large enough to hold six ice cube trays, it never was able to actually freeze them. Harold was very old and worn out.

Clear, plastic bins maximize storage efficiency in this energy saving Sun Frost fridge.

Replacing Harold

My Sun Frost RF16 refrigerator/freezer (16 ft.^{3}; 0.45 m^3) was a breath of fresh air. By comparison, it is incredibly roomy. It has three large glass shelves in the main compartment and three shelves on the door. It has a separate freezer with one small half-shelf and another shelf on the door.

The whole unit sits on a two-drawer, 13-inch (33 cm) stand that has a Hedgerow Green Formica surface and aluminum trim to match the refrigerator. I keep all my pot and pan lids in one drawer, and all my plastic food storage containers and lids in the other. Two compressors are positioned on top of the appliance—one is for the reefer and one for the freezer. Each is separately adjustable.

Whenever our business clients come to our house to look at our renewable energy system, they always ask to see my appliances. That means the RF16, the dishwasher, and propane stove upstairs and the Sun Frost F10 freezer, the propane dryer, and super-efficient washing machine in the basement.

Shelf Life

You know that cooking magazine interview question: "What three things are always in your refrigerator?" My answer would be: Pecorino Romano cheese, Poupon mustard, and a biology experiment growing a beard, lost in the back somewhere.

My biggest problem with the Sun Frost was the fact that the glass shelves are just that—flat, glass shelves. Too many times, I have lost track of some food item and found it again when it was too late. I decided to fix this.

I went to a local discount store and purchased some inexpensive, plastic hobby drawers. Each had its own white plastic shell and a translucent plastic drawer. I bought eight drawers that were 15.5 by 8.5 inches (39 x 22 cm) and two that were 18.5 by 11.5 inches (47 x 29 cm).

I took out all the glass shelves and all the little shelf brackets that hold the shelves in place. I put the two largest drawers on the floor of the unit, and I topped that with a glass shelf. I placed three of the smaller drawers on that glass shelf and topped it with the second glass shelf. I repeated this with three more of the smaller drawers and the last glass shelf. This left enough height on the top glass shelf to place gallon jugs on it upright. I put the remaining two small drawers in the freezer compartment.

Top Drawer

Boy, it was great. I had drawers I could pull out and actually see what was in the back. I had a cheese drawer, a salad drawer, a vegetable drawer, and miscellaneous drawers. Next, I got a Styrofoam egg carton. I cut the top off, placed it under the egg-cup part, and set that into the top shelf on the door. Ta da! I had an egg holder. I felt pretty victorious and clever.

Then I started to notice an ice buildup on the back wall of the refrigerator. The drawer shells were backed up against the wall and not allowing the RF16 to perform as it was designed to. I bought an indoor–outdoor thermometer and taped the outdoor probe inside the RF. As the ice grew on the back wall, the unit became less efficient and less cold.

But I loved the drawers. I resigned myself to emptying the fridge every month and cleaning the ice buildup off the back wall. This last summer, Bob-O noticed the reefer compressor was running a lot (we were on our summertime low-watt diet). He turned up the thermostat on the refrigerator so it wouldn't run so much. The next time I glanced at the recording thermometer, the inside temperature of my refrigerator was 45°F (7°C). Yikes! Yikes again!

I told Bob-O, "You have your tools and I have mine. This is my tool—leave it alone." The important thing here is that our food stay under 40°F (4.4°C), by several degrees preferably.

I had talked to Larry Schlussler at Sun Frost sometime before, and he had suggested that I put the temperature probe into a glass of water so it would not be so sensitive to temperature changes when the door was opened. I did that. I keep the reefer temp between 34 and 38°F (1.1–3.3°C).

Reefer Gladness

So I was lying in bed, almost asleep, when I had a refrigerator epiphany. Why not take the translucent drawers out of their white plastic shells and just set the drawers on the glass shelves? No good reason I could think of.

The next day, I emptied the reefer. After cleaning the ice off the back wall, I put the shelf brackets back in to hold the glass shelves. I put in all three glass shelves at once. I slid the drawers back into their old positions, sans shells.

This is working for me. I can actually put more food and vegetables into the drawers because of the added headroom. I can slide packages of tofu and carrots between the drawers. There is still enough room on the top shelf to put gallon jugs upright. Because the shells are removed, the drawers do not rest against the back wall. The Sun Frost is back to its previous efficiency level.

I still have two small drawers in the freezer. I use one drawer to empty ice cube trays into in the summer. That way I always have ice at the ready. I left the freezer drawers in their shells because the single half-shelf was too limiting. Piling the frozen food on the shelf was okay as long as the packages were flat, but uneven food packages would fall out the door when I opened it.

As a result, I do have to clean the ice out of the freezer once in a great while. It would be a rare freezer, indeed, that had no ice buildup. One thing that helps is to not stand there with the door open for a long time. Letting air into the freezer stimulates the ice forming. The Sun Frosts are not "frost free." Including a frost-free feature in a freezer is terribly energy inefficient, since a built-in heating unit is what keeps ice from forming. The heating unit also changes the temperature of the food closest to the back wall, hastening freezer burn.

Cool Door Latches

My older model RF16 had black, plastic click-locks on the doors. The new Sun Frosts have a really cool magnetic catch to close the doors very snugly. Now there is a retrofit door magnet for older models like mine. I ordered two. They are US$15 apiece and available directly from Sun Frost.

I got out my trusty, floral-handled multi-tool and installed one of the magnetic door catches in the reefer part of my RF16. My old plastic door-catch used to click when it shut. I didn't realize how trained I was to listen for that click, until I didn't hear it. Now as I close the reefer door and walk away, I find myself turning back to make sure it has shut. Even though the magnetic catch is silent now, the door is always tightly closed. My next project is to change out the catch on the freezer compartment.

Old Dogs, New Tricks

Although my Sun Frost RF16 was a great improvement over old Harold, I found I could customize it to my own preferences. All things change; that is a universal truth. We just hope they change for the better. My refrigerator has.

Access

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

Sun Frost, PO Box 1101, Arcata, CA 95518 • 707-822-9095 • Fax: 707-822-6213 • info@sunfrost.com • www.sunfrost.com

Mailbox

Passing the Wrench

Howdy *Home Power*, After 25 years of operating Harris Hydroelectric, often alone, and longing somewhat for my hippy-esque roots, the time has come to pass the wrench to new blood.

Beginning February 1, 2006, all sales and service of the turbines will be through Dennis Ledbetter of Lo Power Engineering (707-986-7771), a separate business. Most of you already know him from his years at AEE. He has been building and siting hydro systems for years.

I will continue to be involved in manufacturing R&D and will provide technical support. I will continue warranty and upgrades on PM systems that I have built.

Since making my first waterwheel in 1981, the renewable energy industry has grown from a few eccentric "back to the landers" living in tipis and cabins, to a force that has the potential to save the world from the destructive path of oil addiction and nuclear power.

I am not going away. Expect interesting developments in new and exciting ways to extract power from water, air, and heat. I'll have more time to inject myself into the debate on energy policy.

As earlier indicated, feel free to call on hydro questions in general, our systems in particular, or just as old friends. See you at the fairs,

Don Harris • Davenport, CA

Solar Living Center Seeks Help

Dear *Home Power*, As many of you already know, the Solar Living Center in Hopland, California, was hit by the worst flood in more than 50 years on December 31. While fortunately, our interns were able to be boat-rescued from the site, the devastation to the site from being 8 to 10 feet under water for many hours is staggering. The geodesic dome that housed the interns burned to the ground, destroying their personal property, their living quarters, and their kitchen. Five vehicles were submerged and destroyed, including a tractor. All of the natural buildings on site were damaged. Archives, tools, sustainable living workshop materials, furniture, and personal property were destroyed. The landscape, fences, dock, and road all suffered damage. We estimate a minimum of US$150,000 in direct damages was done to the site (not including the Gaiam Real Goods inverters that were destroyed with the shipping container submerged).

Flood and fire at the Solar Living Institute.

The good news is that no one was hurt. The bad news is that our flood insurance does not cover any of the damage. Our nonprofit needs to rebuild and get back on its feet. For anyone feeling generous, the Solar Living Institute needs your help now more than ever to get back on its feet, and donations will be heartily appreciated. To donate online, go to www.solarliving.org/flood.cfm. Of course, all donations are fully tax deductible. Thank you in advance for your generosity!

Doron Amiran • Hopland, CA

Saving Energy

Dear *Home Power*, I want to thank you for the great information that anyone can get from your publication, from just saving money on your utilities to full-blown renewable energy system analysis. I have been reading the magazine for more than a year now, and have gained a wealth of knowledge, and still have lots more to learn. From reading *Home Power*, I have been able to get my utility bills at my apartment down to about US$40. My electricity bill is now less than US$10 a month, at 60 KWH a month. I did this by switching all lights to compact fluorescents, by making sure that all phantom loads are unplugged when not in use, and by setting the temperature in my fridge correctly so it doesn't waste electricity.

As for my gas bill, that runs around US$31 a month. This winter, I wrapped all of my windows to keep cold air infiltration down and, at the same time, give a bit of R-value to these windows. The thermostat is rarely ever turned up above 55°F, since I always open the drapes in the morning and the sun heats the apartment from about 57°F to 75°F before noon. Once the sun is done for the day, I close the drapes and lock in the heat. The apartment stays warm all day and into part of the night. I keep the thermostat at 55°F through the night, and if I get cold I just switch on an electric blanket, which is a lot cheaper than heating the whole house.

The only waste of gas that I have is that all the gas appliances run on pilot lights—the stove, the water heater, and the furnace, which is an old oil burner converted to natural gas. Unfortunately, I cannot persuade the apartment complex to put in more energy efficient appliances, so this is great for what I have accomplished so far. Thanks again for all the guidance that you have provided me and the masses, and keep up the great articles and reviews of new and upcoming ideas and products.

Richard Cullen • Riverside, NJ

Teaching by Example

Hello *HP*, I remember the day I called and placed my order for the magazine. As an avid *HP* reader, I have been informed and educated in the ways of RE. As a high school shop teacher (now it's called "consumer technical education"—CTE), I love to learn and pass on knowledge to students

Students and teachers see the light.

and fellow teachers. My goal is to have 100 percent of the teachers in Wisconsin have at least one compact fluorescent (CF) bulb in their home. So far, I have the Darlington high school teachers "enlightened," and now I'm moving on to the middle school.

In the picture, you can see one of my fellow shop teachers Mr. Dinges (far right), using the ol' convincer to inform his students about CFs. We have incandescent and compact fluorescent bulbs hooked to a Brand Electronics power meter to show how wasteful incandescents are. Seeing is believing. Who knows, maybe the students will challenge the teachers to become "enlightened" by installing CFs in their homes. Changing the world one bulb at a time,

Dick Anderson • Darlington, WI

RE for Hurricane Relief

Living in Florida and having experienced more than one hurricane close call has given me a new perspective on renewable energy sources. I do everything I can to promote renewable energy. I probably drive my colleagues at work crazy, or at least some think I am a nutcase. I keep a steady flow of e-mail and letters going to my state and federal representatives, though I have little hope any of them will listen. But I am very persistent, so who knows.

I believe the solar industry in particular missed an incredible opportunity to promote this source of energy. Hurricane Katrina wiped out the utility grid for weeks on end in some areas. This would have been a great time for solar energy suppliers and installers to loan or donate systems to the areas involved. Even now, I think some portable solar-electric systems would be useful for powering cleanup and rebuilding. I wonder how many homes might have been saved if solar-electric systems had been rushed in to help with water pumping.

In the future, I hope that renewable energy sources will be used more extensively after natural or other disasters. Each time utilities are disrupted, there are news stories of people becoming trapped in elevators, hospitals without emergency power, and so on. This makes no sense to me. Solar and wind electricity would be ideal to power backup systems. I hope renewable energy suppliers and installers will use future events to promote renewable sources and make the public (and officials) aware that the technology is economical and reliable. Sincerely,

Richard J. Molby • Tampa, FL

Dust Duty

With dusty conditions and sandstorms here in Iraq, we have to clean our panels weekly.

Harv Ortiz • somewhere in Iraq

Sand and solar?

Insulating Windows

Dear *Home Power*, I read your article on insulation basics and found it very helpful and informative. The thing you brought up only in passing is the importance of sealing and proper ventilation—both equally important for a healthy, comfortable, efficient home. The other issue I wanted to point out is the importance of insulated shading. It isn't nearly so important to have R-30 walls if 75 percent of the wall is glass—even if you spend extra and get triple-pane, low-E, krypton gas-filled windows. This still gives a whole-wall R-value of 10 or so (depending a lot on particulars). If you got "tight," double-paned, low-E, argon gas-filled windows and added insulated shades, the whole-wall R-value could be as high as 20 or more, and cost a lot less (again, depending on particulars).

An article on insulated shades (*not* curtains) and the amazing difference in total house comfort and energy use would be a great service to your readers. Even here in Alabama, insulated shades are one of the most cost-effective ways to seal up the last big leak—windows. It helps that my wife and I made the shades ourselves after reading some about the technology at the Humboldt State/CCAT Web site (after following the link from the *Home Power* Web site). The best references on insulation and smart building I've seen are from ACEEE. You might make those references available to interested readers, since this is an extremely important topic! Thanks—keep up the great work!

John Morris • Cullman, AL

Dear John, Thanks for your good comments. You're absolutely right—finding and sealing leaks (such as around windows and doors), and ensuring that your home has an adequate air exchange rate for good air quality is very important. In fact, each of these topics could easily be a stand-alone article.

With any wall system, the whole-wall R-value depends on many factors, including the number of windows installed in the wall, the construction type and thickness of the framing members (for example, whether you use 2 by 4 or 2 by 6 studs), and the spacing of the studs (which influences the amount of thermal bridging that occurs). As you point out, the thermal performance of a wall that is taken up mostly by windows will *be very different than a wall without any windows, due to the difference in the thermal resistance of or heat transmission through the materials. (Those interested in seeing how changing these variables influences whole-wall R-values can check out Oak Ridge National Laboratory's interactive online calculator at: www.ornl.gov/sci/roofs+walls/AWT/InteractiveCalculators/rvalueinfo.htm.)*

Your suggestion of using draperies and insulating panels to mitigate heat loss (and gain) through windows is an excellent strategy. According to the Department of Energy's Office of Energy Efficiency and Renewable Energy, using conventional draperies can reduce heat loss from a warm interior space by up to 10 percent. In addition to closing all draperies at night, the EERE also recommends closing all draperies on windows that don't receive sunlight during the day. Hanging draperies as close to the windows as possible, letting them fall onto a windowsill or floor, and sealing them at the sides and center (using magnetic tape or Velcro) may help reduce heat loss by up to 25 percent.

Specially designed, insulated shades are also available through several distributors. I'm most familiar with the Warm Window thermal shades (www.warmcompany.com; also available from www.cozycurtain.com). These shades incorporate four layers of insulated fabric and a magnetic edge strip to secure the edges of the shades to the window frame. According to company claims, a Warm Window shade over a single-pane window boasts an R-value of 7.69. You can order custom shades or buy a kit from the companies listed above. Or, as mentioned, you can download instructions for making your own at the Humboldt State University's Campus Center for Appropriate Technology at www.humboldt.edu/~ccat/energyconservation/index.html.

Another strategy is to use insulating window panels, which can have R-values ranging from 3.8 to 7, depending on their thickness. These panels, which typically consist of a core of rigid foam insulation, are inexpensive, and easy to make and install. Their two small drawbacks are that they block out most, if not all, incoming light (if you're using them during the day) and take up storage space when not in use. Thanks for reading,

Claire Anderson • Home Power

Prius Mileage

I am being bombarded with new articles claiming that the Toyota Prius' stated mileage is erroneous beyond belief. I have asked three Prius drivers if the mileage they are getting measures up. One said yes, one no, and the other one had no idea. I understand that anyone can drive so poorly that they make a hash out of any promised mileage, but I need feedback from one of the few groups I would trust on this matter, and that's you and yours at *Home Power*. What is the truth? Thanks.

Sel Gossett • Jax, FL

Hi Sel. Your letter brings to mind the old caveat that is applied to many things these days—YMMV (your mileage may vary). This is from the "Wise Driving" article in HP111:

"When I bought my hybrid electric car, a 2001 Toyota Prius, the mileage estimate on the highway was 45 mpg (19 km/l) and the city estimate was 52 mpg (22 km/l). I expected an average mileage about halfway between, perhaps 48.5 mpg (20.6 km/l). This year, at the beginning of spring, I reset the mileage meter, and in the 5,880 miles (9,463 km) I have put on since, I have averaged 58.5 mpg (24.9 km/l). My car is not special. When I loan it to other people, they get the estimated mileage or worse. My message: These cars can deliver their EPA-rated mileage and sometimes more, but drivers must do their part. And this is true for all vehicles, not just hybrids. My Prius seems to get its best mileage at speeds below 50 mph (80 km/l), possibly even below 40 mph (64 km/l)."

I hope that helps a little, and I hope you'll read the whole article, which is full of tips on how to maximize your fuel efficiency.

Michael Welch • Home Power

High Voltage Danger

Dear Richard Perez, As a hands-on PV person, I enjoyed your article about troubleshooting PV systems using digital multimeters (DMMs; also sometimes called digital voltmeters, DVMs) in *HP110*. Let me relate a recent experience that I had and offer a word of caution.

I and another engineer were testing a 75 KW PV system that had less-than-expected performance. I finally traced the problem to unequal current from the various strings. I was checking the string current in a string that was operating at 340 volts and about 6 amps. These ratings were well within the capabilities of my Fluke 189 DVM, and I was using the internal ammeter function of the DVM to check the string short-circuit current.

Since DC arcs maintain themselves for a considerable time and are hard to extinguish, I was *very quickly* applying and removing the DVM probes to the string output terminals in a combiner box to minimize the arc and any subsequent damage to the probe tips or terminals.

At one point, this "modest" current and voltage drew a 4-inch vertical arc for a fraction of a second as I pulled the probes off! The arc was longer than normal due to the heating effect and vertical orientation (remember the Jacob's Ladder from high school science lab?). As the arc formed, I had visions (panic attack?) of it jumping to the grounded combiner case and destroying the combiner. It finally went out as the probe moved farther from the terminal.

It occurs to me in hindsight that I could have thrown myself across a nearby module to cut off the current and extinguish the arc if things had gotten out of hand. From now on, when we measure module or string current where voltages are much above 100 volts, we connect a properly rated DC safety switch (disconnect) in series with the DVM leads and the string terminals, and let the safety switch make and open the connection. This places the DC arc in a location designed to handle it and safely extinguish it.

John C. Wiles • Las Cruces, NM

Anderson Connectors

Hi Ian! You mentioned "Anderson connectors" in passing in your column in *HP111*, but then didn't bring them up again! I use them almost exclusively for my low-voltage DC connection needs. The Amateur Radio Emergency Service (ARES) promotes a standard of "red on the right, with large part down" so that amateur radio operators can quickly swap gear and power during emergencies. Fixtures with these arrangements are readily available, albeit somewhat pricey. Here's one source: www.powerwerx.com. I think these should be promoted as the preferable solution. The weight of tens of thousands of amateur radio operators should be enough to make this an attractive alternative.

One can easily make (or buy) a cigarette adaptor, or do as I do and immediately lop off those abominations and solder on a pair of Anderson connectors as soon as I get the item home from the store! (Well, if it's expensive, I wait until the warranty expires to avoid any balking on warranty service.)

I have a total of sixteen Anderson outlets in my vehicle, and the first thing I do to a new vehicle is surreptitiously hang one down from behind the dashboard—preferably wired directly to the battery with #10 wire and a 40 A fuse!

Anderson connector.

Jan Steinman • West Linn, OR

Hi Jan, Anderson connectors are a good option for many homebrew DC applications. They are sturdy and fairly safe. I'm not sure they are the dream receptacle I'm wishing for, but they could be a contender. Thanks for the information, which I'm sure will be of use to some readers.

Ian Woofenden • Home Power

Wasteful Lifestyle

Dear *Home Power*, I read the article on the student solar home project, "Solar Innovation at the Capitol" in *HP111*. "To get the most points, the teams had to emulate the typical American lifestyle of turning on loads on a schedule not affected by the climate or weather."

Doesn't the typical American use lots of energy only because it has been cheap and usually subsidized? Why does the Department of Energy wish the student architects to assume Americans are like chronic drunks who can't stop gulping more electricity than they need?

We have an off-grid house with 400 watts of PV. That is a lot different than the 4,000 or even 12,000 watts the contestants used, even given that our home is in sunny New Mexico. Why were there no clotheslines in the pictures?

Steve Baer • Albuquerque, NM

Hey Steve, I live off grid with 700 watts of PV, and I hear what you're saying. The article sidebar on page 17 talks a bit about why the arrays were so large at the Decathlon. Basically, they were designing for full autonomy, and could not shed loads due to weather like we do with our off-grid systems. The teams were also penalized if they used generators.

I was in Washington, D.C., at the Solar Power 2005 conference, and had a chance to spend some time touring the Decathlon demonstration homes. While the specific rules of the competition don't reflect the reality many of us would like to see in terms of energy consumption, I did leave the site feeling inspired and impressed by the systems that the students put together. The coolest thing was that all the homes were designed from the ground up, with a complete system approach in mind. That sure doesn't happen enough. Best,

Joe Schwartz • Home Power

YOUR HOME CAN CAUSE TWICE AS MANY GREENHOUSE GASES AS A CAR.

Discover steps you can take to reduce air pollution from your home and car at **energystar.gov.**

ENERGY STAR® is sponsored by the U.S. Environmental Protection Agency and the U.S. Department of Energy.

ENERGY STAR

RE happenings

INTERNATIONAL

Internet courses: PV, green building & intl development. Solar On-Line (SóL) • 720-489-3798 • info@solenergy.org • www.solenergy.org

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

CANADA

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

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

CHINA

Jun. 28–30, '06. Beijing. Wind Power Asia 2006. Wind energy conf. & exhibition. Info: Unique Intl Exhibition Ltd. • 86-10-88-145-170 or 86-10-88-145-171 • sonya.xia@windpowerasia.com • www.windpowerasia.com

GERMANY

May 16–19, '06. Hamburg. WindEnergy 2006. Intl trade fair. Info: www.windenergy.de

Sep. 4–8, '06. Dresden. European PV Conf. & Exhibition. Info: WIP-Munich • 49-89-720-12-735 • pv.conference@wip-munich.de • www.photovoltaic-conference.com

NEPAL

Kathmandu. School of Renewable Energy Ltd. • 97-701-424-4003 • sre@nepalmail.com • www.sre.org.np

NICARAGUA

Jun. 30–Jul. 11, '06 (again Jan. 8–19, '07). Managua. Solar Cultural Course. Lectures, field experience & ecotourism. Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

RUSSIA

Apr. 26, '06. Moscow. Day of Science. Science & technology forum, including RE. Info: Leonid Gavrilov • 7-095-299-3366 • leo@ngoclub.org • www.ngoclub.org

SCOTLAND

Jun. 7–9, '06. Crieff. Hidroenergia '06. Info: European Small Hydro Assoc. • 01-202-886-622 • info@british-hydro.org • www.british-hydro.org

SPAIN

Jul. 12–16, '06. Granada. Solar Cookers & Food Processing Intl Conf. For researchers & practitioners. Spread access to solar cooking, water purification & solar food processing. Info: Terra Foundation • solar@terra.org or Solar Cookers Intl • bev@solarcookers.org • www.solarconference.net

UKRAINE

Apr. 23–25, '06. Kyiv. Chornobyl+20: Remembrance for the Future. Intl conf. on the nuclear accident. Info: Tetyana Murza • 380-362-237-024 • tanyam@nirs.org • www.ch20.org

U.S.A.

Info on state & federal incentives for RE. NC Solar Center • www.dsireusa.org

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

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

ARIZONA

Apr. 29, '06. Tucson. Tucson Solar Potluck. Bring solar oven &/or bring a dish. Music, food, PV demo, solar fountains & kids' activities. Info: 520-885-7925

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

ARKANSAS

Jun. 21–25, '06. Fayetteville, AR. 2006 Solar Splash. World championship of solar and/or electric boating. Displays, solar slalom, sprint & endurance events. Info: Fayetteville Visitors Bureau • 800-766-4626 • www.solarsplash.com

CALIFORNIA

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

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

COLORADO

Aug. 7–14, '06. Paonia, CO. Camp-Us, RE camp for teens. Discover relationships between energy, nature, spirit, technology & social diversity. Hands-on activities, lectures & recreation. Info: 970-921-5529 • hareef99@yahoo.com • www.youthcamp-us.org

Sep. 16–17, '06. Fort Collins, CO. Rocky Mt. Sustainable Living Fair. Exhibits, workshops, RE, alternative fuel vehicles, planet youth, food & more. Info: Rocky Mt. Sustainable Living Assoc. • 970-224-FAIR • kellie@poudre.com • www.sustainablelivingfair.org

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

FLORIDA

Apr. 22, '06. Melbourne, FL. Florida Solar Music Fair. Solar- & wind-powered music, renewable & sustainability displays, speakers & exhibits. Info: Green Campus Group • hrobinson@fit.edu • http://my.fit.edu/~fleslie

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

ILLINOIS

Apr. 21–22, '06. Bloomington, IL. Illinois Sustainable Living & Wellness Expo. Workshops & exhibitors, incl. RE, green building & simpler living. Info: Center for Sustainable Community • 815-256-2204 • csc@stelle.net • www.centerforsustainablecommunity.org

IOWA

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

MICHIGAN

Dimondale, MI. '06 RE workshops. Apr. 1 & May 13: Intro to RE; Apr. 8 & Jun. 3: Intermediate Solar Heating; Apr. 24–28: PV Apprentice Training; May 6: Intermediate Wind; Jun. 21–23: System Integrator Certification Course. Info: see GLREA below.

Jun. 16–18, '06. Onekama, MI. Michigan Energy Fair. Exhibits, vendors & workshops on green building, solar architecture, wind energy, energy efficiency, alternative fuel vehicles & more. Music & food. Info: Great Lakes RE Assoc. • 800-434-9788 • info@glrea.org • www.glrea.org

MISSOURI

Apr. 10, '06 (again May 29, Jul. 15 & Jul. 16). New Bloomfield, MO. Wind power, PV, dome housing, greenhouses, hydrogen & more. Mid-America RE Center, 9810 State Rd. AE, New Bloomfield, MO 65063 • 800-228-5284

MONTANA

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

NEW HAMPSHIRE

Apr. 8, '06. Plymouth, NH. Waste Veggie Oil Conversion workshop. Info: see listing below.

Jun. 17, '06. Dorcester, NH. Solar Workshop. Home heating, PV, SDHW & solar cooking. Info: D Acres of NH • 603-786-2366 • dacres@cyberportal.net • www.dacres.org

NEW MEXICO

Apr. 21–23 (again 29–30), '06. Albuquerque, NM. PV Design & Installation for Women. Siting, sizing & safely installing a PV system. Tours of PV systems, hands-on labs & an installation. Info: NM Solar Energy Assoc. • 505-281-0471 or 888-886-6765 • marymac@hubwest.com • www.nmsea.org

May 26–28 (again Jun. 3–4), '06. Albuquerque, NM. PV Design & Installation Co-Ed. Description & info: see above.

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

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

NEW YORK

Apr. 10–14, '06. Olivebridge, NY. PV Design & Installation course. Info: see SEI listing for Colorado.

Apr. 17–21, '06. Olivebridge, NY. Advanced PV course. Info: see SEI listing for Colorado.

Jun. 21–22, '06. New York, NY. RE Finance Forum. For bankers & investors. Info: ACORE & Euromoney Energy Events • www.euromoneyenergy.com

NORTH CAROLINA

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

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

OHIO

Sep. 30–Oct. 1, '06. Athens, OH. Athens Area Sustainability Festival. Workshops on alternative building & energy & sustainable living lifestyles. Arts & crafts, music & children's program • 740-674-4300 • fun@susfest.org • www.susfest.org

OREGON

Jun. 22–25, '06. Detroit, OR. Breitenbush Hot Springs RE Conf. Presentations on PV, solar thermal, biodiesel, efficiency, regs & codes, financing & big picture presentations. Info: Breitenbush Hot Springs • 503-854-3320 • office@breitenbush.com • www.breitenbush.com

Jul. 26–27, '06. John Day, OR. Pre-SolWest hands-on installation workshop. Info: see below.

Jul. 28–30, '06. John Day, OR. SolWest RE Fair. Exhibits, workshops, keynote speaker, family day, speakers, music, alternative transportation & Electrathon rally. EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

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

PENNSYLVANIA

Jun. 23–25, '06. Portage, PA. East Coast Alternative RE Fair. Exhibits, vendors & education on RE & sustainable living. ECARE • 814-736-8818 • info@ecarefair.com • www.ecarefair.com

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

RHODE ISLAND

Jun. 3, '06. Coventry, RI. Sustainable Living Festival & Clean Energy Expo. Exhibits & workshops on solar, wind, biofuels, alternative vehicles & building. Music & food. Info: Apeiron • 401-397-3430 • info@apeiron.org • www.apeiron.org

TENNESSEE

May 10–14, '06. Summertown, TN. Solar installer course, incl. hands-on install. Info: see next listing.

Oct. 19–22, '06. Summertown, TN. Personal oil independence course. Grow your own fuels; put PV on your roof. Info: The Farm • ecovillage@thefarm.org • www.thefarm.org

TEXAS

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

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

UTAH

Apr. 17–22, '06. Salt Lake City. PV Design & Installation course. Info: see SEI listing for Colorado.

VIRGINIA

May 20, '06. Warrenton, VA. Piedmont Alternative Energy Expo. PV, water heating, biodiesel & veggie oil, solar toys, hybrid automobiles & experts to explain the technologies. Info: Rappahannock League for Environmental Protection • 540-937-9934 • altenergyexpo@rlep.org • www.rlep.org

WASHINGTON STATE

Apr. 1, '06. Guemes Island, WA. Intro to RE workshop. Solar-, wind- & hydroelectricity, solar cooking & hot water. Classroom & tours. Info: see SEI in Colorado listings Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Apr. 3–5, '06. Guemes Island, WA. Solar Hot Water workshop with *Home Power* solar thermal editor Chuck Marken. Classroom, tours & installation. Info: see above listing.

Apr. 7–9, '06. Guemes Island, WA. Utility-Interactive PV workshop. Classroom, tours & hands-on installation. Info: see above listing.

WISCONSIN

Jun. 23–25, '06. Custer, WI. RE & Sustainable Living Fair (aka MREF). Exhibits & workshops on solar, wind, water, green building, alternative fuels, organic gardening, energy efficiency & healthy living. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: see MREA listing below.

Custer, WI. MREA '06 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

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

readers' marketplace

HYDROELECTRIC SYSTEMS: Pelton and Crossflow designs, either complete turbines or complete systems. Assistance in site evaluation and equipment selection. AC Systems for standalone or grid interconnect operation. Manufacturing home and commercial size turbines since 1976. Send for a free brochure. Canyon Industries Inc., P.O. Box 36 HP, Deming, WA 98244, 360-592-5552. E-mail: citurbine@aol.com • Web page: canyonhydro.com • HP11202

HELP WANTED BUILDING PASSIVE SOLAR Cement Domes Learn to build your own- Housing also provided www.2BbyD.com • HP11203

COSOLAR.COM discount prices from Colorado Solar Electric. OutBack Inverters in stock 1-800-766-7644 • HP11204

SINGLE AND DUAL AXIS SOLAR TRACKER CONTROLS up to 48V and 5A output. www.theanalogguy.com • HP11205

SURPLUS INDUSTRIAL BATTERIES: Save up to 70% on unused military and industrial batteries. Many types and sizes, super H.D. Factory crated. Also chargers, wind and solar equipment, new and used. D.P.S.D. Inc. 3807 W. Sierra Hwy. #6, Acton CA 93510. 661-269-5410. Fax 661-269-3601. • HP11206

MICRO SINE WAVE INVERTERS in stock. Brand new, formerly Trace. $499 + s/h. No dealers 386-677-5736 • HP11207

ECOMALL: The largest environmental portal of earth-friendly companies and resources. Renewable energy companies, news and information. www.ecomall.com. To advertise, call 845-679-2490. • HP11208

LARGE GAS REFRIGERATORS 12, 15 & 18 cubic foot propane refrigerators. 15 cubic foot freezers 800-898-0552 Ervin's Cabinet Shop, 220 N County Rd. 425E., Arcola, IL 61910 • HP11209

XXXXXXXUNI-SOLAR XXXXXXXX XXXXXX 64 Watts $359 XXXXXXXX M55 Siemens panels $260/SQ 80 watts $350. New 1500 AH Absolight 12V batteries $1900. TraceX SW5548 $2450. Ex 2KW inverter SB $850. Buy, sell New/Used 760-949-0505 • HP11210

HONDA GENERATORS - 1000 to 10,500 watts. Fast shipping and great prices! www.hayesequipment.com 1-800-375-7767 • HP11211

DC SUBMERSIBLE WELL PUMPS. Complete, ready to install. $219 includes IMMEDIATE FREE SHIPPING. Visit www.nemosolar.com or call 1-877-684-7979 • HP11212

I AM A SOLAR WHOLESALER looking for retailers to carry my solar electronic and hobby goods. Phone # (916) 486-4373. Please leave message. • HP11213

TRINIDAD COLORADO: Get more out of life and your money with this active/passive, 2000 SF home, 2bedr 1 & 1 3/4 baths on 40 private acres. Built in 2003. $350,000. This and more solar-powered homes can be found at www.SolarRealty.net. (970) 728-3205, 1-800-571-6518. The worlds only Solar-powered real estate office, John Janus, Broker • HP11214

EDTA RESTORES SULFATED BATTERIES. EDTA tetra sodium salt, $12/lb. plus $5 S&H for 1st lb. plus $1 S&H for each additional lb. Trailhead Supply, 325 E. 1165 N., Orem, UT 84057, (801) 225 3931, E-mail: trailheadsupply@webtv.net, info at: www.webspawner.com/users/edta. • HP11215

AFFORDABLE-SOLAR.COM Grid Tie - Off Grid. Solar Panels, Inverters, Energy Efficient Appliances, Friendly Knowledgeable people, Fair Prices. Look us up on the Web at www.Affordable-Solar.com or call Toll Free 1-800-810-9939 • HP11216

SOLAR HEATERS FOR SALE! Get free heat from the sun for your home, office, garage, etc. Visit us today at www.hotboxsolar.com or by phone at 1-607-731-2741. HotBox Solar. 263 Glenwood Ave. Elmira Heights, NY. 14903 • HP11217

VARI-CYCLONE: DC powered ceiling fan, 40% more airflow with no increase in power consumption. For more info contact RCH Fanworks, the #1 manufacturer of DC powered ceiling fans, 2173 Rocky Crk. Rd. Colville, WA 99114 PH: 509-685-0535, E-mail: info@fanworks.com, Web: www.fanworks.com, Dealer inquiries welcome. • HP11218

SURVIVAL UNLIMITED.COM - Emergency Preparedness & Survival Supplies. Wind Power from 439.00+. Many great products & prices! 1-800-455-2201 www.survivalunlimited.com • HP11219

WWW.EARTHTOYS.COM - Online library and emagazine all about alternative energy systems and equipment • HP11220

50+ Custom MICROHYDRO TURBINE sizes in stainless or plastic, brass nozzles 5-29mm, arbors, site study tools, www.H-Hydro.com • HP11221

ENJOY ENERGY INDEPENDENCE - Wind Power - Solar PV - Solar Hot Water - Solar Water Pumping - Biodiesel - LED Lighting - Edmonton AB Canada 780-466-9034 www.trimlinedesigncentre.com • HP11222

SOLAR CELLS New 5" monocrystal 50 per pack - 125 watts $150.00 make your own solar panels email for specs: none1120@juno.com • HP11223

OVERCOME YOUR ENERGY DEPENDENCE WITH SOLAR. COMPLETE SELECTION of reliable solar energy products for everyday living. Just about anything using electricity can be solar powered—cost efficiently. Free catalog. www.DiscoverPower.com 858-581-0051 Or 800-842-5678. Discover Power • HP11224

WANT TO LIVE RENT-FREE - anywhere in the world? There are empty homes in every state and country, and property owners are looking for trustworthy people to live in them as property caretakers and housesitters! The Caretaker Gazette contains these property caretaking/housesitting openings in all 50 states and foreign countries. Published since 1983, subscribers receive 1,000+ property caretaking opportunities each year, worldwide. Some of these caretaking and housesitting openings also offer compensation in addition to the free housing provided. Short, medium and long-term property caretaking assignments are in every issue. Subscriptions: $29.95/yr. The Caretaker Gazette, PO Box 4005-E, Bergheim, TX 78004. (830) 336-3939. www.caretaker.org • HP11225

ENGINEERING SOFTWARE PROVIDES ENGINEERING E-SOLUTIONS FOR ENERGY CONVERSION SYSTEMS. Free e-material is available at http://members.aol.com/engware • HP11226

HYDROS, P.M. BRUSHLESS DC units with Harris housing and wheel. Up to 70% efficiency. From $1350. www.homehydro.com 707-923-3507 CA • HP11227

AUCTIONS AND STORES FOR ALL AE PRODUCTS AND SERVICES: www.tedjec.com/auctions/ • HP11228

JACOBS WIND GENERATORS. www.brightok.net/~windyoaks242 • HP11229

FOR SALE: ES & D STREAM ENGINE 2 nozzle water turbine. Like new, used 6 months. $1650 OBO. 260-768-8132 • HP11230

SUNRISE SOLAR PUMP & CONTROLLERS $275, 4 KW Dakota 110v wind generator & 35' tower $3500. (406) 547-2266 • HP11231

PTO TRACTOR GENERATOR. 26KW with trailer & driveshaft. Used only 25 hrs. Works on any tractor 20-60 hp with 540 rpm PTO. $2500 OBO Call Mike 619-468-3277 • HP11232

WWW.ELECTROPORTAL.COM WIND/cng-lpg generators, solar heaters- lights, e-bicycles (+ trikes, kits), folding electric wheelchairs, new eco-batteries, CNG 3-wheelers • HP11233

ONAN GENERATOR RS12000, Model 12 GHAB. 350 hrs, new battery. $4000. Located in Eastern CA. Lloyd @ 760-377-3542 • HP11234

LOWEST COST PV ON EARTH- Nano Tech is Here. 435-867-8514 or 702-300-6925 smithja@sisn.com • HP11235

XANTREX (trace) USED 3624 INVERTERS with stacking kit. Will sell as a pair or separate. $500 each. (909) 584-1147 • HP11236

EASTERN IOWA OFF GRID HOME FOR SALE, 3.7 acres 20 min. from Iowa City. Ph.319-643-5650 laugh@avalon.net • HP11237

SAVE 80% HEATING WITH SOLAR. New technology can boil water even in winter! Solar heating packages for homeowner and installer. E-mail sales@maslintechnology.com • HP11238

Readers' Marketplace Rates

Rates: 25¢ per CHARACTER, include spaces & punctuation. $20.00 minimum per insertion. All Readers' Marketplace ads are published in both the print and Web versions. Please send a check or Visa, MasterCard, American Express, or Discover card data with ad. Please, no money orders. We do not bill Readers' Marketplace ads; they must be paid for in advance of publication. Your cancelled check or credit card bill is your receipt.

Submit your ad by:

- **E-mail:** (preferred) readersmarketplace@homepower.com
- **Fax:** 541-512-0343
- **Phone:** 800-707-6585 or 541-512-0201

Help us prevent fraud! *Home Power* Readers' Marketplace ads from individuals must supply serial number(s) for equipment being sold. Businesses must supply published phone number(s) and a physical address. While *Home Power* is doing everything we can to prevent fraud, we can assume no responsibility for items being sold.

SUPER EFFICIENT ROTARY HYDROPONIC APPLIANCES. Home/Commercial. Food Safety/Security, www.volksgarden.com 1-877-962-3278 • HP11239

installers *directory*

Do you want a renewable energy system, but don't want to install it yourself? You deserve a system that meets your expectations and budget! A renewable energy professional will design and install a safe, code-compliant system, and offer you service and support after the sale. Check out the installer listings below.

Home Power **does not guarantee the quality provided by the businesses listed below— please shop carefully, request references and certifications, and compare.**

Owens Electric & Solar, Providing quality power solutions since 1964. Full range of energy conservation & turnkey services including efficiency upgrades & PV solar system installations for residential & commercial applications. Licensed, bonded, certified, & insured C-10 Electrical Contractor (#464389) serving northern CA. 1-877-57-SOLAR. info@owenselectricinc.com www.owenselectricinc.com

Solar Wind Works specializes in consultation, sales, design, service, & installation of complete RE systems. US Distributor for Proven Wind Turbines. We supply all components. Grid-connected or grid-independent. Truckee, CA 530-582-4503, 877-682-4503, NABCEP Certified Installer. CA Contractor's Lic # 796322 chris@solarwindworks.com, www.solarwindworks.com

Canada

Energy Alternatives has been serving Canadians for over 20 years. A licensed electrical contractor (BC Lics # 86683) with professional installers throughout Canada. Expert consultation & design services, turn-key installed systems or DIY packaged system kits. Extensive inventory for fast delivery. Visit www.EnergyAlternatives.ca, Call 1-800-265-8898. Canadian dealer inquiries welcome.

Colorado

Burnham-Beck & Sun, Solar & Wind Energy Systems. Located in Fort Collins, Colorado, we make site evaluations, system designs, and installations in Northern Colorado, Southern Wyoming. We drop-ship equipment anywhere in the US. Retail products include PV modules, wind turbines, inverters, batteries, efficient appliances. 970-482-6924. mailto: BurnhamBeckSun@aol.com. www.burnhambeck.com

Namaste Solar Electric Inc., designs, sells, installs & services residential & commercial solar electric systems; over 10 years experience. Grid-tied & stand-alone systems in CO & neighboring states. We live with the technologies we sell & we stock our home-tested products. Our guiding principles: People, Planet, Prosperity. (303) 447-0300 Fax (303) 443-8855 www.namastesolar.com ray@namastesolar.com

Simple Solar Systems is your full-service provider of consultations, designs, sales, and installations of residential and commercial solar electric systems. Grid-tie or Stand Alone. 15 years in the industry. Together, let's live consciously for our planet. Licensed and Insured. CoSEIA and NABCEP Certified Installer, Joe Callahan (303) 541-9852 joe@simplesolarsystems.com www.simplesolarsystems.com

Solar Solutions Ltd. provides photovoltaic, wind & hybrid power systems & components for stand alone systems, grid tied, RV's & remote water pumping. Committed to providing the highest quality service & customer satisfaction. A proud member of Colorado SEIA and a lifetime member of the Colorado RE Society and ASES. Xantrex Certified Dealer. 888 44solar or 888 447-6527 www.solarsolutions.com

Connecticut

Sunlight Solar Energy, Inc. Milford, Connecticut. The state's largest grid tied residential design & installation company. We take care of the Connecticut Clean Energy Fund, Utility & local building paperwork. Everything to get your meter spinning backwards. Our specialized installers are nationally certified. Call for info & a reference from your neighbor. www.sunlightsolar.com. 203-878-9123

Florida

ECS Solar Energy Systems (tel) 352-377-8866 www.ECS-solar.com / tom@ECS-solar.com We service FL, the Caribbean and the Southeastern U.S. FL's first solar contractor since 1977. Solar pool heating, hot water, and electric systems –commercial & residential. Solar lic. # CVC056643 Florida state certified for "grid-connected" systems. Contact us now to receive a free solar informational booklet.

Georgia

SC Solar designs/installs PV systems—residential, US military, solar lighting, water pumping, traffic management power systems. Solar thermal & micro hydro. Custom UPS systems for off grid. Installation area: NC, SC, VA, GA, TN, & Mexico. For more info & credentials: 803-802-5522 www.scsolar.com CCR# & Cage Code #1SLJ5.

Idaho

Creative Energies Eastern Idaho's premiere full-service RE company. Solar & wind power for remote cabins, homes & ranches, utility grid-tied solar & wind power, solar hot water & heating, solar water pumping & passive solar home design. We custom design a system that fits your needs & budget. Trace certified dealer. Phone/fax: 208-354-3001 toll free 866-332-3410 info@cesolar.com • www.cesolar.com

Kansas

PowerTomorrow designs and installs the Power of Tomorrow—Today! Specializing in the design & installation of solar hot water & home heat, photovoltaic, & wind power solutions for your residential and commercial needs. As seen on ABC's "Extreme Home Makeover". Since 1982, fully insured. Call 877-427-7767, or visit www.powertomorrow.com

Mexico

SC Solar designs/installs PV systems—residential, US military, solar lighting, water pumping, traffic management power systems. Solar thermal & micro hydro. Custom UPS systems for off grid. Installation area: NC, SC, VA, GA, TN, & Mexico. For more info & credentials: 803-802-5522 www.scsolar.com CCR# & Cage Code #1SLJ5.

Michigan

Backwards to the Future Ltd, installing, designing and supplying solar equipment since 1986. OEM supplier of evacuated tube heat pipe technology for DHW & hydronic heating. Systems building integration by joint venture with registered architect. State licensed residential builder & solar mechanical contractor. POB 409 Fennville MI 49408 tel: 269 2366179 email: info@BTFsolar.com www.BTFsolar.com

Missouri

PowerTomorrow designs and installs the Power of Tomorrow—Today! Specializing in the design & installation of solar hot water & home heat, photovoltaic, & wind power solutions for your residential and commercial needs. As seen on ABC's "Extreme Home Makeover". Since 1982, fully insured. Call 877-427-7767, or visit www.powertomorrow.com

Montana

Oasis Montana Inc: Designs, sells, & installs renewable energy power systems in North America and also offers efficient and gas appliances. Our engineer Dan Healy is a NABCEP Certified Installer. Toll-free: 877-OASISMT or 877-OASISPV. Web sites: www.oasismontana.com, www.grid-tie.com, www.PVsolarpumps.com. E-mail: info@oasismontana.com

Planetary Systems, Inc. In business 10+ years. Sales/design/installation of complete RE electrical, water & hydronic heating systems. Our patented RE "Power Package" simplifies installation & reduces costs. Can be shipped nationwide & installed locally. CAD schematic system drawings/technical support provided. Xantrex Certified Dealer. Phone (406) 682-5646, www.planetarysystems.com

Sunelco, Inc. Montana's premier full service renewable energy dealer, has 20 years of satisfied customers on a global scale. Water pumping to remote homes, we provide free consultation, estimates, design assistance, and life-time tech support on our systems. Get your copy of the Sunelco 16th Edition Planning Guide and Catalog for only $5. www.sunelco.com 888-786-3526

Nevada

Alternative Energy Solutions, Reno, Nevada. We design, sell, install and service PV, wind, off grid and grid tie RE systems, Nevada State Licensed and Bonded Contractor, NABCEP PV Certified Installer. Xantrex / Trace Authorized Service Center, Xantrex Certified Dealer, Outback Factory trained field service technicians and Certified Uni-Solar field laminate installer. 775-857-1157 toll free 1-866-491-SOLR

Solar Unlimited, Inc. serves Nevada's Renewable Energy design, sales, service, and installation needs, including PV, wind, net-metering and off-grid systems. We are authorized dealers for Solarwall, Gillette, Xantrex, Outback, African Wind Power and more. Licensed and insured. Call toll free 866-SOLAR99 or visit www.solarunlimited.net.

Nevada, cont.

Solar Wind Works specializes in consultation, sales, design, service, & installation of complete RE systems. US Distributor for Proven Wind Turbines. We supply all components. Grid-connected or grid-independent. Truckee, CA 530-582-4503, 877-682-4503, NABCEP Certified Installer. NV Contractor's Lic # 59288. chris@solarwindworks.com, www.solarwindworks.com

New Hampshire

Sunweaver Incorporating innovative technologies for power, water and heat. Encouraging knowledge and direction towards resource responsible solar living. Installing in New England and the Caribbean since 1985. www. sunweaver.org. mailto: info@sunweaver.org 603-942-5863 Showroom hours: Monday-Saturday 11am-6pm

New Jersey

Akeena Solar is the nation's largest residential solar electric installer with two NABCEP-Certified PV Installers on staff. Our design/build services coupled with our complete financial analyses, based on actual site conditions, support our growing list of satisfied customers in making the switch to clean reliable energy. Serving CA, NJ, MA, RI, CT, & NY. Visit www.akeena.net or call 888-akeena-8

New Mexico

Cedar Mountain Solar, LLC Leading installer of solar heating systems. Integrated design/build services to architects, contractors, and homeowners. Specialize in hybrid solar/boiler hydronic heating systems for radiant floors, baseboards, pools, spas, and domestic hot water. 1285-J Clark Rd. Santa Fe, NM 87507 ph 505-474-5445 fax 505-474-6818 www.cedarmountainsolar.com info@cedarmountainsolar.com

Direct Power and Water Corp designs, engineers & professionally installs turn-key solar electric systems for remote homes/log cabins, commercial, telecommunication, & water pumping applications. NABCEP Certified Design Engineer Daniel Duffield & Master Electrician EE98J Dave Hammack have over 30 years experience and live by PV. References provided. (800)260-3792 www.directpower.com

Paradise Power Company is a small company located in Taos, New Mexico, the solar capital of the world. Not restricted to any locality though most of our work is in New Mexico, Colorado, and Texas. We offer a complete electrical service specializing in solar and alternative electrical system design, sales, installation, maintenance and lifestyle. 505-737-5896. paradise@taosnet.com•www.paradisepower.net

Positive Energy Inc. High quality renewable power systems. Licensed, bonded, and insured electrical contractor serving Santa Fe and northern NM. Owner Allan Sindelar is NABCEP certified and is a certified dealer/installer for Xantrex, Outback, and Sunnyboy. 505 424-1112. E-mail: info@positiveenergysolar.com. Website: www.positiveenergysolar.com

Remod Solar Service Solar Heating Specialists for over 27 years with thousands of happy customers. Installation, design & repair. Licensed NM Electrical, Plumbing and HVAC contractor. Solar space heating, solar water heating, radiant floor integration and solar pool heating. Old and slow but at least we're expensive. Remod Inc. Albuquerque Lic. # 26528 (505) 247-4522 chuckmarken@qwest.net

New York

Suntric Renewable Electric Systems, Experienced, qualified installers of photovoltaic, wind, and micro-hydro stand alone systems. Located on the western end of the Adirondack Park in northern New York State. Site evaluations, design consultations, sales and service. Off grid since 1976. Edwin & Pamela Falk, 6920 Abbey Road, Lyons Falls, New York 13368 • 315-348-6893

Solar & Wind FX Inc. NY's only Off-grid Design & Training Center, where a client can see the latest RE & Green building technologies. A family owned, full service company focusing on Western NY that provides site evaluation, design, installation & the all important, service after the sale. Member of NESEA & NYSEIA, SEI alumni & a NYSERDA installer. 585-229-2083, solarandwindfx.com

North Carolina

SC Solar designs/installs PV systems—residential, US military, solar lighting, water pumping, traffic management power systems. Solar thermal & micro hydro. Custom UPS systems for off grid. Installation area: NC, SC, VA, GA, TN, & Mexico. For more info & credentials: 803-802-5522 www.scsolar.com CCR# & Cage Code #1SLJ5.

Solar Village Institute, Inc. NC's premier solar, wind, micro-hydro dealer-installer-educators. Off-grid since 1992. Top quality, pro work, guaranteed. NC, SC, VA, GA, AK. Specializing in Wind/Solar hybrid off-grid systems. New/remodels. Christopher W. Carter, Pres. SEI alumni, Xantrex Cert. dealer. David Del Vecchio, installation manager. www.solarvillage.com, chris@solarvillage.com, 800 376 9530

Sundance Power Systems, Inc. is the largest provider of Renewable Energy in Western North Carolina. Since 1995, Sundance has been providing high quality Residential and Commercial Design and Installation of PV, Wind, Hydro, Solar Thermal and Hydronic Heating Systems throughout the southeast. Phone: 828-689-2080 Email: info@sundancepower.com Web: www.sundancepower.com.

Ohio

REpower Solutions: Northeast Ohio's renewable energy provider for home and business. Design, installation, and education for PV and wind systems. NABCEP Certified Installer. Xantrex Certified Dealer. e-mail: power@repowersolutions.com. Website: www. repowersolutions.com. P.O. Box 91992, Cleveland, OH, 44101. 216-402-4458.

Third Sun Solar & Wind Power, Ltd. is Ohio's leading renewable energy contractor. Complete design and installation of off-grid, utility tied, PV and wind systems in OH, KY, IN, IL, MI, PA, WV. Owner Geoff Greenfield is NABCEP Certified Solar PV Installer. We are committed to excellent customer service & the highest quality systems. www.third-sun.com. (740) 597-3111.

Oregon

Electron Connection Licensed in CA and Oregon. NABCEP Certified installer. Serving northernmost California and southern Oregon. PV, wind, microhydro installs. (800) 945-7587 email: bob-o@electronconnection.com, www.electronconnection.com OR CCB# 149724

Mr. Sun Solar: Since 1980, the Northwest's leading solar installer. Over 1,200 projects including solar hot water, solar pool heating, solar attic fans, and on- and off-grid PV systems. Dealer for Sol-Reliant™, The Solar Water Heater Built to Last - OG-300 and Bright Way™ approved. Phone: (888) SOL-RELY (888-765-7359). Web: www.MrSunSolar.com and www.SolReliant.com

Sunlight Solar Energy, Inc. specializes in full-service, turn-key, grid tied residential & commercial PV systems. Fully licensed, providing consultations, efficient system design, professional installations, and competitive pricing. Over 20 years of experience with two Licensed LRTs, one NABCEP Certified PV installer, and one seasoned alumni of SEI. For more info./referrals: www.sunlightsolar.com, 541/322-1910

Pennsylvania

www.windturbine-1.com

Appalachian Wind Systems, LLC has been serving PA, WV & MD for 6 years. Distributor for Cyclone wind turbines, Synergy wind turbines, Sun solar panels, LED lighting, stand alone & grid tie inverters and other products. Site evaluations and financial analyses. We also sell, service & install 10–60 meter NRG meteorological towers & first stage wind analysis. For more information, call 724-452-0326

South Carolina

SC Solar designs/installs PV systems—residential, US military, solar lighting, water pumping, traffic management power systems. Solar thermal & micro hydro. Custom UPS systems for off grid. Installation area: NC, SC, VA, GA, TN, & Mexico. For more info & credentials: 803-802-5522 www.scsolar.com CCR# & Cage Code #1SLJ5.

Texas

Meridian Energy Systems specializes in the design and installation of high quality solar and wind energy systems throughout the State of Texas...and beyond. Factory trained technicians and NABCEP Inaugural Certificant on staff. Visit our website www.meridiansolar.com or call 512-448-0055

North Texas Renewable Energy Inc. North Texas' premier solar and small wind energy service. Complete system design and installation. Available service contract Independence–Reliability–Conservation. Jim Duncan answers@NTREI.com 817.917.0527

Utah

Solar Unlimited, Inc. Southern Utah's leading design, sales, service and installation professional for all your alternative and Renewable Energy needs, including PV, wind, net-metering or off grid systems. We are authorized dealers for Solarwall, Gillette, Xantrex, Outback, African Wind Power and more. Licensed and insured. Call toll free 866-SOLAR99 or visit www.solarunlimited.net.

Vermont

Vermont Solar Engineering has provided the finest in renewable energy throughout New York and New England, since 1991. We design, install, and support solar electric, wind electric, and solar hot water systems. K. Herander, NABCEP™ certified installer. Xantrex Certified Dealer. NYSERDA eligible installer. Vermont Solar and Wind Partner. www.vermontsolar.com 1-800-286-1252

Virginia

Dunimis Technology Inc. Providing alternative energy systems since 1992. NABCEP certified solar technicians on staff. We specialize in the more demanding upscale off-grid residential & commercial installations. Installations completed in ID, TX, PA, NJ, NC, VA, and WV. P.O. Box 10, Gum Spring, VA 23065, Phone 804-457-9566, jryago@wwjv.net., www.pvforyou.com

Washington

Mr. Sun Solar: Since 1980, the Northwest's leading solar installer. Over 1,200 projects including solar hot water, solar pool heating, solar attic fans, and on- and off-grid PV systems. Dealer for Sol-Reliant™, The Solar Water Heater Built to Last - OG-300 and Bright Way™ approved. Phone: (888) SOL-RELY (888-765-7359). Web: www.MrSunSolar.com and www.SolReliant.com

Washington, cont.

Power Trip Energy Corp. "Craft Your Personal Energy Policy" Full service electrical contractors specializing in solar installations in Western Washington. Design & install grid-tied and off-grid, beautiful and practical PV projects for residential, commercial, & municipal clients in the greater Puget Sound Region. www.powertripenergy.com (360) 643-3080. info@powertripenergy.com, WA LIC# POWERTE964JN

Seraphim Energy, Inc. Full service electrical contractor serving the Columbia River Watershed. We specialize in on and off grid wind, sun and water powered systems, meeting all your design, installation and procurement needs. From 100W to 100GW, plug into Seraphim Energy. WA# SERAPEC971MG, 800.265.6288, www.seraphimenergy.com, re@seraphimenergy.com

SolarWind Energy Systems, LLC P.O. Box 1234, Okanogan, WA 98840 (509) 422-5309 www.solar-wind.us WA Cont. # SOLARES983RQ. Serving Eastern WA & Northern ID grid-tied & off-grid RE systems. Solar PV, wind, solar hot water, remote stock watering. Design, installation, service, maint. Solar Energy International (SEI) trained. Lic. & bonded. bclark@solar-wind.us or jmartin@solar-wind.us

Wisconsin

Photovoltaic Systems Co., since 1980 we have been designing, installing and servicing solar electric systems statewide in WI. NABCEP Certified Installer, Xantrex certified dealer & authorized service cntr.; MREA instructor teaching basic thru advanced PV systems workshops. James Kerbel 7910 hwy 54 Amherst Wi. 54406 715-824-2069 PVSOLAR@wi-net.com

Wyoming

Creative Energies Wyoming's premiere full-service RE company. Solar & wind power for remote cabins, homes & ranches, utility grid-tied solar & wind power, solar hot water & heating, solar water pumping & passive solar home design. We custom design a system that fits your needs & budget. Trace certified dealer. Phone/fax: 307-332-3410 toll free 866-332-3410 info@cesolar.com • www.cesolar.com

RE Installer? Get Listed.

Our readers continue to look to *Home Power* for referrals to RE installation professionals in their area.

For more information or to get your business listed in *Home Power*'s installers directory, e-mail advertising@homepower.com or call 541.512.0201.

adopt a library!

When Karen and I were living with kerosene lamps, we went to our local public library looking for a better way to light up our nights. We found nothing about small-scale renewable energy. As a result, one of the first things we did when we started publishing *Home Power* sixteen years ago was to give a subscription to our local public library.

If you'd like to do the same for your public library, we'll split the cost of the subscription with you. Inside the U.S., you pay $11.25 and we'll pay the rest. Outside the U.S., the same offer stands, so call us for rates.

— Richard Perez, Publisher

Check with your local library before signing them up. Eligible libraries must be open to the general public.
PO Box 520, Ashland OR 97520 • 800-707-6585 • 541-512-0201 subscription@homepower.com

advertisers *index*

For easy online access to advertisers, visit www.homepower.com/advertisers

home power

The Hands-On Journal of Home-Made Power

Smart Solar Strategies

For Whole-House Energy Efficiency p. 14

Expert Advice

How To Buy Used Solar Hot Water Panels p. 68

Install a Solar Attic Fan

Step-by-Step Weekend Project p. 24

Cash Back!

Tax Credits for Your Home Energy Upgrades p. 88

BEST Appliance Value

Determine Life-Cycle Costs Before You Buy p. 82

Apr / May 06, Issue 112
$6.95 US • $8.95 CAN
04
0 74470 78082 3
homepower.com

bp solar

beyond petroleum®

the future
is in our hands

www.bpsolar.us