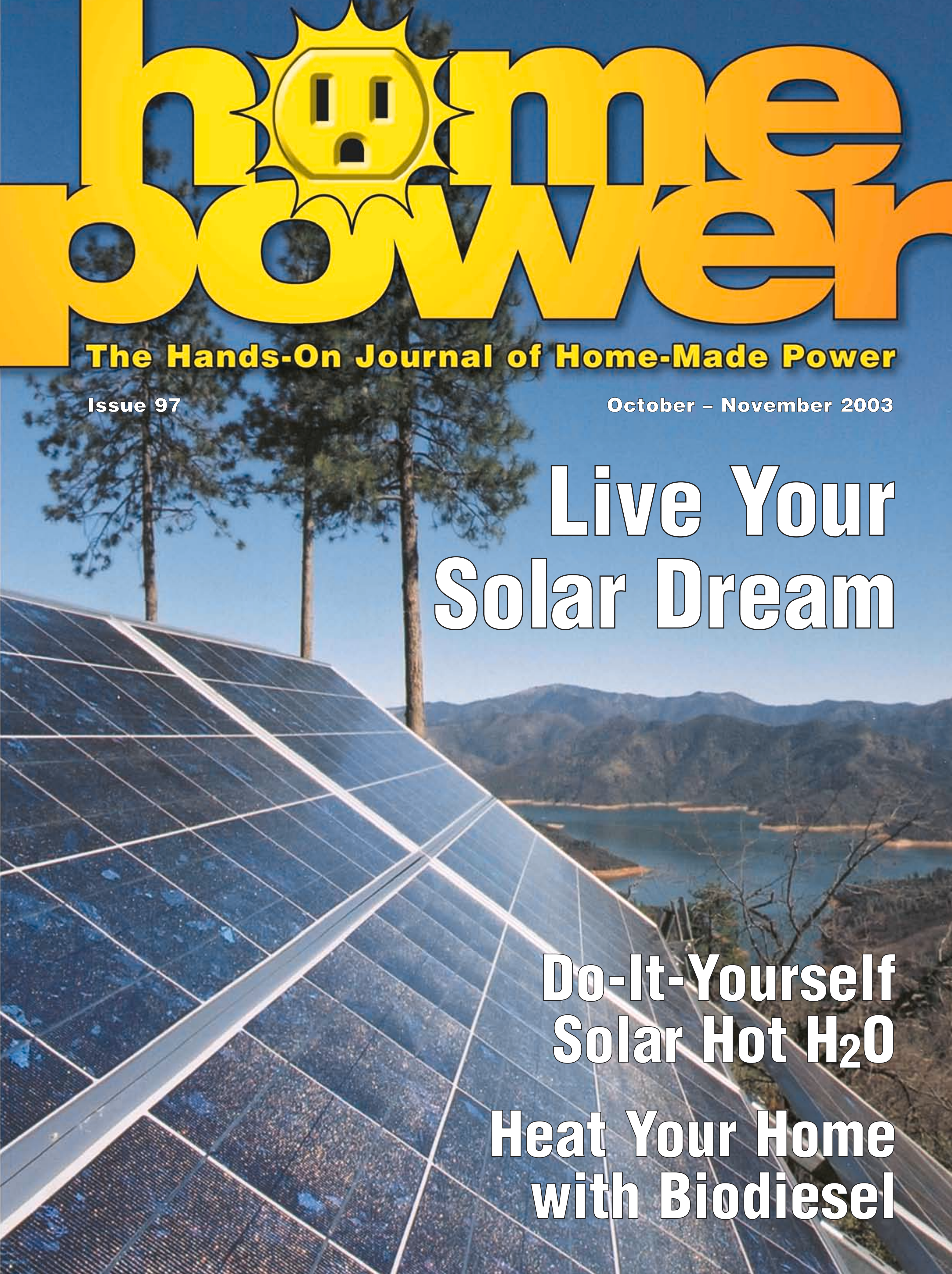
home power

The Hands-On Journal of Home-Made Power

Issue 97

October – November 2003



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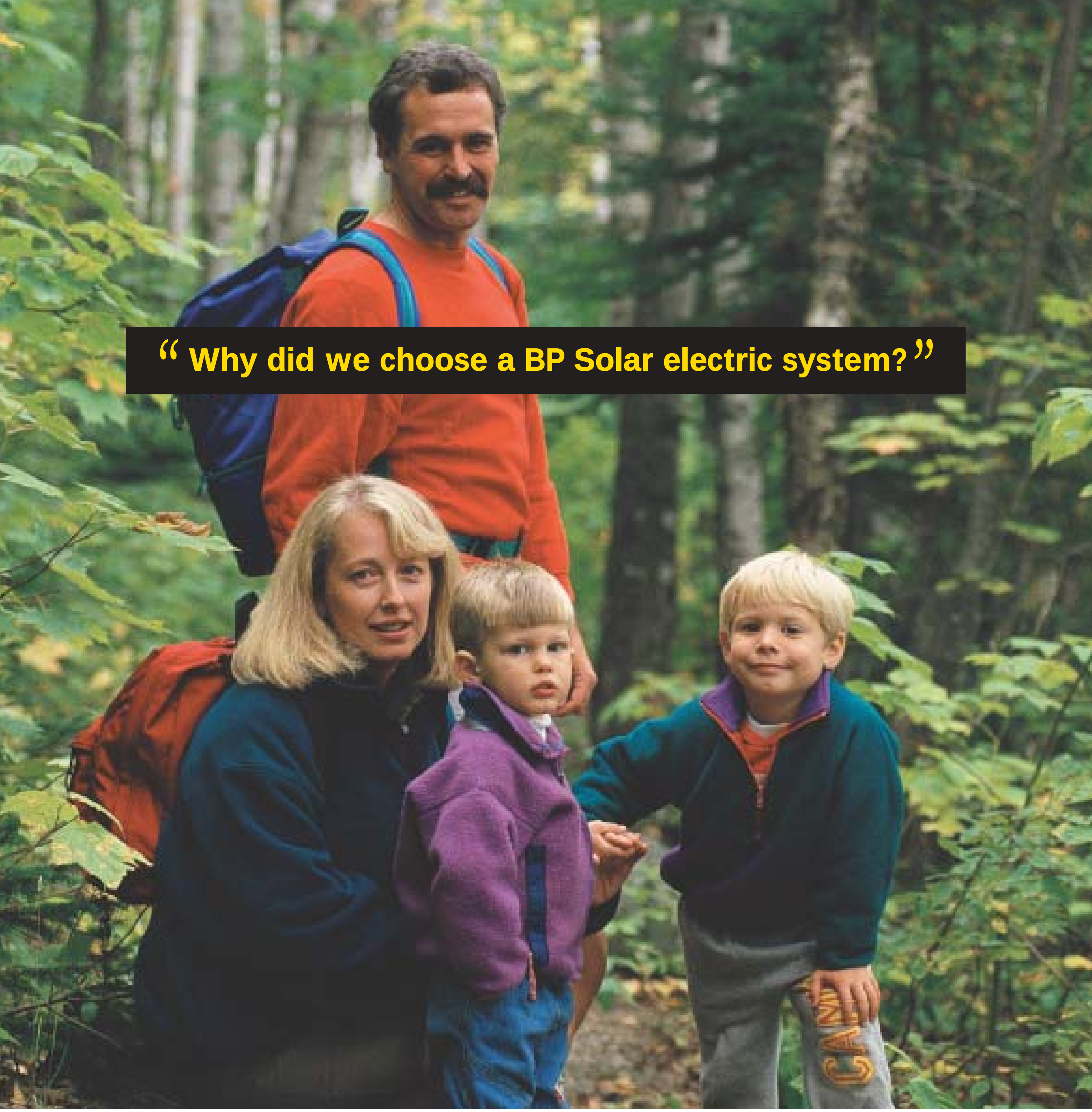

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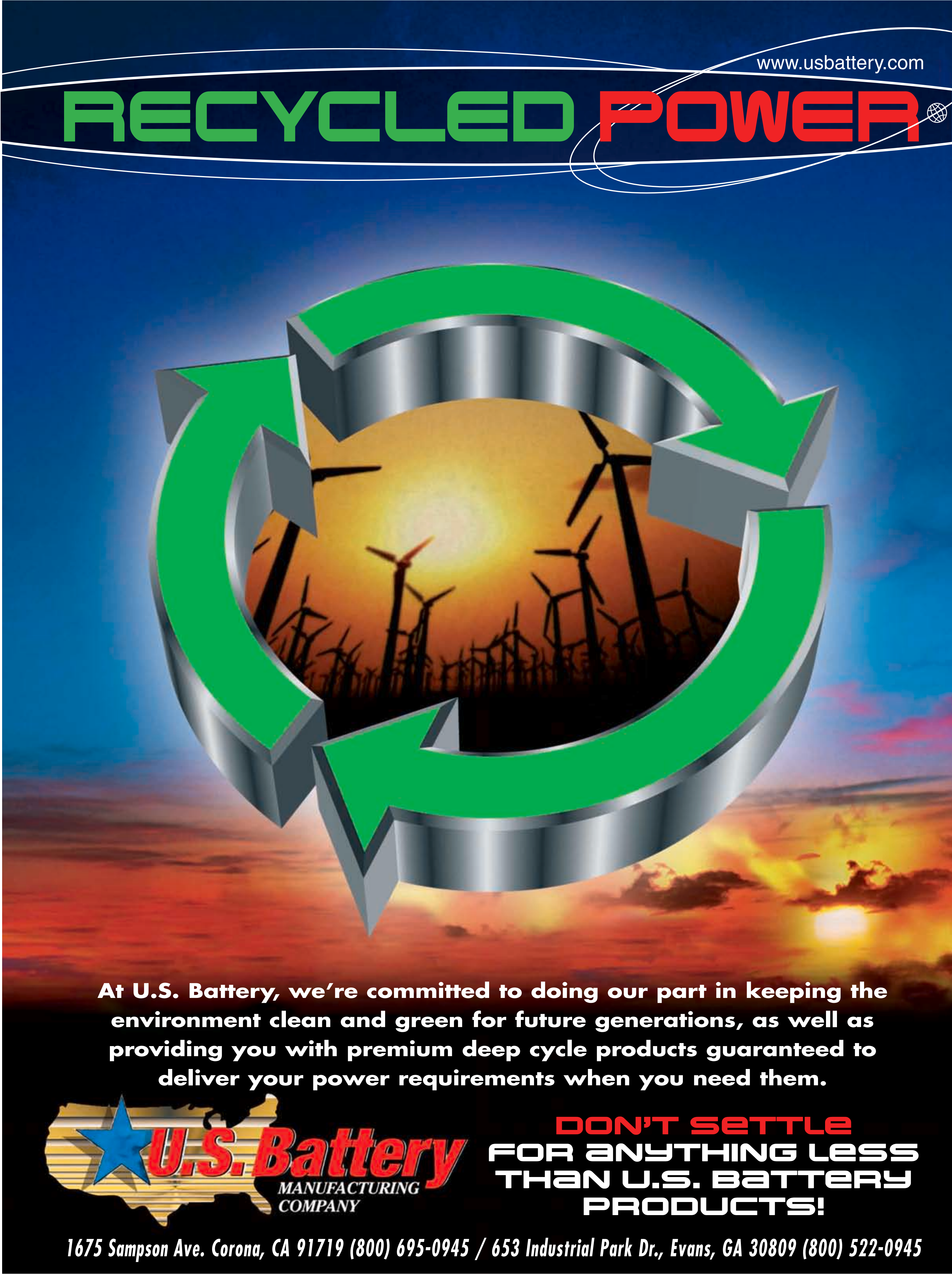
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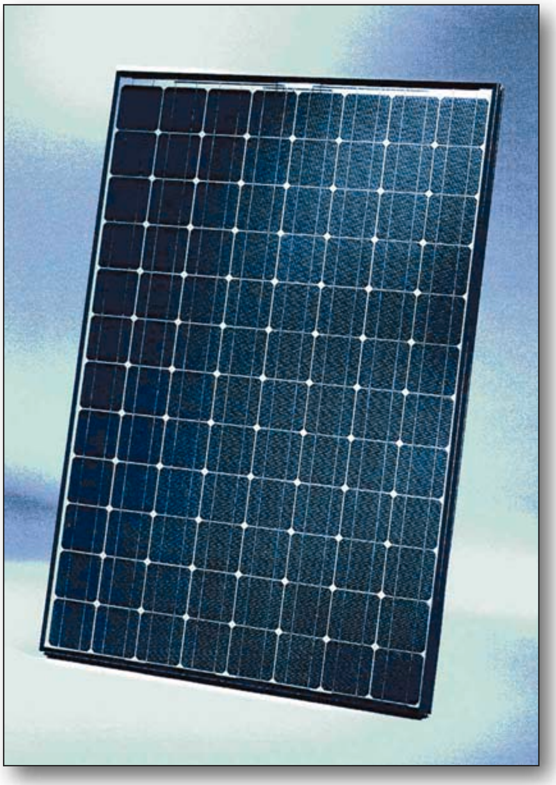

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*PTC stands for PVUSA Test Conditions. PTC watt rating is based on $1000 W/m^2$ irradiance, 20º ambient temperature and 1 m/s wind speed.

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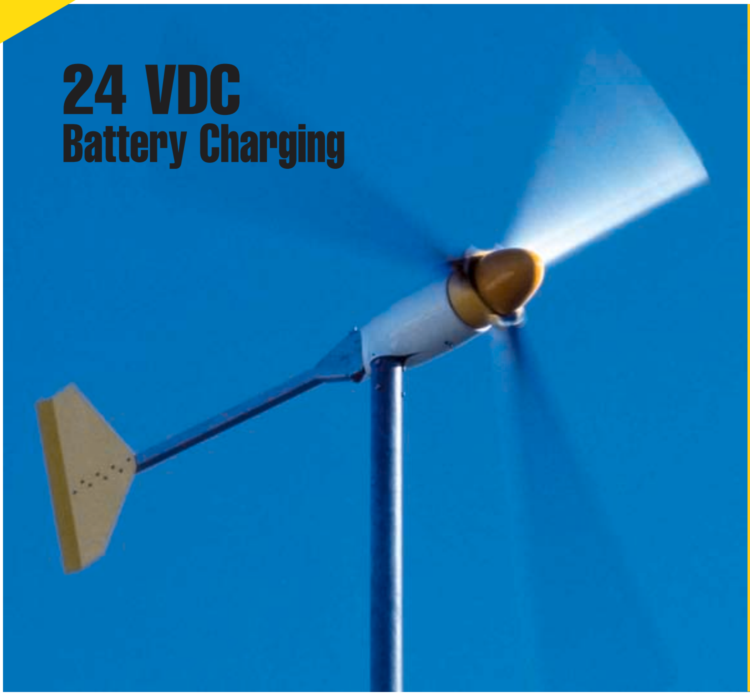

Features

- 5-Year Warranty (Industry's Longest)
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- Tower Winch System using Hand Drill Power
- Installation & Support by Over 500 BWC Dealers

The Bergey XL.1 24 VDC battery charging wind system is the most technically advanced small wind turbine on the market today. It provides superior energy production performance with the "Tornado Tuff" ruggedness that has made Bergey turbines best sellers since 1980. And, best of all, the XL.1 is value priced to give you the most bang for your buck.

The XL.1 now features an upgraded PowerCenter controller that idles the rotor once the batteries are full (Warning: Be prepared to spend hours flipping lights on and off to cause the rotor to speed up or slow down. Highly addictive to techies.) and provides a convenient push button brake function. In addition, we doubled the dump load capacity (to 60A) and gave it proportional (PWM) control to more accurately maintain battery voltage, added a "wattmeter function," made customizing set-points a snap, and added a polarity checker for the wind and PV inputs.

Compare features, performance, price, reputation, and warranties. We think you will find that the Bergey XL.1 is the clear choice for your home power system. Get product information and find a dealer near you by visiting our web site: www.bergey.com.

PowerCenter Controller

- 60A Wind Regulator
- 30A Solar Regulator
- 60A Dump Load Control Circuit
- Voltage Booster for Low Winds
- Battery and System Status LEDs
- "Wattmeter" LED Function
- Timed Equalization Function
- Push Button Rotor Brake
- Slow Mode Rotor Idling
- Easy Set-Point Adjustment
- Polarity Checker

Typical Performance: 5.2 kWh DC per day

4 Times More Energy Than the Air 403[1] **1.8 Times More Energy Than the Whisper H40[2]**

1–Air is a registered trademark of Southwest Windpower, Inc.
2–Whisper is a registered trademark of Southwest Windpower, Inc.

11.2 mph (5 m/s) Average Wind Speed at Hub Height, Rayliegh Distribution. Based on manufacturer's published power curves.

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HP97 contents

On the Cover

PVs on custom racks by Baran Galocy overlook beautiful Shasta Lake in northern California. Photo by the Great McGarigal GraFX Company.

Regulars

All of the People,

All of the Time

For sixteen years, *Home Power* has been encouraging the mass adoption of home-scale renewable energy (RE) technologies. It has been satisfying to watch the use of renewables become broader and deeper as the technologies, the industry, and the audience evolve and grow.

Along the way, we've learned that people choose renewable energy technologies for many different reasons. Energy independence, positive environmental impact, homeland security, reliability, and cost-effectiveness are among the most common motivators.

To be true to our mission, the magazine content needs to reflect this diversity. With the help of a growing pool of authors and editors representing varied perspectives, we hope we're living up to this responsibility.

Home Power doesn't discriminate based on *why* anyone chooses renewable energy. We're not in the business of advocating one motivation over another. Our job is to provide concrete information on *how* to use RE. By showing how people from all walks of life are doing it, we hope more *HP* readers will find something inspiring, and move from thinking about RE to actually using the technologies.

If we align the magazine behind a single opinion or ideology, we inevitably risk alienating potential RE users who have differing viewpoints. This would slow our progress toward a sustainable energy future—something we can't afford to do.

We hope you support this inclusive approach aimed at reaching the widest audience with the most compelling, motivating, down-to-earth, real-world coverage of renewable energy technologies. Renewable energy resources are available to all people, regardless of their viewpoint. *HP's* RE information is here for everyone too.

–Scott Russell, for the *Home Power* crew

Think About It

What's the use of a fine house
if you haven't got a tolerable planet to put it on?

—Henry David Thoreau

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"Hard Day At Work"
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Solar Solidarity

An IBEW-Supported PV System

Vincent Endter

I have been interested in solar electricity for many years, but the timing never seemed right for installing a system. When my union, the International Brotherhood of Electrical Workers (IBEW) joined with the National Photovoltaic Construction Partnership (NPCP), it was time to act.

Through the NPCP, union members can purchase prepackaged systems at wholesale cost. The NPCP will even carry the California rebate for the member, lowering the out-of-pocket expense even further. The NPCP helps train union electricians to install solar-electric systems, and shows business and industry that solar-electric systems are a viable addition to conventional utility supply.

The system supplied by the NPCP consists of Sharp 165 polycrystalline PV panels and SMA Sunny Boy inverters. We had a choice of 14 panels and an 1,800 watt inverter; or 18 panels and a 2,500 watt inverter. The installation hardware is the responsibility of each member. I chose to purchase two of the larger systems. This gives me a peak AC output rating of about 5,000 watts.

The Sunny Boy 2500 inverter is a grid-tie only inverter, with no provisions for battery backup. Most IBEW members live in cities where dependable electrical service means that the additional cost of battery backup does not make financial sense.

These eighteen Sharp 165 modules, in two parallel strings of nine, feed one Sunny Boy inverter.

Design

The first step for me was figuring out how I was going to fit 36 PV panels on my roof to take full advantage of the sun. I have a ranch-style home shaped in a U, so I have two south-facing roofs. Unfortunately, one roof has two skylights and both roofs receive shade from two of my neighbors' trees. I worked out a layout that would fit with the skylights, and had to use both roofs to fit all the panels.

The second bank of modules, same as the first bank, feeds the system's other Sunny Boy inverter.

Unistrut rack material on top of the new metal shake roof.

It is very important to keep PVs unshaded. I have observed that with 12 percent of my array shaded, the output drops by 50 percent. The shade is coming from my neighbors' trees, with the worst tree located two houses away. During the summer when the sun is higher in the sky, this tree no longer shades my system. One palm tree will still shades my panels for about two hours a day.

My house had a shake roof. Part of the roof was 40 years old; the other part was only 8 years old, but the newer part had just started leaking. The thought of installing all those panels just to have to remove them in a couple of years to reroof did not sit well. My wife and I decided to reroof first.

After researching various roof types, we chose a metal shake roof that was guaranteed for 50 years and designed to be walked on. The roofing company even guaranteed all the roof penetrations for the PV panel supports. One of the beauties of this type of roof is that it has 2 by 2 supports every 8 inches (20 cm) running parallel to the roof ridge to support the metal tiles. These 2 by 2s also made the PV supports easy to install.

The city I live in, San Jose, has only three requirements for a permit for rooftop installation of a PV system:

- The panels have to be less than 18 inches (46 cm) above the surface of the roof.
- The total weight of the system cannot exceed 4 pounds (1.8 kg) per square foot.
- All supports must be limited to 40 pounds (18 kg) each.

If your system does not meet these requirements, you have to submit structural drawings and calculations for your installation. My system met all the requirements. The only additional information they required was a one-line diagram of the electrical, and a sketch of the physical installation. The entire permit application process took only 20 minutes, which is quite fast for the city of San Jose.

Technical Specifications

System type: Batteryless grid-intertied system

PV specs:

- Panel manufacturer and model: Sharp Electronics NE-Q5E2U
- Number of modules: 36
- Module wattage rating: 165 W
- Module voltage rating: 24 VDC
- Array voltage: 216 VDC nominal
- Each parallel subarray of PVs: Modules are wired in four series-connected strings, with nine modules in each string, and two strings paralleled per inverter.
- Operating current: 9.5 A
- Operating voltage: 311 Vmp
- Maximum voltage: 387.9 V
- Short circuit current: 10.9 A

Array combiner box manufacturer, model, and fuse/breaker size: Hoffman enclosure with a dual fuse holder and two, 10 A, 600 V, DC-rated fuses.

Array disconnect model and fuse/breaker size: Square D HU361RB, 600 VAC/DC at 30 A, nonfused disconnect.

Inverter manufacturer and model: Two SMA Sunny Boy SWR2500U, 2,500 watts each.

System performance metering: Sunny Boy Control Light, with RS485 modules, monitors the inverters, and Sunny Data Control software logs the data.

Average KWH per month: Minimum 300 KWH in December; Maximum 1,300 KWH in June/July, estimated.

Utility KWH cost: Winter off-peak, US$0.08; peak, US$0.12; Summer off-peak, US$.08; peak, US$0.32

Percentage offset by PV system: 150 percent, estimated

Installation: PV Mounting

Since I am an electrician, I was not worried about the electrical part of the installation. I did more research on the physical installation of the PV panels, but found very little information on various ways of attaching the PV panels to my roof. I happened to find out about a solar home tour in the city of Palo Alto. It was there that I first saw UniRac PV mounting supports.

The UniRac system looked very much like the Unistrut system that I use for work, so I decided to make my own. I was able to order Unistrut in aluminum, to save weight in the installed system and to prevent corrosion from galvanic

Hanger bolts, Unistrut rails, and custom-made brackets (Z-bracket shown) for securing the panels make up this mounting system.

Custom U-brackets hold down adjacent panels.

interaction with the panels. I used hanger bolts to support the Unistrut. This bolt has wood screw threads on one end, and machine screw threads on the other. These bolts were screwed into the 2 by 2 roof supports at 4 foot (1.2 m) intervals. The total weight was 15 pounds (7 kg) per support. I attached the Unistrut to the hanger bolts with a 3/8 inch (10 mm) bolt, lock washer, washer, and rod coupling.

The brackets that hold the PV panels to the Unistrut were custom made. There are two types—a Z-bracket for the end of a row of panels and a U-bracket for between adjacent panels. These brackets were made out of 1/8 by 1 1/2 inch (3 x 38 mm) aluminum. I had them made 1/8 inch shorter than the panels were tall to allow some spring in them so they would hold the panels down very tightly. The brackets are connected to the Unistrut with 1/4 inch (6 mm) Unistrut nuts and 1/4 inch bolts with lock washers. Three days after I mounted the panels, we had the biggest windstorm in 25 years, with winds gusting to 90 mph (40 m/s). None of the panels moved, so I am confident in my mounting method.

Installation: Wiring

The Sharp 165 watt panels are 24 VDC nominal. Each panel comes with integral Multi-Contact connectors on USE-2 wires 4 feet (1.2 m) long. This wiring system is UL listed and rated for 90°C (194°F), wet, and direct sun locations.

The Sunny Boy inverters are designed for "string" wired panels (series connected). PV voltage and power decrease as temperature increases. Both the maximum high and low temperatures at your site need to be considered when calculating the number of panels in series. The SMA Web site has an online calculator for determining how many panels need to be in the string at your site to best meet the voltage requirements of the inverter. The strings can be paralleled to increase the connected wattage. I have nine panels per string, with two strings paralleled per inverter.

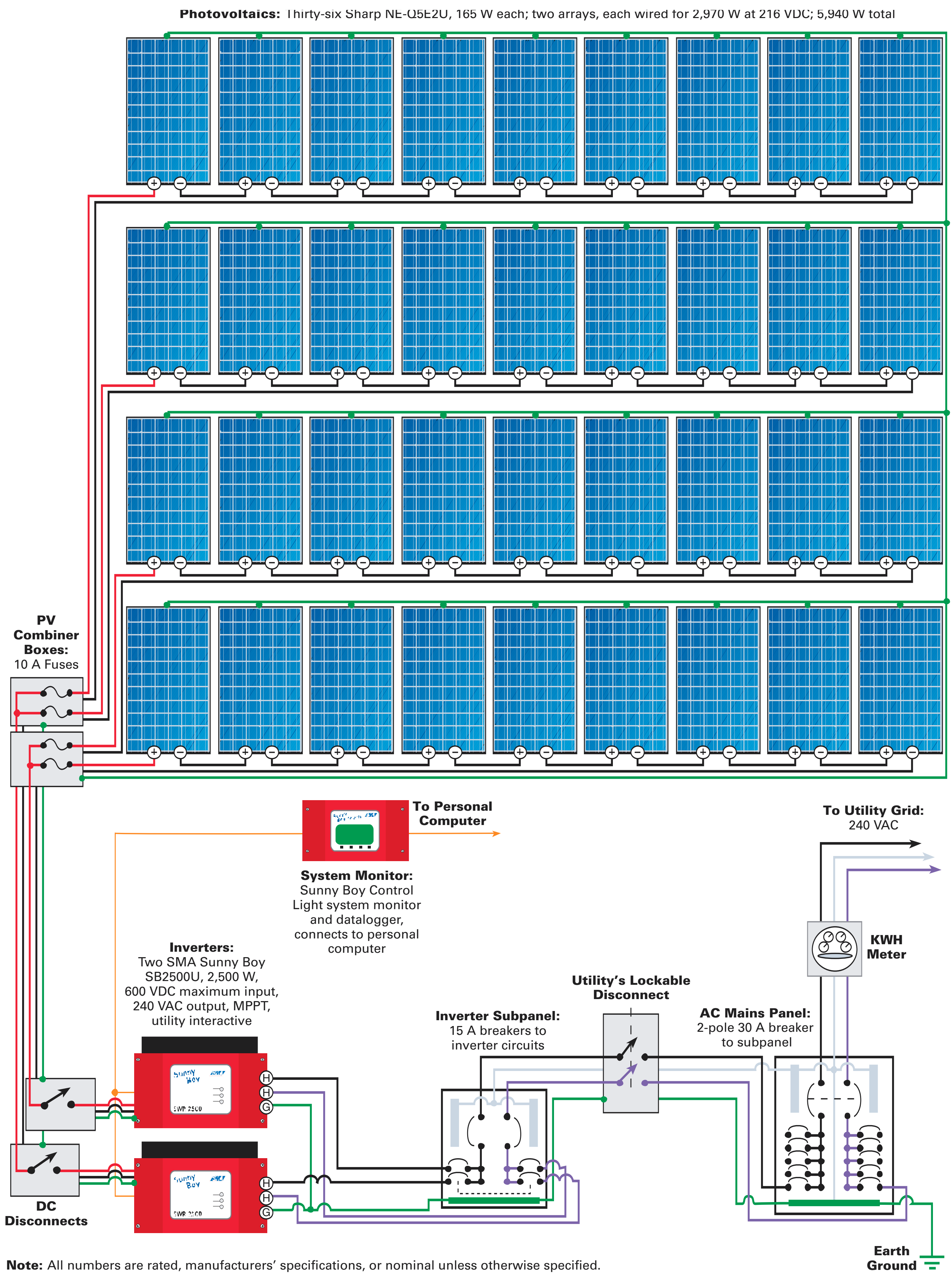
Wiring the panels was as simple as plugging the MC cable from each panel into the cable from the next one. I needed to order custom Multi-Contact cables to bring the positive and negative output wires to the combiner boxes. The wiring was secured underneath the panels with UV resistant zip ties. I had to install some conduit for the wires where they run in the open between the skylights. This is very important. In some cases, the voltage in the wires could be close to 400 volts DC, which can be deadly. I did not want any chance of someone accidentally contacting these wires.

When the strings are paralleled, each string needs to be protected by a series fuse. Each module has a specific series fuse rating that is dictated by the manufacturer based on the operating characteristics of the module. The 165 watt Sharp modules I used require a 10 A, 600 VDC-rated series fuse. These are often installed in combiner boxes. I made my own combiner boxes by purchasing 6 by 6 by 4 inch NEMA 3R boxes and installing a dual fuse holder in each. It's important to note that some electrical inspectors will not allow homemade combiner boxes, even if all of the individual components are UL listed. Make sure to run your ideas by the local inspector first. Total cost of each box was about US$40 versus US$200 for a manufactured combiner box. From each box, it was a simple matter to run a raceway with three, #12 (3 mm^2) wires (including one ground wire) to each DC-rated disconnect and then to the inverters, which are mounted in the garage. This is one of the benefits of high voltage, string (series) installations—a lot less wiring and smaller wires.

I used my normal electrical supply houses for the material used in my installation. Both my sales reps and I learned about DC-rated equipment. I had done some telephone central office installations that were 48 volt DC, but this was my first high voltage DC installation. The DC fuses and DC disconnects had to be special ordered.

Inspection

Once everything was wired, I called for an electrical inspection. The electrical inspector had never seen Multi-Contact connectors. He was going to turn down the



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

Equipment & Labor

IBEW members get fantastic deals on group-purchased RE equipment, but most folks could expect to pay more than US$30,000 plus labor for a system like ours. The NPCP fronted the money for the California rebate, and they received the rebate directly from the state.

I supplied all of my own labor for the installation as follows:

- **DC wiring from the roof to the inverters:** 6 hours
- **Mount and wire the inverters:** 4 hours
- **Install the Unistrut supports:** 8 hours
- **Mounting and wiring the panels:** 6 hours
- **PG&E required disconnect, conduit, and wire:** 6 hours
- **Total:** 30 hours

installation until I showed him the UL listing I had downloaded from the Internet for just this reason.

The inspector was also confused about what constituted a "separately derived system." Separately derived systems are typically generators, transformers, etc. PV systems that have battery backup are also separately derived systems. My grid-tie system is not. It is 240 volts, tied directly to the main panel (no transfer switch), and does not derive its own neutral. I spun my wheels on this issue until I insisted we call the inspector's boss. His boss agreed with me and the inspector signed the permit (though his ego was a bit bruised).

Then all I had to do was throw the switch and start generating, right? Wrong! My utility, PG&E, insisted on inspecting the system, and they wanted to verify that I had a disconnect switch within 10 feet (3 m) of my meter. This disconnect requirement is a sore point with me and others who have to deal with PG&E. Their requirements were written in the 1970s, when the state legislature required them to purchase electricity from small generators. With today's inverter technology, it is virtually impossible to backfeed their distribution system when it is de-energized, making this requirement obsolete for my type of PV installation.

But I installed the required disconnect. It added almost US$500 to the installed cost of the system (though the disconnect itself was less than US$50). If I had not needed the disconnect required by PG&E, I could have run both inverter outputs into an existing subpanel that was less than 3 feet (0.9 m) away from the inverters and I would have been done. Instead, I had to install another subpanel just for the two inverter outputs and then run a new 50 foot (15 m) raceway from my inverters, under my house, to the new disconnect next to the meter.

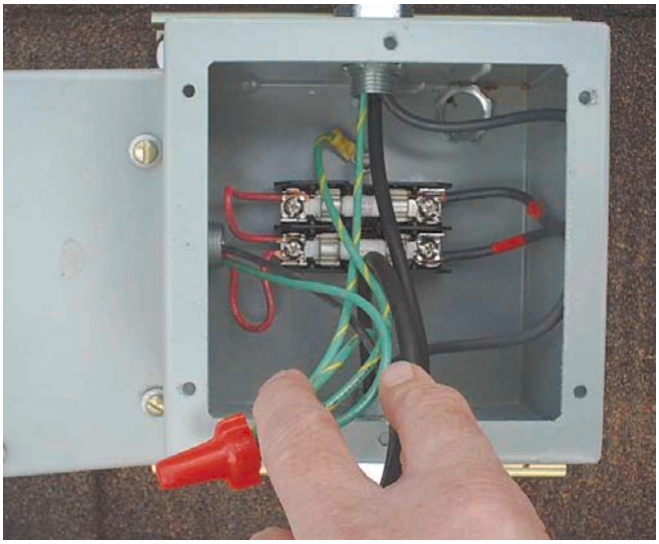
PG&E will not schedule an inspection until they receive a copy of the final electrical permit. Once they receive the permit, it takes them ten days to call and schedule an inspection. When they called, the earliest inspection they could do was 30 more days out (our city inspection was 24 hours). When their inspector finally showed up, he told me that he had not had any inspections in the last 6 weeks and he could have inspected my system 30 days ago. It makes me wonder if PG&E is truly committed to renewable energy sources.

At the same time as our utility inspection, I had them upgrade our meter to a time-of-use meter. The price we now pay for electricity is higher from noon to 6 PM weekdays than the rest of the time. During the summer months, it is 32 cents per kilowatt-hour for these times and only 8 cents per kilowatt-hour for the off-peak times. This will benefit us because our system will generate most of its electricity during the peak time. We will be *selling* to the utility for 32 cents during these time periods. If your goal is zero billing instead of zero usage, your system can be sized smaller if you can get time-of-use metering. The cost of the new meter was US$277.

Results

For the first month (December 12th to January 11th) that our system operated, we generated 298 KWH of electricity. This was about 10 percent lower than I had calculated. Some of the loss was due to very cloudy conditions for the time period. Most of the loss was due to the shade from the trees.

Two SMA Sunny Boy 2500 inverters, two DC disconnects, and the AC panel.



One of the homemade combiner boxes with 10 A, DC-rated fuses.

The time-of-use meter shows that when Vincent took the photo he was selling at the rate of 3.5 KW to PG&E.

Our usage averages about 800 KWH a month. We should end up generating as much electricity as we use. With the time-of-use meter, we will have a net dollar credit each year. The law in California changed in the last couple of years, and now any credit goes to the utility, instead of a payment going to the customer. We will start over at $0 each year.

I have only been net metered for a few months and I am already "in the black," having generated more electricity than I have used. I will know more by the end of the year, but I am projecting a 50 percent surplus in my electrical energy use. When I moved into this house, I changed most of the appliances to gas to keep my utility bill down. With all the excess energy I am generating, I will be changing back to electric appliances as they need to be replaced. In the interim, I will be using more electric space heaters this winter.

Goals

We hope that our PV installation will:

- Pay for itself in a reasonable period of time (at current rates, we are guessing between 6 and 8 years).
- Be some small help to alleviate California's electricity problems and our country's dependence on oil.
- Encourage others to do the same.
- Be a showcase for selling PV systems.

It should be noted that we had done about all we could to reduce our electrical usage prior to our PV installation. We have either T8 fluorescent lamps with electronic ballast or compact fluorescent lamps for our lighting. Our dryer, water heater, and cooktop are gas. For each dollar spent on electrical reductions, you save three to five dollars on the cost of a PV system. Efficiency combined with solar electricity gives us an economical system that is a good example to others.

Access

Vincent Endter, Clark Electric, 3469 Victor St., Santa Clara, CA 95054 • 408-988-4358 • vince@vincenancy.com

Sharp Solar Systems of America • 630-378-3357 • www.sharp-usa.com • PVs

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

Multi-Contact USA, 5560 Skylane Blvd., Santa Rosa, CA 95403 • 707-575-7575 • Fax: 707-575-7373 • sales@multi-contact-usa.com • www.multi-contact-usa.com • Multi-Contact connectors

Unistrut Corporation, 35660 Clinton St., Wayne, MI 48184 • 800-521-7730 or 734-721-4040 • Fax: 734-721-4106 • www.unistrut.com

National Photovoltaic Construction Partnership (NPCP; for union electricians), 20 Bursley Pl., White Plains, NY 10605 • 866-983-2819 or 212-581-4030 • Fax: 604-983-2869 • operations@npcpunited.com • www.npcpunited.com

International Brotherhood of Electrical Workers (IBEW), 1125 15th St. NW, Washington, DC 20005 • 202-833-7000 • Fax: 202-467-6316 • journal@ibew.org • www.ibew.org

California Energy Commission (CEC), 1516 9th St. (MS 45), Sacramento, CA 95814 • 800-555-7794 or 916-654-5127 • Fax: 916-653-2543 • renewable@energy.state.ca.us • www.consumerenergycenter.org/erprebate/index.html • Buydown information

In conjunction with with the release of our new line of VFX vented Sinewave Inverters/Chargers, we're also introducing the HUB - 4. Offering complete connectivity for your OUTBACK Power System.

FX Series Sealed Sinewave Inverter/Chargers

FX2024 2.0 kWAC 24 VDC $1795 USD
FX2048 2.5 kWAC 48 VDC $2245 USD

Sealed Construction Features:

- Powder Coated all aluminum die-cast chassis
- Internal electronic components are cooled by heat transfer
- Gaskets on all openings to provide water-resistance
- Sealed design protects internal electronics from salt, dirt, contaminated air, bugs, critters, mold etc.
- Conformal coated circuit boards to resist corrosion
- Designed to allow easy field servicing and repair

Ideal Applications:

- Hot and humid climates where a protected area is not available for installation of the inverter/charger system
- Salt air environments such as Hawaii where you can't get away from the salt air and where there is little difference between indoors and out doors
- Dirty environments where dust or drifting organic matter such as cottonwood could clog an air opening in an unattended system
- Boats and RV's where water might splash on the inverter Greater control of unwanted radio frequency interference

MX60 $649 USD

New Features:

- Data logging (64 days)
- Amount of time in float, logged Amp hours and kilowatt hours, 140 Voc (three 24v modules in series)
- Adjustable current limit

WinVerter™ - Monitor FX $60.00 USD

- Windows based software that works with the OUTBACK FX Series inverters via the Mate Remote Control

Available through RightHand Engineering

VFX Series Vented Sinewave Inverter/Charger

VFX2812 2.8 kWAC 12VDC $2345 USD
VFX3524 3.5 kWAC 24VDC $2345 USD
VFX3648 3.6 kWAC 48VDC $2345 USD

Vented Construction Features:

- Powder Coated all aluminum die-cast chassis
- Internal electronic components are cooled by outside air
- Stainless steel screen to protect air intake and Internal fan
- UL94V0 plastic vent grills to protect the air exhaust. All openings are 0.0025 inches square to keep out dirt, bugs, and other critters.
- Air inlet comes with removable washable foam filter insert to trap small particles
- Conformal coated circuit boards to resist corrosion
- Higher output power when inverting or battery charging when compared with the sealed FX inverter versions
- Designed to allow easy field servicing and repair

Ideal Applications:

- Montana or Arizona etc. where salt air is not a problem and climate is dry
- More watts per dollar
- Installations where well protected environments are available

HUB - 4 $195 USD

- The HUB-4 system communications manager allows the interconnection of up to 4 OUTBACK power conversion devices with the MATE. The interconnection creates a completely integrated Power System that is coordinated and managed by the MATE.
- The HUB - 4 allows the MATE to control any combination of four FX series inverter/chargers and MX60 MPPT charge controllers

OutBack Power Systems

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Successful Solar Businesses—2004

Build a Healthy Business—Build a Healthier Planet

A three-day conference at SUNY in Farmingdale, New York, taught by Richard Perez of Home Power, Bob-O Schultze of Electron Connection, and Bob Maynard of Energy Outfitters on how to start and operate a successful renewable energy business.

Topics include:
how to start a small solar business, renewable energy career choices, managing a small business, managing employees, marketing renewable energy, legal and tax issues, and using computers.

Dates: February 20–22, 2004

Place: SUNY Farmingdale Campus, Farmingdale, Long Island, New York

Cost: $425 (includes three lunches and a Saturday night banquet). Conference fee is nonrefundable, but transferable. This conference is sponsored by NESEA, NYSEIA, and SEBANE and members will receive a $25 discount.

PV Technology Workshop:
For those wishing to come up to speed quickly on PV technology, a special one-day workshop, taught by NYSEIA, will be held at the same location.

Date: February 19, 2004

Cost: one-day PV workshop: $75

Conference and workshop size is limited, so contact Home Power at 800-707-6585, 541-512-0201, or richard.perez@homepower.com to reserve your place.

Interest is very high in this conference, so reserve early if you wish to be sure of a place. Lodging will be available at discounted rates for conference participants.

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

Solar Water Pumping Makes Sense

Windy Dankoff

Workshop participants assemble the rack for the pumping system's solar array.

Butch and Linda Sagaser have a spectacular homesite in sunny eastern Oregon, overlooking the John Day River. After 15 years in a mobile home, they are finally building their dream house. They have grid electricity, so solar electricity was a distant dream, until it began to make sense for their water supply. With their finances already stretched by their homebuilding project, solar electricity had to be economically viable.

For Butch and Linda, energy efficiency has been a priority for a long time. Before moving to their property, they lived off-grid both on land and on a boat, so they learned how to minimize their energy consumption. Since then, they have followed the basic guidelines of avoiding electric heating and cooling, and buying efficient appliances.

Water pumping was the Sagasers' biggest electrical load, until this project was completed. Although they have a shallow well, their pump accounted for more than one-third of their electrical energy consumption. It was a 230 VAC jet pump, a nonsubmersible pump that is not very energy efficient. When they ran water up to their new homesite, 80 vertical feet (24 m) uphill from their old house, they found that the water came out at a dribbling rate. Installing a more powerful pump did not fit their energy goals. It was time to look for an efficient solution.

Butch and Linda also have frequent grid failures. They are hooked to a long rural utility line, exposed to frequent lightning and ice storms. Utility failures can last for hours and sometimes days. With wood and propane for heating and cooking, and some handy oil lamps, the grid outages would only be an inconvenience if they weren't deprived of their water supply. A solar powered water pump sounded like the ideal solution.

Considering a Solar Powered Pump

The Sagasers had seen solar pumps demonstrated at the SolWest Renewable Energy Fair, and knew that ranchers and off-grid homeowners had been using them since the 1980s. Recently, the pumps have become very reliable, and the costs have dropped. A low-volume solar pump can draw the water slowly, using a small solar-electric array, and pump all day long into a storage tank. The Sagasers have a well that only produces a few gallons per minute, so the slow pumping concept sounded most appropriate. They asked their friend Jennifer Barker for advice.

Jennifer heads the Eastern Oregon Renewable Energy Association, and lives with her husband Lance on a solar powered homestead (See *HP83*, page 50). Jennifer offered to help survey the Sagasers' homesite, to see how much pumping lift would be required.

Jennifer and Linda set out to measure the elevation gain from the water well up to the proposed storage tank site. Their tool of choice was a laser level (a common construction tool) on a 5 foot (1.5 m) stand. Starting from the well, which is located 30 feet (9 m) below the old house, they pointed the light horizontally in the direction that they would walk up the hill. The spot where the light struck the ground became the next measuring point. They only had to count the number of stages of measurement, and multiply by 5 feet.

The elevation gain proved to be 30 feet (9 m) from the top of the well to the old house, plus 80 feet (25 m) up to the

The pump controller wired.

How the Sagasers' Solar Pump Works

The photovoltaic array is built from typical crystalline modules. Four, 75 watt modules are wired in series for 300 rated watts at 48 volts nominal. The DC output from the PV array runs through a safety disconnect switch to a pump controller that is made especially for their pump. The controller gives the motor the form of electricity that it needs to start and run under widely varying conditions. The controller also allows the use of a remote float switch to turn the pump off when the tank is full, and a low-water probe to prevent the pump from running dry if the water source drops too low.

The pump uses a "helical rotor" that seals water into cavities and forces it up as it turns. When it slows down in low-sun conditions, it can still produce the full lift. This forcing action is called "positive displacement." It is much more energy efficient than a conventional submersible pump that uses impellers and centrifugal force.

The controller gets the pump started and running in low-light conditions by reducing the voltage from the solar-electric array, and boosting the current. This is like putting a vehicle into low gear. It then "inverts" the DC output of the array to 3-phase AC. This means that overlapping AC waves deliver energy continuously, unlike ordinary single-phase AC that we have in our homes. The controller varies the frequency of the AC output to vary the motor speed. At startup, it brings the speed up slowly, so no power surge is required. It limits the frequency to prevent overspeed, and cuts the power when sunlight is insufficient.

Cut-away view of the helical rotor mechanism, showing cavities that form between the rotor and the rubber stator.

Battery Systems

Solar pumps are also available for battery systems. They can run on demand to supply pressure any time. This is how most domestic wells work, and it's economical where an elevated tank isn't feasible. If the Sagasers had a battery-based system within about 250 feet (75 m) of the well, and a faster-flowing well, I would have recommended tying their pump to the battery system and using an 80 gallon (300 l) pressure tank instead of the elevated storage tanks.

new house, plus 90 feet (27 m) up to the tank site. Adding the well depth of 20 feet (6 m), the total vertical lift (pumping height) is 220 vertical feet (67 m). The 90 foot drop from the tank to the house produces 40 psi (2.7 bar), which is excellent pressure for a house that has well-designed (low-friction) plumbing.

Solar Pump Selection & Planning

Jennifer called me to see what kind of solar pump I would suggest. I looked at the sizing chart for our submersible solar ETAPUMP to find a system that would perform the necessary vertical lift at a modest cost. I selected a system with a peak flow rate of 2.5 gallons (9.5 l) per minute, because their well can't produce much more than that.

The chart indicated that the daily output of water from this system would range from about 400 gallons (1,500 l) per day in winter, to about 1,000 gallons (4,000 l) per day in summer. That's about twice the water that the Sagasers were consuming. They said they would be happy to make a pond and expand their garden, lawn, and orchard, if the system wouldn't cost too much and would last for years without trouble.

I explained that the ETAPUMP system was new on the market, but has only one moving part, no batteries, and a four-year warranty. They were getting more interested. What about installation? I was planning a return trip to the SolWest Renewable Energy Fair in July 2002. Jennifer proposed that I do the installation as part of a hands-on educational workshop just before the fair. It sounded like a great idea.

I only needed to find a local dealer to supply the pumping system, and to do some of the groundwork in advance. Jim Slater of Eastern Oregon Solar Electric was the likely suspect. He had not yet seen the new ETAPUMP, so he was wary of being in the spotlight. I sent him the instruction manual, and it gave him the confidence to accept the job.

Windy Dankoff (far left) advises the crew on lowering the pump—the well is only 20 feet (6 m) deep.

The pump sits below the surface. A pitless adapter fitting allows the pipe to pass through the well casing below the frost line, and it seals dirt out.

Installing the Pump

Jim worked with Butch Sagaser to do the groundwork in advance. They set the support pipe for the solar-electric array, and buried electrical conduit to the well. Butch ran water pipe all the way up to a 1,200 gallon (4,500 l) storage tank, and buried the pipe below the frost line. We planned to have the students install the solar array, controller, and pump in one day.

The workshop was scheduled for two days in late July. Ten eager participants showed up, including some homeowners, a teenager and his mother, and an Americorps volunteer. Two experienced volunteers came from Solar Wind Works in Truckee, California. They helped answer questions and tried not to work too hard.

Technical Specifications

System type: Batteryless PV water pumping system

Pump: ETAPUMP Model HR-04 helical rotor pump with 65 V, 3-phase brushless permanent magnet AC motor; maximum capacity, 0.55 KW

Controller: ETAPUMP PV-Direct Controller, Model EP-600. Controller contains maximum power point tracking and linear current booster circuitry, variable frequency 3-phase inverter, remote float switch, and low-water shutoff functions.

LEDs on the controller indicate: System On, Pump On, Full Tank/Off, and Low Water/Off

PV manufacturer and model: BP Solar 75TU

PV module STC wattage rating: 75 W

Nominal array voltage: 48 V

Array disconnect model and fuse/breaker size: Square D 30 A fused disconnect with 10 amp fuses

We spent the first day in the classroom where I explained the basics of water pumping, solar electricity, solar pumps, and system design. The second day began with a drive out to the Sagasers' homesite. I was happy to see that Jim and Butch had prepared everything "by the book."

The participants got to work bolting up panels, wiring, splicing cable, plumbing, and simply watching and learning. We dropped the pump in by hand because the well is only 20 feet (6 m) deep. The sun was hot, but nobody complained—it would be our fuel source! At about 3:30 PM, we turned the switch on. We heard a gurgling sound in the pipe as water started its way up to the storage tank. The sun was getting low, and clouds were blowing by, but luck was with us. It took a half hour to fill 600 lineal feet (180 m) of 1 1/4 inch pipe. We took a little break, and then hiked up the hill to watch the water start spilling into the tank 220 vertical feet (67 m) up the hill.

Next, we scrambled down the hill and got out our multimeters to measure voltage and current at the pump

Butch and his daughter Rachel watch the first water enter their 1,200 gallon (4,500 l) storage tank. A second tank has since been added, and both are buried.

Letter from the Sagasers

Butch and I are thrilled with our water system. We have two tanks above the house now, piped together, for a total storage of 2,400 gallons. I frequently check their water levels, and am happy to see that they are almost full even when I think I've used a lot of water that day. Butch says the overflow is running daily. We use it to water fruit trees and grass.

We have already seen a decrease in our electricity bill. It would be safe to say that we are saving 3 KWH a day with our new system. At US$0.08 per KWH, we are saving US$7.20 a month, but we are pumping to twice the height, now that we are in our new house, and using more water. This summer, when we used the overflow in the yard, we saved still more because we no longer needed the small electric pump that we used to have for irrigation.

We thank Windy, Jim, and Jennifer for their help, and hope our project will spark other people's interest.

Thanks,

Linda & Butch

Pump System Costs

Item	Cost (US$)
ETAPUMP Integrated System #ETA-04-300, includes: Pump, HR-04 with motor; Controller, EP-600; 4 BP Solar 75TU PV modules, 75 W; UniRac fixed PV rack; Disconnect; Low-water probe	$4,100
2 Polyethylene water tanks, 1,200 gal.	1,400
Wire, conduit, etc.	180
Total	$5,680

The installation crew says, "We did it!"

connections. I explained to the students that the voltage to the pump varies with the sunshine, and determines the speed of the motor. The torque load on the motor (how hard it is to turn) determines the current draw, and that is determined by the height of the water lift. We watched the voltage vary with the sunshine. The current stayed constant, as expected, because the height of the water lift doesn't change.

The pump is supplied with a low-water probe. If the water level drops lower than the probe, the controller turns the pump off. This prevents the pump from being damaged if the well runs dry. To demonstrate this function, we pulled the probe out of the water, and sure enough, the pump stopped. We also watched the effect of changing sun conditions. As clouds came by, the pump slowed down and stopped occasionally. As we were ready to leave, with the sun nearly setting, we were surprised that the pump was still going—very slowly—but still producing a trickle.

Celebration by Candlelight!

That evening, Butch and Linda's neighborhood had a five-hour power-grid failure! We couldn't have planned it better. The solar pump had already pumped enough water into their tank for them to wash the dishes and to shower off the day's dust, and to invite a neighbor for a shower. Cheers!

Butch and Linda recently added one more 1,200 gallon (4,500 l) tank so they can be totally independent. The Sagasers' solar pump has supplied their water for more than a year. The only time they ran low was in December when they had practically no sunshine for more than a month. Their 2,400 gallon (9,000 l) storage was nearly depleted. Their old AC pump was still installed however, so they used it to supply the house for two days. After the fourth half-day of sun, the solar water tanks began to overflow once again.

Butch says "It works like a champ. This is simplicity at its best." He estimates that in about ten years, the system will have paid for itself and he'll be pumping free water. Their utility rate is quite low, at US$.08 per KWH, but the system cost was lowered by an Oregon tax credit.

Solar pumps are making a difference in the world, especially in areas that are remote from utility lines where it is expensive to buy and transport fuel, and to maintain engines. The Sagasers found solar pumping to be cost effective even though they have utility electricity. The most water is needed when the sun shines brightest, so solar electricity is the logical renewable energy source for water supply.

Access

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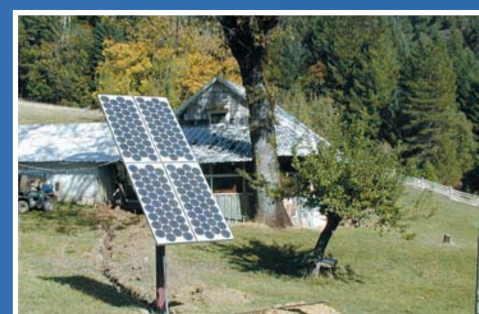
Butch and Linda Sagaser, 49002 Hwy. 26, Mt. Vernon, OR 97865 • 541-932-4753 • skibums@highdesertnet.com

Jim Slater, Eastern Oregon Solar Electric, 28599 SCC Dunhan Rd., Prineville, OR, 97754

Eastern Oregon Renewable Energies Non-Profit (EORenew) and SolWest Renewable Energy Fair, Jennifer Barker, PO Box 485, Canyon City, OR 97820 • Phone/Fax: 541-575-3633 • info@solwest.org • www.solwest.org • The author thanks Jennifer Barker of EORenew for her contributions to this article.



The Legacy of King Coal

David Muhly

A 2,000 acre mountain in Boone County, West Virginia is reduced to a pile of rubble.

I moved to the Dismal Creek section of Giles County in the mountains of Southwest Virginia in 1973. It was just what I was looking for after some years of anti-war and community activism, coast-to-coast traveling, and saving up a little money for a down payment. Fifteen acres or so, surrounded by the Jefferson National Forest, 4 miles (6.4 km) from the nearest neighbor, utility hook-up, or phone line...it was a back-to-the-lander's dream. I was getting away.

I came to renewable energy (RE) out of necessity, actually. Having the local utility, American Electric Power Company (AEP) run 4 miles of wire through the National Forest to one household was out of the question. Over time, kerosene and Aladdin lamps had given way to 12 volt taillight bulbs and then RV fluorescent fixtures in my household. The transistor radio hanging by a coat hanger had moved over for the homemade 12 volt turntable (made out of an old eight track tape player motor) and a 12 inch, 12 volt, black-and-white TV. Civilization had come to the mountain, and I needed a way to power it.

It wasn't until many years later, when we actually moved into the larger house we were building by hand, and cash became a little easier to come by, that I finally made the tentative moves into RE. This was still in the late 1970s, however. PV was expensive and modern inverters were in their infancy. Except for excellent resources such as *Alternative Energy* magazine, and (a decade later) *Home Power* (to which I was almost a charter subscriber), information was scarce at best. The Internet, of course, did not exist.

I am an auto mechanic with a BA. I'm not an architect, a mason, a carpenter, a plumber, or an electrician. But I figured that if I could build our house from the first shovelful of dirt up, plumb it, and wire it, I could design and install an RE system. The beauty of RE, of course, is that it can be a completely modular project. Gradually over the years, a panel at a time, a component at a time, the system took shape. I now have about 1 KW of PV, and a modern system that supplies all the electricity I need.

RE for Survival

I had come to RE because I had to. I did it the way I did because I wanted to. I enjoyed putting the system together piece by piece, learning at every step of the way. In 1994, however, I realized that RE was more than just a situational necessity, a personal preference, or a hobby. I realized that RE was a powerful educational tool and that (despite what Dick Cheney says) it embodies the fundamental recognition of energy conservation and attention to the state of our natural resources. Realizing this as a society will be necessary if we are to survive.

In 1994, my wife Donna and I became involved in the community-based struggle to deny that same utility, AEP, the right to cross the National Forest and our communities in rural Southwest Virginia with a 765,000 volt transmission line, the largest in use in this country. This area already has one of the accursed monstrosities, buzzing and crackling through field and forest as it wheels electricity from AEP's coal plants in the Ohio Valley and West Virginia, south and east to lucrative markets in North Carolina and northern and eastern Virginia. Claiming that southern West Virginia, eastern Kentucky, and southwest Virginia were at risk from brownouts and blackouts by 1998 if another 765 KV line was not built, AEP began to obtain the necessary state and federal permits for construction in 1991.

Eleven years and many skirmishes later, the Sierra Club and other conservation and citizens' groups are preparing to take the issue to federal court. AEP has plenty of financial incentive to continue to push this project forward, described by *U.S. News and World Report* (August 6, 2001) as the "the nation's longest-running battle over a high-voltage power line." Daily revenues from electricity transmitted on the proposed line to eastern markets could easily exceed US$2 million, with a net annual profit to AEP of over US$80 million.

Dave & Donna Muhly's passive solar home with roof-mounted PV array uses no coal power.

As a result of all of this activism, I came to know more about electricity generation and transmission than I ever wanted to know. I found myself talking knowledgeably about concepts like "orders of dispatch," and "peak shoulder load." I could look at energy flow diagrams across the AEP transmission system and see where, how, and when shortages or bottlenecks would occur. I testified before the Virginia State Corporation Commission, and I organized citizen participation in and expert testimony for the state permitting process.

King Coal in the Driver's Seat

What I learned went far beyond a struggle over a single (albeit horrendous) transmission line. Through it all, I came to know the driver behind the wheel of the community "bus" that is the electricity industry in this country, and the whole world for that matter. I came to realize that flipping on a switch anywhere on the grid allows that bus driver to punch your ticket. And when you sit down in your seat with your black and dusty ticket in your hand, King Coal swings around from the driver's seat and grins.

He grins through the bad teeth of broken promises to families, communities, and entire states. He winks with the gristled eye of destroyed water supplies and blasted and twisted landscapes. And he turns around, pedal to the metal, and will drive this bus to oblivion, to the edge of the precipice.

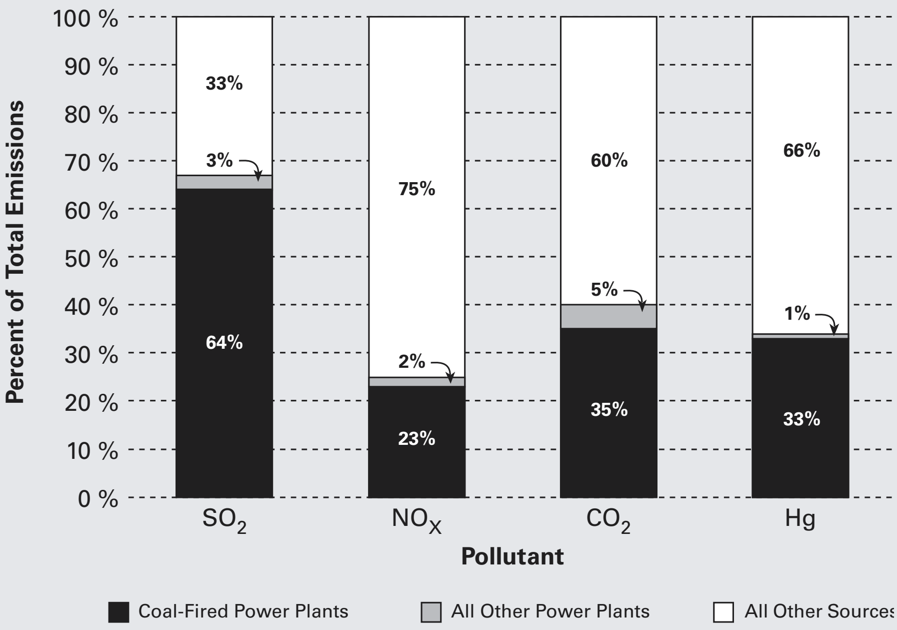
American Electric Power Company is the largest consumer of coal in the Western Hemisphere and one of the nation's top twenty coal producers. It is one of the largest suppliers of electricity in the United States. It owns and operates more than 42,000 megawatts of generating capacity, strings 38,000 miles (61,000 km) of transmission lines across the region (plus more than 186,000 miles; 300,000 km of distribution lines), and supplies electricity to more than 5 million customers in eleven states.

It owns the fourth largest inland barge fleet in the country (1,800 barges and 32 tugboats), used for shipping western coal to its Midwestern plants. It owns 7,500 rail cars, used to transport coal to its generating facilities from coal holdings in Ohio, Kentucky, Louisiana, Pennsylvania, Texas, Colorado, and West Virginia.

Nearby in West Virginia, AEP also contracts to purchase coal from entities such as CONSOL, Massey, and Arch Coal, mainly to feed its West Virginia plants. Many of these plants operate as if they are "grandfathered" from compliance with the New Source Review provisions of the Clean Air Act of 1970. That interpretation of the law is currently the subject of litigation by several Northeastern states, as well as a number of environmental groups, including the Sierra Club.

Meanwhile, plants such as John Amos in West Virginia spew hundreds of thousands of tons of toxins into the air annually, including mercury, cadmium, and other heavy metals. The General Gavin plant on the Ohio River recently bought the town in which it's located, moving the residents out lock, stock, and barrel, rather than clean up the sulfuric acid that rains down on them when the wind blows the

Coal-Fired Power Plant Emissions



From 2000 EPA data

wrong way. Throughout the Appalachian region, lakes are dying, trout streams are dead, and citizens suffer sickness and mortality as a result of AEP's uncontrolled emissions.

Clean Coal?

But none of that is news. And if you believe the pandering speech of the current administration in Washington or the press materials from industry (which are pretty much the same thing), you might believe that all of this could be done away with if we all would just heartily embrace the misnamed "clean coal technology." We are to believe that this oxymoron masquerading as a social program or "energy plan" will deliver us from these dark ages of respiratory arrest and environmental degradation, particularly if we also sign on to the Bush administration's "Clear Skies Initiative," a giant step sideways, if not backwards, in protecting this country's air.

The truth is, there is no such thing as "clean coal." Even if you could burn it without emissions (which you can't), and dispose of the waste and ash in an environmentally sound manner (which has never happened), there still remains that vexing little problem of getting it out of the ground.

That wouldn't be a problem if the coal was just lying around on the surface like pebbles on a beach, but it isn't. It is a problem, a very big problem, and recent "advances" in surface mining technology have made it even bigger. We have entered the age of "mountaintop removal" mining, or MTR, and to understand that we need to know a smattering of mining history.

What once was a hardwood forest-covered mountain.

Mining History

The history of underground coal mining in the Appalachians is well known. It's a history of torturous working conditions, ruthless operators, bloody union battles, places such as Kayford and Matewan, and names such as Mary Harris "Mother" Jones.

By the mid-twentieth century, deep shaft mining had become less and less profitable for operators, as rich seams (relatively) close to the surface had become fewer, and the labor costs associated with punching and operating shafts hundreds of feet in the ground became prohibitive. Thin seams (some only a couple feet thick) were numerous near the surface, and the practice of stripping off the topsoil to get to them became the mining practice of choice for many. Risk was lower, labor requirements were less, but the profit margin was thin. It took "sifting" through a lot of material to get a relatively small amount of coal.

In 1977, Congress passed the Surface Mining Control and Reclamation Act (SMCRA), designed to prevent the abuses that the activity of surface (strip) mining was wreaking upon the environment. Among other regulations, coal operators were forbidden to mine within 100 feet (30 m) of streams, and mined land was required to be returned to its "approximate original contour," or AOC.

The exemption (which later events would show was large enough to drive an overweight coal truck through) to that provision allowed for the land to remain in other than AOC if the resulting land would be used for "industrial or commercial" purposes. The former requirement concerning

The Side Effects of a Coal-Fired Power Plant

A 500 megawatt coal plant produces 3.5 billion kilowatt-hours per year, enough to power a city of about 140,000 people. It burns 1,430,000 tons of coal, and uses 2.2 billion gallons of water and 146,000 tons of limestone. It also puts out, each year:

- 10,000 tons of sulfur dioxide. Sulfur dioxide (SO_2) is the main cause of acid rain, which damages forests, lakes, and buildings.
- 10,200 tons of nitrogen oxide. Nitrogen oxide (NO_x) is a major cause of smog, and also a cause of acid rain.
- 3.7 million tons of carbon dioxide. Carbon dioxide (CO_2) is the main greenhouse gas, and is the leading cause of global warming. No regulations limit carbon dioxide emissions in the U.S.
- 500 tons of small particulates. Small particulates are a health hazard, causing lung damage. Particulates smaller than 10 microns are not regulated, but may be soon.
- 220 tons of hydrocarbons. Fossil fuels are made of hydrocarbons. When they don't burn completely, they are released into the air. They are a cause of smog.
- 720 tons of carbon monoxide. Carbon monoxide (CO) is a poisonous gas and contributes to global warming.
- 125,000 tons of ash and 193,000 tons of sludge from the smokestack scrubber. A scrubber uses powdered limestone and water to remove pollution from the plant's exhaust. Instead of going into the air, the pollution goes into a landfill or into products like concrete and drywall. This ash and sludge consists of coal ash, limestone, and many pollutants, such as toxic metals like lead and mercury.
- 225 pounds of arsenic, 114 pounds of lead, 4 pounds of cadmium, and many other toxic heavy metals. Mercury emissions from coal plants are suspected of contaminating lakes and rivers in the northern and northeastern states and Canada. In Wisconsin alone, more than 200 lakes and rivers are contaminated with mercury. Health officials warn against eating fish caught in these waters, since mercury can cause birth defects, brain damage, and other ailments. Acid rain also exacerbates mercury poisoning by leaching mercury from rocks and making it available in a form that can be taken up by organisms.
- Trace elements of uranium. All but 16 of the 92 naturally occurring elements have been detected in coal, mostly as trace elements below 0.1 percent (1,000 parts per million, or ppm). A study by DOE's Oak Ridge National Lab found that radioactive emissions from coal combustion are greater than those from nuclear energy production.

In addition, the 2.2 billion gallons of water it uses for cooling is raised 16°F (9°C) on average before being discharged into a lake or river. By warming the water year-round, it changes the habitat of that body of water.

stream protection was just ignored by the companies and the regulators, or the companies argued that streams that flowed only under wet conditions were not really streams at all.

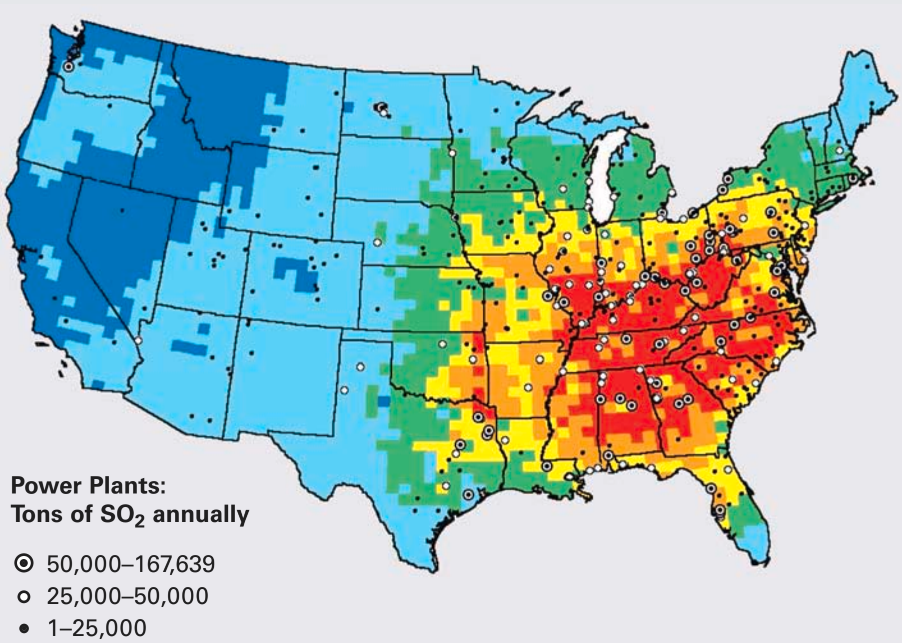
Mountain Top Removal (MTR)

The big change in surface mining came about, however, when technology caught up with greed, and huge pieces of equipment—draglines—became available. Of a sudden, the cost/benefit ratio involved in having to move large quantities of soil to get to those thin seams became less important. A dragline, such as "Big John," is basically a large shovel—a very large shovel. Big John stands like a twenty-story-tall crane, and its bucket can scoop up more than 83 cubic yards of material in one pass. Eight Jeep Cherokees could fit in the bucket.

Using a combination of draglines, high explosives, and a fleet of dozers, loaders, rock trucks, and pans that are dwarfed by the draglines and the walls of earth they create, hundreds of feet of mountaintops and slopes are shaved off, and systematically destroyed. Everything exposed or in place that is not coal, euphemistically called "overburden," is pushed off the side of what once was a mountain into the valley below. This overburden consists of dirt, topsoil, vegetation, rocks, and entire hardwood forests.

These "valley fills," unlike earlier surface mining operations that created ziggurats of reclaimed land and fills

Deaths Attributed to Power Plants



Deaths per 100,000 Adults Attributable to Power Plant Emissions

0–1 | 1–10 | 10–20 | 20–30 | 30–40 | >40 (max 70)

Image courtesy of Abt Associates.

that were built from the valley floor up, are no more than the legalized dumping of mine waste. One MTR mine can strip away up to 10 square miles (26 km^2) and dump hundreds of millions of tons of what was once a mountain into as many as twelve valley fills, up to 1,000 feet (305 m) wide and a mile (1.6 km) long.

The explosive charges regularly used by MTR sites to loosen the earth are equivalent in power to 10 to 100 times the force of the Oklahoma City bombing. Rock dust and debris rain down continuously on nearby communities. When the whistle blows, the ground shakes, foundations crack miles away, aquifers are driven underground, and streams disappear. Most communities near MTR sites, communities that have been home to hundreds of hardworking miners' families and others for generations, have been reduced to ghost towns, vandalized, and burnt. United Mine Workers (UMW) President Cecil Roberts' comments on the subject notwithstanding, many members of the rank and file, who have lost jobs to this machine-intensive process and have watched their communities disappear, feel strongly that they have been betrayed.

Thirty years ago, only one-tenth of West Virginia's coal production came from surface mining operations. Today, it's well over one-third. Between 1995 and 1998, West Virginia issued permits to surface mine more than 27,000 acres. Between 1999 and 2001, 40 projects were permitted in West Virginia, resulting in the loss of 61 miles (98 km) of stream and 15,000 acres of forested habitat. Approximately 10 permits per month are issued in Kentucky. In West Virginia, it's estimated that to date more than 300,000 acres of hardwood forest have been destroyed and more than 1,000 miles (1,600 km) of mountain streams have been forever and irretrievably buried.

The absolute scale of the destruction is overwhelming. Between 15 and 25 percent of southern West Virginia's mountains have been leveled, while regulators look the other way, legislators check their pockets for donations from King Coal, and the appeals courts overrule injunctions and lower court decisions. Mountain top removal/valley fill mining has been called an "abomination before God," the "ultimate blasphemy," and the "height of human arrogance." It is certainly all these things. And it goes on.

Are You on the Bus?

So when we, as RE users, flip on a switch bringing us electricity that comes not from coal, but from the sun or the wind or a small hydro installation, we can rest assured that we are not contributing to this wholesale destruction. But is that enough?

I think not. I believe we are compelled to speak, loudly and publicly, about the alternatives to this horror. I am certain we are responsible to do what we can, when we can, however we can to make the public and our legislators aware that there are alternatives, and that we will show the way.

So when we take that seat in the bus, we'll move to the back, thank you, and together we'll rock that bus away from the edge of the precipice. Together, we'll open the windows and let the sun and the wind in.

Access

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Union of Concerned Scientists, 2 Brattle Square, Cambridge, MA 02238 • 800-666-8276 or 617-547-5552 • Fax: 617-864-9405 • ucs@ucsusa.org • www.ucsusa.org

Southwings, PO Box 4744, Chattanooga, TN 37405 • 800-640-1131 or 423-892-4842 • info@southwings.org • www.southwings.org • A not-for-profit environmental aviation service that provided the flyovers of mountaintop removal/valley fill sites for the photos in this article

Sierra Club, 85 Second St., 2nd floor, San Francisco, CA 94105 • 415-977-5500 • Fax: 415-977-5799 • information@sierraclub.org • www.sierraclub.org/energy

Charleston Gazette, 1001 Virginia St. E., Charleston, WV 25301 • 800-982-6397 • Fax: 304-348-1233 •

kward@wvgazette.com • www.wvgazette.com/static/series/mining • An extensive series by Ken Ward on surface mining

Citizens' Coal Council, 1705 South Pearl, Room 5, Denver, CO 80210 • 303-722-9119 • Fax: 303-722-8338 • ccc6@mindspring.com • www.citizenscoalcouncil.org • Contacts for local groups active in MTR issues

Ohio Valley Environmental Coalition (OHVEC), PO Box 6753, Huntington, WV 25773 • 304-522-0246 • Fax: 304-525-6984 • ohvec@ohvec.org • www.ohvec.org/issues/mountaintop_removal/index.html

The Coalfield Communities of Southern West Virginia, Penny Loeb • cfdodge@msn.com • www.wvcoalfield.com • A community-based overview of mining's impacts in southern West Virginia

Clear the Air, 1200 18th St. NW, 5th floor, Washington, DC 20036 • 202-887-1715 • Fax: 202-887-8880 • info@cleartheair.org • www.ClearTheAir.org • Online resources on energy and coal-fired utility plants

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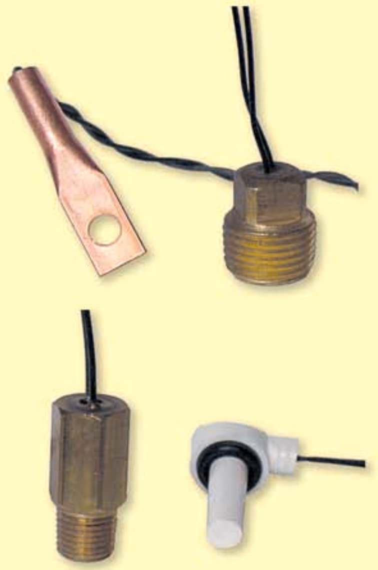
What the Heck? 8

Thermal Sensor



Ten K ohm sensors come in many forms. Clockwise from the upper left, a standard copper sensor, a pipe thread brass plug sensor, a white swimming pool sensor with "O" ring to attach to PVC pipe, and a variation of the brass plug sensor.

Used In: Solar hot water systems and other heating, ventilation, and air conditioning (HVAC) systems

AKA: Thermistor

What It Is: An electrical device that changes resistance when the temperature changes

What It Ain't: "Captain, Spock here. Sensors indicate a class M planet. Very little intelligent life."

Sensors are used with differential controls ("What the Heck?," *HP 94*). They are placed on equipment at designated locations, and measure temperatures remotely from a controller or monitor.

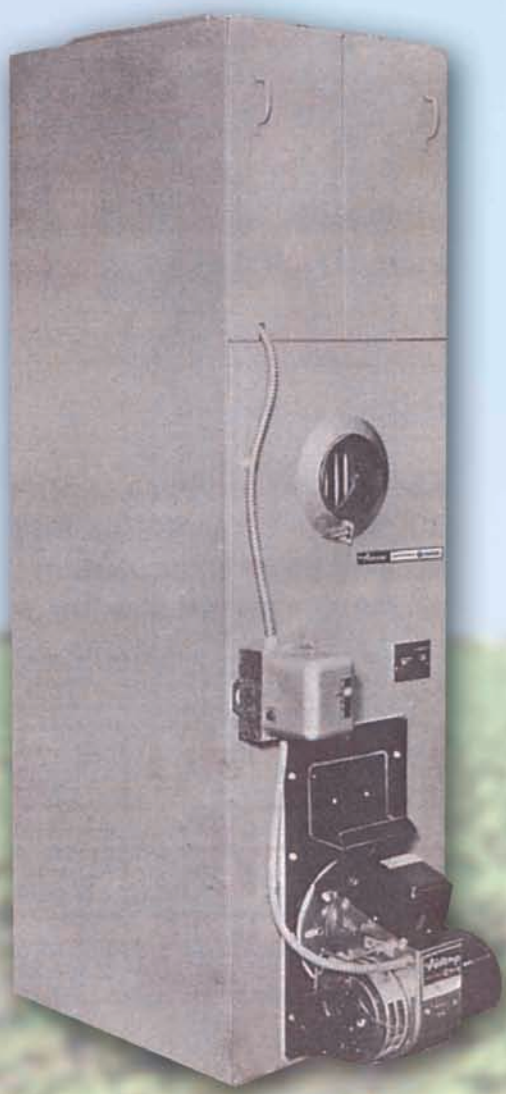
Sensors in a solar heating system provide the system's differential controller with the information necessary to efficiently turn pumps, blowers, or other electrical devices on or off. This is like your brain receiving and processing information from your fingers, and removing your hand from a hot frying pan. Low cost, ease of installation, and design flexibility make thermistors a good choice in controls that require remote temperature sensors.

All thermistors have what is called a curve, a graphical representation of the different resistances at different temperatures. This curve can be quite different for sensors of the same rating. The ratings are normally given for a temperature of 25°C (77°F). A 10 K sensor, the standard in the solar heating industry, will measure 10,000 ohms (10 K ohms) at its rated temperature. These sensors' resistance is inversely proportional to the temperature. When the temperature goes up, the resistance goes down.

–Smitty, AAA Solar Supply Inc. • smitty@aaasolar.com

My Chrysler Is a Furnace & It Runs on Biodiesel

Carol E. Moné



Our otherwise all-electric house came with a forced-air heating system driven by a 30-year-old Chrysler AirTemp, oil-fired, counter-flow furnace. It is a sturdy behemoth no longer manufactured, inefficient by today's standards, but in pretty good shape. This is not a unique story; a quarter of all furnaces in use in the U.S. are more than 20 years old, inefficient by today's standards, yet still operating.

Of Dinosaurs & Fossil Fuels

Our furnace burned red diesel #2. Initially, we didn't want to think too much about burning diesel. We tried to ignore the guilt associated with the air pollution caused by this filthy practice. We knew that the repairman could keep the AirTemp purring with appropriate replacement parts.

So we put the furnace problem on the back burner and concentrated on saving energy by eliminating electric appliances for cooking, clothes drying, and water heating. Using nonrenewably sourced electricity for heating-type appliances results in more pollution than switching these appliances over to natural gas.

We installed a solar water heater on the roof. We insulated the walls and attic, and replaced single-pane windows. At least we were conserving; we weren't using *that* much diesel. The plan was to eventually replace the heating system with a cleaner burning propane furnace when we could afford it.

Friends with bigger pocketbooks than ours did just that. Shortly after their environmentally sound conversion to propane, propane prices went up. My friends had a relatively clean-burning, energy-efficient furnace all right, but it was very expensive to operate. And they were still dealing with a fossil fuel.

Biodiesel Is Not Just for Cars

When I learned that our local diesel supplier was selling a soy-diesel blend, I phoned and requested the next fill-up of my fuel tank to be a biodiesel blend. Most of the literature for biodiesel is about putting it in vehicles. But I had read a 2001 government-sponsored study, *BNL-68852, Biodiesel Blends in Space Heating Equipment*. You can download this document from the promised files download area of the *Home Power* Web site (see Access). The study reported that blends of biodiesel and heating oil could be used for home heating with scarcely any modifications to the equipment.

The study showed major environmental benefits, like a big reduction of toxins and smoke. Many of our neighbors heat with wood, so reducing smoke in our neighborhood was worth thinking about. The report also said that biodiesel's heating value was roughly comparable to diesel. Biodiesel has a value of about 121,000 BTU per gallon compared with about 130,000 BTU per gallon of #2 diesel fuel oil.

The study also rated characteristics of different blends, indicated as Bx with x representing the percent of biodiesel in the blend. My supplier sells Envirodiesel from World Energy, and blends it himself. He first sold me B50, but now I can get B100. I just got my first fill-up from Footprint Recycling, a new, local supplier that makes biodiesel from used restaurant fryer oil.

Biodiesel is defined as a "diesel-like" fuel made out of processed vegetable oil, rendered tallow, or waste grease. Despite its definition, it isn't "diesel-like" at all. Diesel is a dirty, toxic, fossil fuel. Vegetable oil is a renewable, clean fuel. It seemed a shame to mix the two.

Our 550 gallon (2.08 kl) diesel tank, of course, still contained quite a few gallons of #2 diesel oil, and the report suggested that B20 could be substituted for #2 diesel oil with no modifications. Using a little algebra, I calculated that we could create a B20 blend by adding 200 gallons (757 l) of B50.

Lessons Learned

The furnace ran just fine on the tank mix for a long time. But when it got really cold, and the furnace was running just about all the time, I learned more about biodiesel than I ever expected to know.

NREL Biodiesel Facts

BD Air Pollution Reductions over Diesel Fuel

Emission	B100	B20
Carbon monoxide	-43.20%	-12.60%
Hydrocarbons	-56.30%	-11.00%
Particulates	-55.40%	-18.00%
Nitrous oxides	5.80%	1.20%
Air toxics	-60–90%	-12–20%
Mutagenicity	-80%–90%	-20%

BD vs. Diesel Fuel Properties

Property	Diesel	Biodiesel
Fuel standard	ASTM D975	ASTM PS121
Fuel composition	C10-C21 HC	C12-C22 FAME
Heating value (BTU / Lb.)	130,250	120,910
Kinematic viscosity, @ 40°C	1.3–4.1	1.9–6.0
Specific gravity, @ 60°F (kg / liter)	0.85	0.88
Density, @ 15°C (lb. / gal.)	7.079	7.328
Water (PPM by weight)	161	.05% max
Carbon (% by weight)	87%	77%
Hydrogen (% by weight)	13%	12%
Oxygen (% by differential weight)	0%	11%
Sulfur (fuel standard = 0.05% by weight)	max	0
Boiling point (°C)	188 to 343	182 to 338
Flash point (°C)	60 to 80	100 to 170
Cloud point (°C)	-15 to 5	-3 to 12
Pour point (°C)	-35 to -15	-15 to 16
Cetane number	40 to 55	48 to 60
Stoichiometric air to fuel ratio (weight to weight)	15	13.8
BOCLE scuff (grams)	3,600	>7,000
HFRR (microns)	685	314

From Department of Energy Document DOE/GO-102000-1048, May-2000

Material Compatibility with Biodiesel Fuels

Material	B%	Effect on Material (Compared to Diesel Oil)
Teflon	B100	Little change
Nylon 6/6	B100	Little change
Viton A401-C	B100	Little change
Viton GFLT	B100	Little change
Polyurethane	B100	Little change in hardness Swell increased 6%
Fluorosilicon	B100	Little change in hardness Swell increased 7%
Polypropylene	B100	Hardness reduced 10% Swell increased 8-15%
Nitrile	B100	Hardness reduced 20% Swell increased 18%
Tygon	B100	Worse
Polyvinyl	B100	Much worse
	B50	Worse
	B40	Worse
	B30	Worse
	B20	Comparable
	B10	Comparable

Source: Renner Petroleum, Eureka, CA

The first thing I learned was, *don't* mix it yourself in your tank at home. If you decide to convert to biodiesel, first flush your tank of all the old dino diesel.

Biodiesel has more solvent action than regular diesel. This means that when you blend it in your tank, it will ungunk all the sludge that is in the tank. An older tank will have an accumulation of rust, caused by moisture in the tank, and residue from impurities in the diesel fuel.

The ungunking process doesn't happen quickly. During the first few months of operation, it will glop up the filtration system and require a couple of replacement filters. There's real potential for clogging the fuel lines and the jets, too, especially if you don't have a filter on your tank. Don't expect your supplier to automatically provide you with this information, although ours did mention that we might have "problems." It is worth considering the price of a new tank (budget US$250) to avoid the problems this ungunking can cause.

Second, biodiesel doesn't have a shelf life of much longer than 6 months (actually about the same as diesel without additives), so a smaller tank size of about 240 gallons (908 l) is a good idea. Locally, there is a discount for buying more than 200 gallons at a time, so a 240 gallon tank would allow us to take advantage of the discount without buying so much that it begins to degrade before it gets used.

Pump Problems

Clearly the most important concern in burning biodiesel in your home furnace has to do with the pump. After about 6 months of happily burning the soybean biodiesel/petroleum diesel oil blend, our furnace pump froze. It was a 30-year-old pump, the original equipment, so we thought nothing of it and replaced it with a new Suntec pump. When the brand-new pump failed, we wanted to be sure the new fuel was not causing problems.

We contacted Suntec and inquired about the pump's shaft seal. It was nitrile. With dirty diesel, it doesn't matter what your seals are made of, but biodiesel will eventually dissolve nitrile. We asked what they manufactured that could handle biodiesel. Suntec replied, "We currently do not have a unit rated for any grade of biodiesel fuel. We are working to rate our units for biodiesel fuel and anticipate doing so this calendar year. However, we are only looking to rate them for B20 and lower fuels."

The Chrysler's fire box burns biodiesel or petroleum diesel—but one burns cleaner...

The 30-year-old furnace's new pump has Viton seals to accommodate biodiesel.

Carol Moné standing in front of the new biodiesel fuel tank after a routine fuel filter check.

Should Your Fuel Be Vegetarian?

Andrew Cooper

While all vegetable oils have high energy content, they require processing to assure trouble-free use in unmodified diesel engines. As fuels, both vegetable oils and their esters (compounds) are promising alternatives for diesel engines. However, due to their high viscosities and gelling in cold temperatures, vegetable-oil-based diesel fuels still have problems with flow characteristics and atomization upon injection.

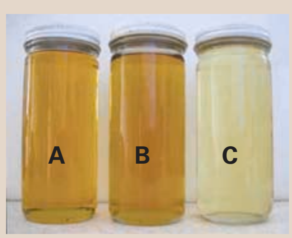
Transesterification of vegetable oils is a widely accepted method for reducing the viscosity of triglycerides and forming alkyl esters—biodiesel. Biodiesel offers immediate answers for improving the flow characteristics and fuel properties of vegetable oils because of biodiesel's reduced viscosity and lowered flash point.

Commercial biodiesel produced in the United States consists primarily of virgin soybean oil and rendered greases. It is very difficult—nearly impossible—for rendering companies to reduce the amount of animal fats present in rendered greases below 1 percent. Although animal fats and their esters can be used as components of biodiesel, their use in nearly any climate can be troublesome. (For example, waxing or crystallization can occur, which hinders fuel combustion.)

Samples of fuel at 70°F (left) and 40°F (right).

Sample A is Footprint Recycling's biodiesel that contains no animal fats. Sample B is commercially available biodiesel. Sample C is pure lard biodiesel.

All three samples have a low viscosity at 70°F. At 40°F only sample A is OK to put straight into your tank.



Transesterified oils have fuel properties close to those of diesel fuels, but their physical properties differ. Biodiesel containing animal fats has a much warmer gelling temperature and can begin to crystallize at approximately 55°F (13°C). This limits its use in virtually any climate where temperatures fall below 55°F.

Biodiesel can be used for heating oil in nearly any climate if the following precautions are followed:

- Use biodiesel produced from vegetable oils not containing animal fats,
- Use biodiesel that has a cloud point below 36°F (2°C),
- Treat the biodiesel with anticoagulants to prevent gelling, and /or
- Cut the biodiesel with kerosene or petroleum diesel at a 10 to 30 percent blended ratio.

If the biodiesel shows signs of clouding or gelling in colder temperatures, mix in a ratio of either petroleum diesel #2 at 30 percent (70% biodiesel) or a ratio of kerosene at 10 to 15 percent (85–90% biodiesel). This will maintain the cetane (ignition) value at lower temperatures and reduce the temperature range at which the fuel begins to gel.

A Fresh, Clean Start

We replaced the pump with another Suntec, and simultaneously replaced the old 550 gallon tank with a tidy 240 gallon tank, and filled it up with B100, or "neat" soybean oil biodiesel. We would have gone for B100 in the beginning had it been available. Running a funky old furnace is a hassle, even with dino diesel, so we were able to take our biodiesel learning experiences in stride.

We live near the coast in northern California, where it doesn't get too cold. The furnace only puts in long hours in the wintertime. If you live where it gets freezing cold, it is worth knowing that B100 has higher cloud and pour point temperatures than # 2diesel. The cloud point is when the fuel takes on a cloudy appearance. This indicates the fuel has thickened. The pour point is when the fuel is close to turning into a gelatin-like substance. While B20 may be functionally identical to #2 diesel fuel oil in all respects, more "soy-ful" blends are not. But any of the standard additives marketed for preventing diesel from gelling can be used in your tank.

Our new tank's sticker says, "Fire Hazard, 1 (slight), Health Hazard, 1 (slight), Reactivity 0." Reassuring. We hope that a new Suntec pump will be on the market soon. Meanwhile Suntec has provided a prototype with Viton seals for us to test this winter with B100.

Europeans have been heating with vegetable fuel oils for a few years. European pumps generally use Teflon or Viton seals, not nitrile. Although these pumps will accommodate biodiesel fuel oil better than pumps designed specifically for #2 diesel, they are not easy to get in the United States.

Biodiesel is more expensive than dirty diesel, but price fluctuations are not as closely tied to the petroleum industry. Currently, it costs us less than US$50 per month for winter heating. We generally average about 25 to 30 gallons (95–115 l) a month October through May, running the heat on a timer, mornings and evenings to 68°F (20°C) and other times around 60°F (16°C). But this all depends upon the weather.

Prices ranged from US$1.57 per gallon in June 2002 for B50 to US$2.10 for B100 in January 2003. Next time, who knows? But what price will we pay if we don't clean up our environmentally destructive habits?

Sweet Smell of Success

We used to be dismayed at how polluting our old oil furnace was—it smelled like a truck garage when it was running diesel. Now it smells hardly at all, or as a good friend said when he stopped by one chilly day, "Whatcha cooking? Smells *good*."

We're very happy now with the switch to a cleaner-burning, renewable fuel. Compared to the option of burning wood—which is *very* particulate-polluting—biodiesel stacks up pretty well. After addressing tank and pump concerns, your ancient diesel furnace can transmogrify into a french-fry-scented, clean-burning heat source for your home. And you can even make your own fuel if you want to.

Access

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Energy Information Administration of the Department of Energy • www.eia.doe.gov/fuelalternate.html

Biodiesel Use and Handling • www.ott.doe.gov/biofuels/pdfs/biodiesel_handling.pdf

Biodiesel Blends in Space Heating Equipment (BNL-68852) • Go to www.homepower.com > Magazine > Files & Downloads > Promised Files

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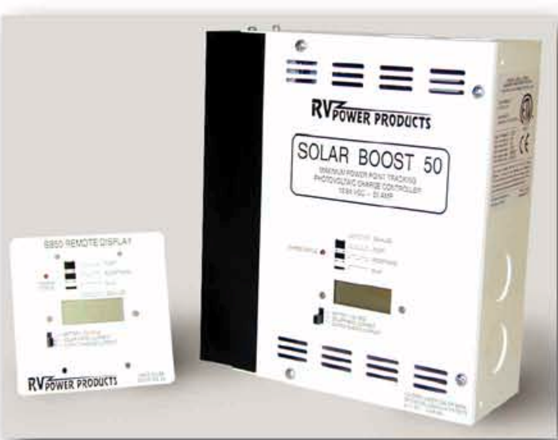

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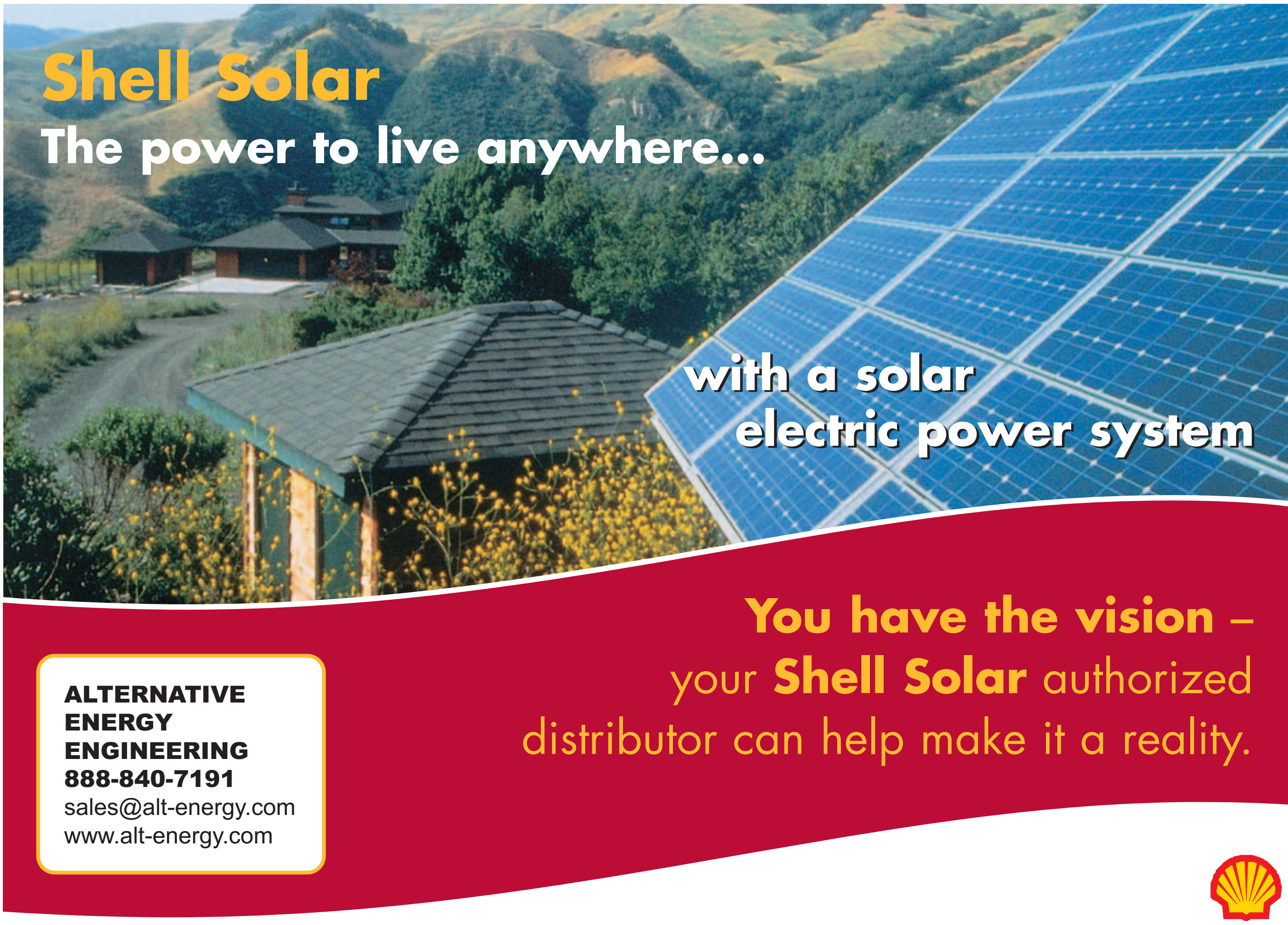
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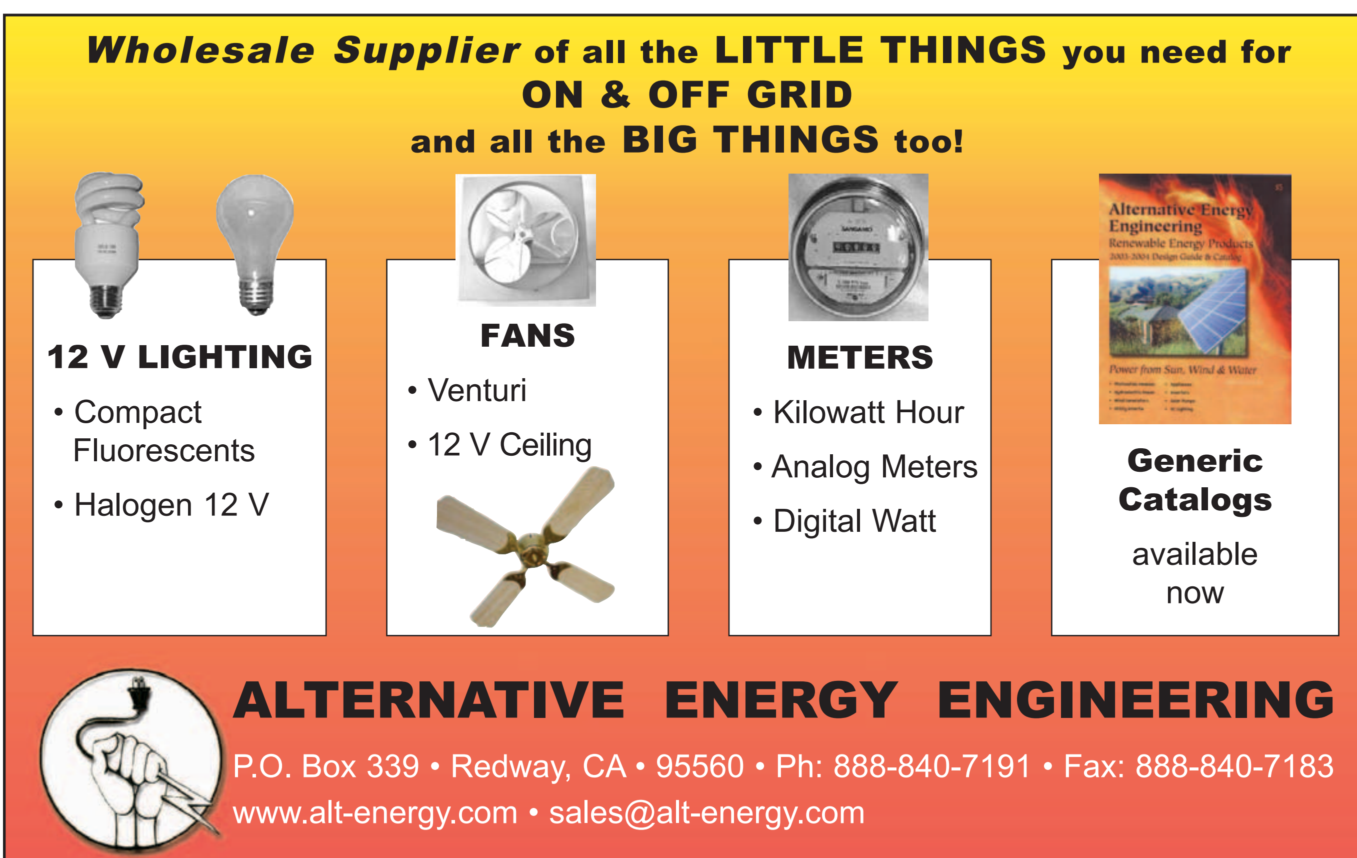
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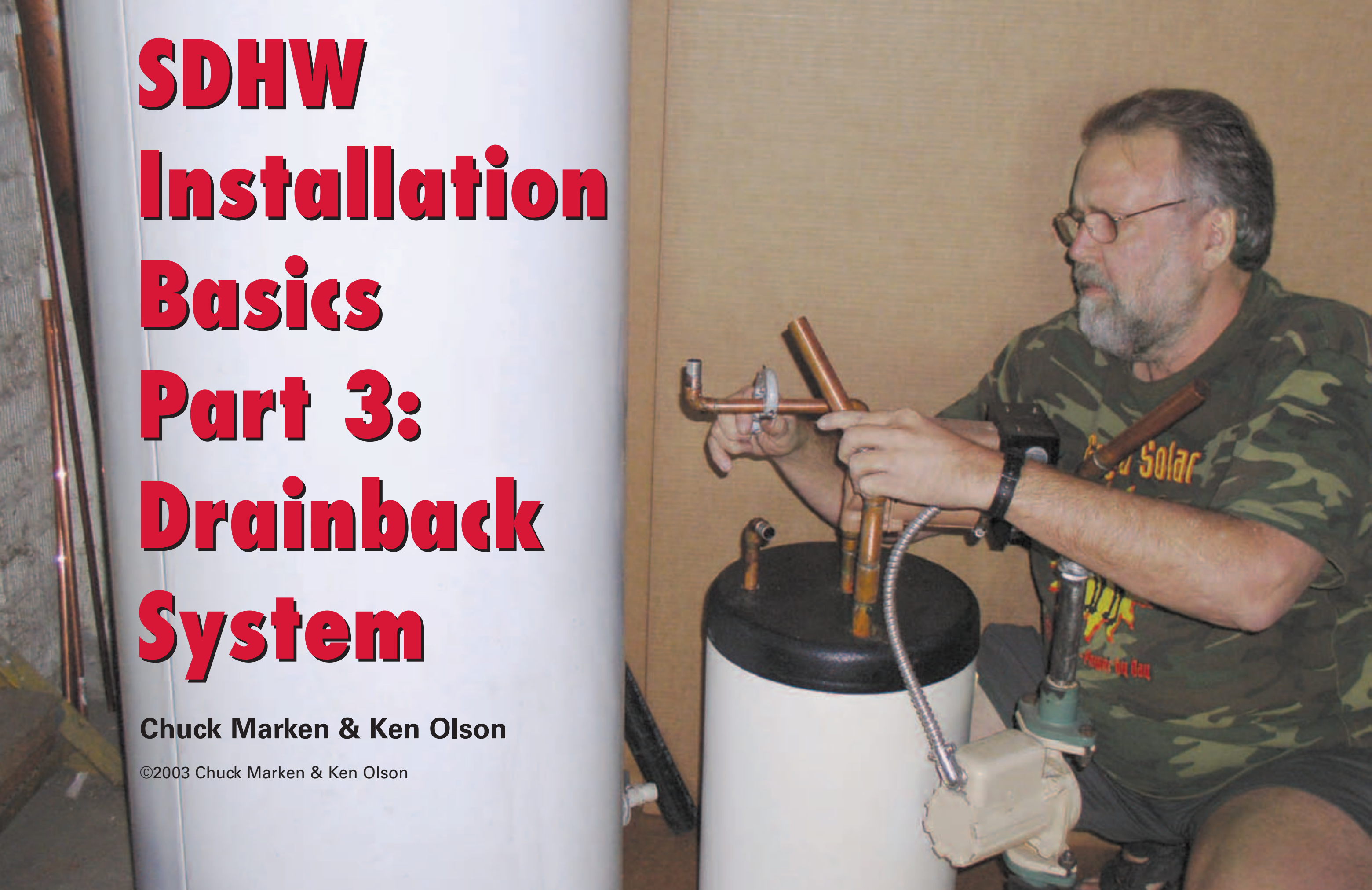
SDHW Installation Basics Part 3: Drainback System

Chuck Marken & Ken Olson



**Chuck Marken installing a do-it-yourself SDHW system—
a factory-made 12 gallon drainback tank with an internal heat exchanger next to an 80 gallon storage tank.**

If you plan to produce solar heated water year-round in a climate that freezes, you need a solar hot water system with freeze protection. Drainback solar domestic hot water (SDHW) systems use the same types of collectors, circulating pumps, and controls as antifreeze systems. They are a bit less forgiving, but require fewer parts and are simpler to install.

The components and operation of drainback SDHW systems were covered in *HP87.* Nuts and bolts installation basics (collector mounting, controls, and soldering) were addressed in *HP94.* Reviewing these articles will give you a good understanding of the subject of this article–the installation of drainback SDHW systems.

Drainback, Not Draindown

Drainback (DB) solar hot water systems should not be confused with the highly problematic draindown system. Draindown systems first appeared in the early 1980s. They circulated tap water through the collectors and relied on an electrically operated valve for freeze protection. Draindown valves were prone to failure for many reasons. We do *not* recommend draindown systems.

Drainback systems have a high degree of freeze protection, although they are not considered quite as fail-safe as the antifreeze closed loop system described in *HP85* and *HP95.* A much simpler design than the closed loop antifreeze system, a drainback system provides good freeze protection in moderate to cold climates.

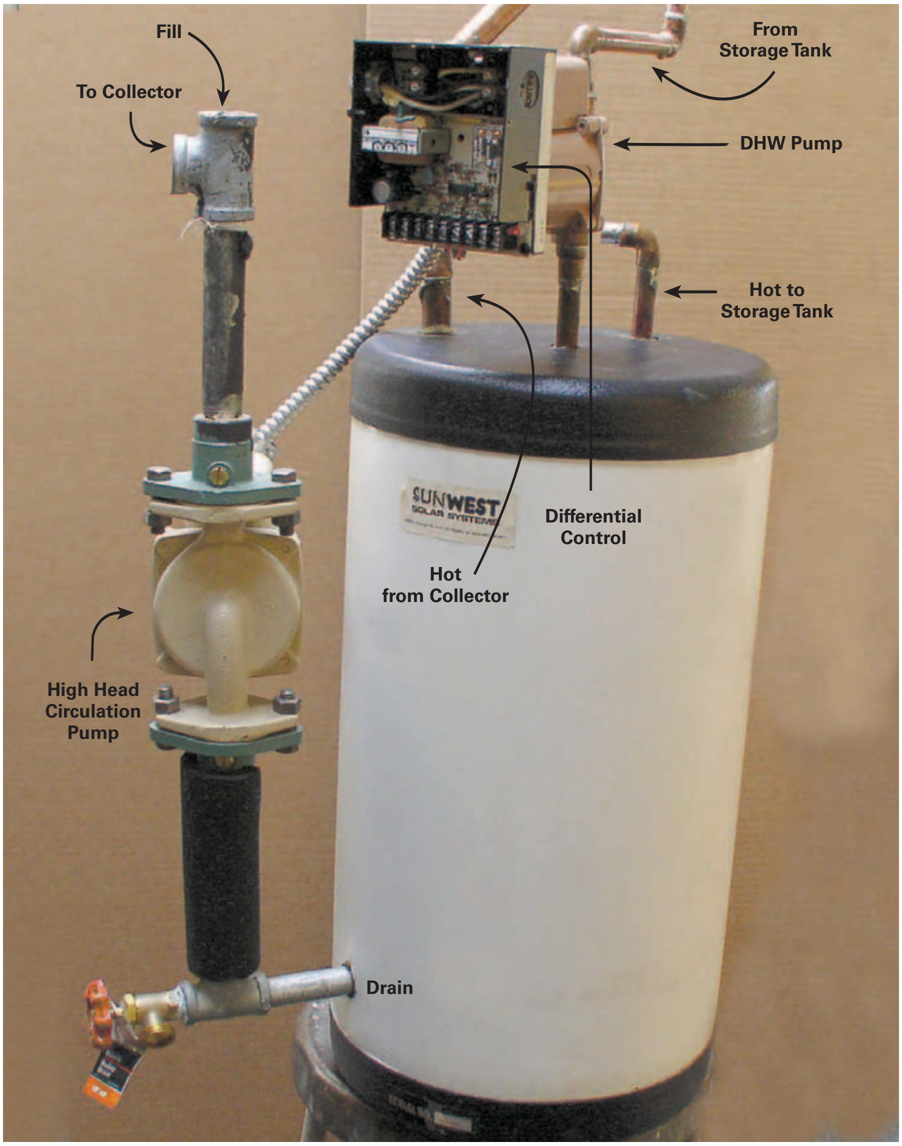
DB System Operation

The major components of a DB system are the collectors, drainback tank (aka reservoir tank), hot water storage tank, heat exchanger, and one or two circulation pumps, depending on system configuration.

The drainback system is a closed loop system. However, unlike the closed loop antifreeze system, a DB system has an unpressurized closed loop, and it does not usually use antifreeze as the collector fluid. The collectors and drainback tank are part of a closed loop, which contains both air and the collector fluid, which is usually water. When the system is not operating, all the water is in the drainback tank, located indoors or in another freeze-free environment. The collectors and outdoor piping have only air left in them. That is the freeze protection strategy.

When the system is activated, the collector loop circulation pump lifts the fluid up to the collectors. Once it passes through the collectors, it returns to the drainback tank by gravity. When the system is deactivated by the controller, the pump turns off and all the fluid in the collector drains back to the drainback tank. Drainback systems require a high head pump to lift the collector fluid the full height to the collectors.

The solar heat removed from the collectors is transferred to the hot water storage tank by means of a heat exchanger. Several tank/heat exchanger configurations are discussed below. DB system design can be very simple. If the proper care is taken with collector mounting and piping, the rest is a breeze.



A factory-made, 12 gallon drainback tank.

Collector & Piping Installation

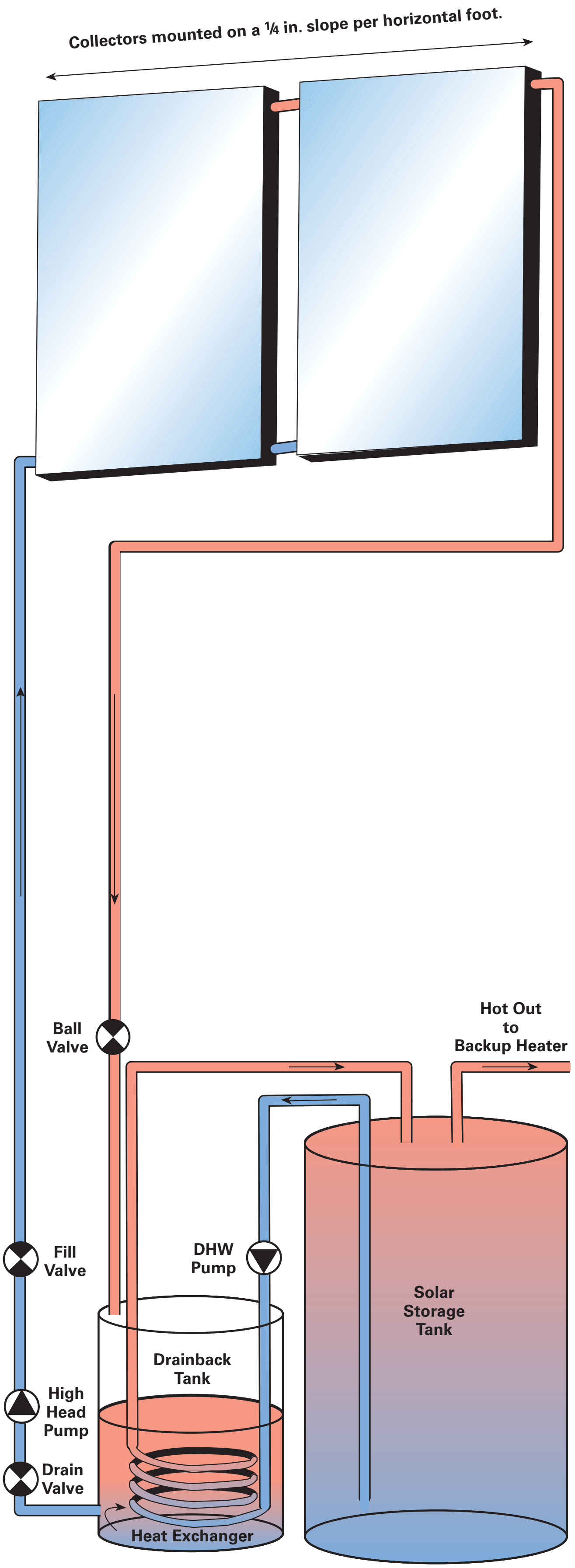
The collector mounting details described in the "Installation Basics" article in *HP94* must be modified slightly for drainback systems. The basics of securing, tilting, and orienting the collectors for all SDHW systems apply to drainback systems. However, drainback collectors must be installed so that they will completely drain when the pump shuts off.

This is accomplished by sloping the collectors toward the collector inlet. The slope should be a minimum of 1/8 inch (3 mm) per foot (30 cm) and preferably 1/4 inch or more (6 mm) per foot. For a 4 by 8 foot (1.2 m x 2.4 m) collector mounted with the long dimension vertical, this will be 1 inch (2.5 cm) per collector. This slight slope will normally not be noticeable to the eye unless many collectors are installed in a long row or near the roof edges. For large systems where the drainback slope may be visible and objectionable, collectors may be installed in multiple shorter rows.

Drainback systems should always be installed with the hot return pipe as vertical as possible. The collector loop piping in drainback systems should be a minimum of 3/4 inch. This minimum pipe size and steep slope allow for air in the drainback tank to quickly rise to the top of the collector and break the vacuum that would otherwise hold the water in the pipe. A well-known demonstration of this vacuum phenomenon is holding your finger over the top of a common drinking straw filled with a liquid. The liquid remains in the straw until you remove your finger. Removing your finger breaks the vacuum by allowing air to enter the top of the straw, allowing the liquid to drain.

Collectors used in drainback systems should have riser tubes at least 1/2 inch in diameter. Most collectors are manufactured with the intention that these small riser tubes will be installed in a vertical orientation. In some collectors, the riser tubes have very little structural integrity when mounted horizontally. For example, mounting 4 by 8 foot collectors with the longer 8 foot dimension horizontal can pose a problem in DB systems. (It's not a problem in antifreeze closed loop systems.) The riser tubes can sag with gravity over time and cause a water trap in the tubing. The trap can hold water that would otherwise have drained out, causing a freeze break in the tubes.

Drainback Design #1



Drainback System Configurations

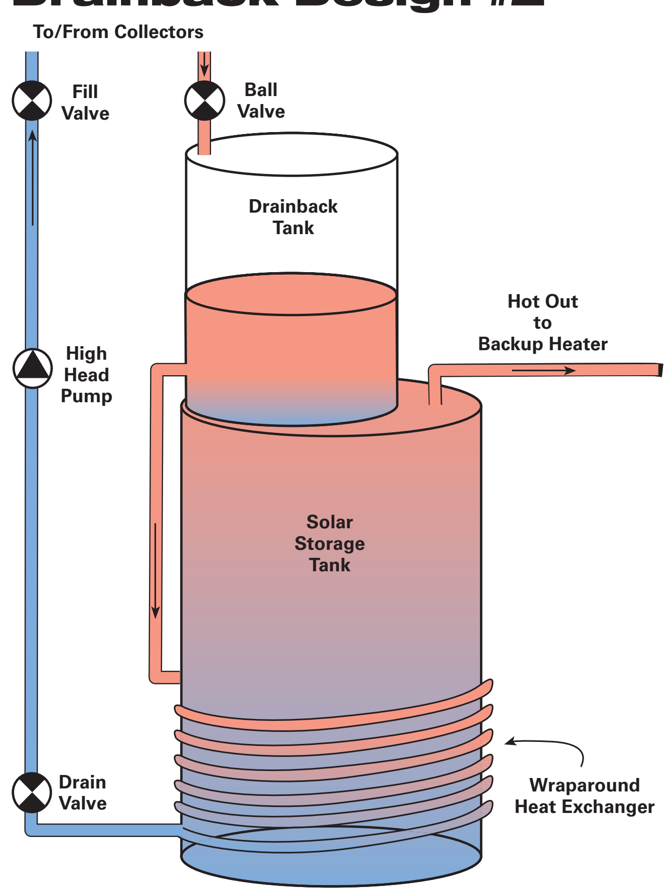
All DB systems have some type of unpressurized tank or reservoir to hold the collector fluid, which is usually water. Technically, the DB tank is unpressurized, although in some systems, pressure can build up with the rise in temperature of the collector loop and DB tank.

Drainback systems may have the heat exchanger integrated with the DB tank, integrated with the hot water storage tank, or external. One classic design (see DB Design #1) uses a DB tank with an integral heat exchanger. The water in the DB tank is circulated through the collectors, and the domestic hot water is circulated through the heat exchanger to a pressurized storage tank. The collector pump and the domestic water pump work simultaneously. The integrated heat exchanger is a coil of copper tubing inside the DB tank. The DB tank is usually filled with potable water, which makes a single-wall heat exchanger acceptable. (See *HP87* and *HP93*.) Systems using a toxic heat transfer fluid are required by most codes to use a double-wall heat exchanger.

DB system designs can also use a DB tank without a heat exchanger (see DB Design #2) if a storage tank with an integral heat exchanger is used. In this configuration, the collector fluid is circulated through both the heat exchanger and DB tank.

DB systems can also be designed with an external heat exchanger (see DB Design #3). This configuration uses two

Drainback Design #2



circulation pumps. The collector loop pump circulates fluid through the collectors, heat exchanger, and DB tank. The domestic water pump circulates potable water from the hot water storage tank through the water side of the heat exchanger. If the collector fluid is not toxic, a single-wall heat exchanger may be used. A simple, low-cost homebrew heat exchanger is described in this issue (see "Homebrew Heat Exchanger").

Drainback tanks need to be large enough to be at least half full when the pumps are on; otherwise the heat exchanger will not be able to transfer heat to the domestic water. The total volume of the DB tank must be at least twice the volume required by the collectors and piping. A 4 by 8 foot collector will hold about a gallon (4 l) of water. In the collector loop, one hundred feet of 3/4 inch tubing will hold 2.3 gallons (9 l), or 4 gallons (15 l) for 1 inch tubing.

Drainback Tank Designs

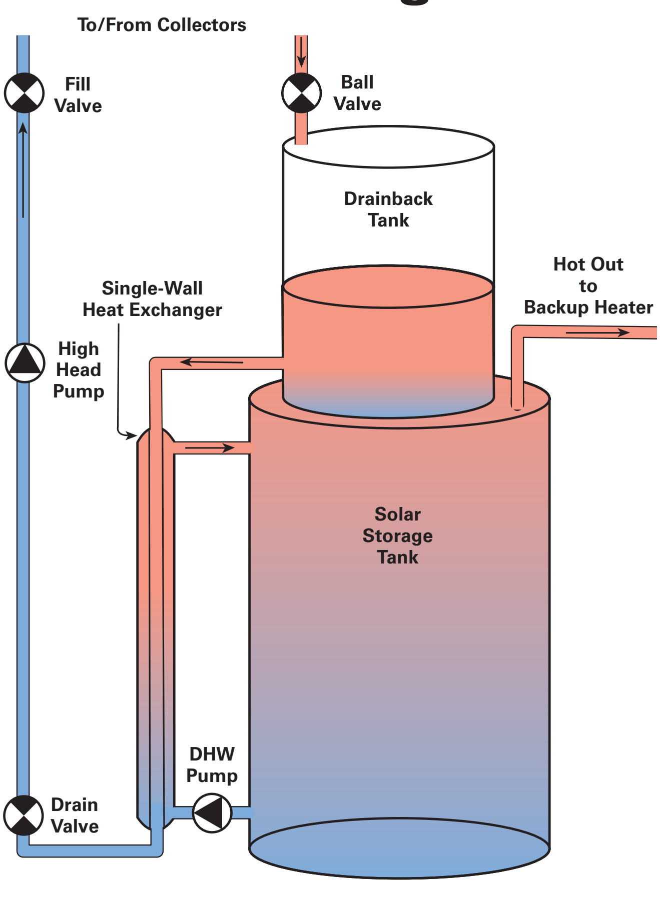
DB tank configurations can be classified into four popular designs. More designs are possible, but they will all be modifications of these four. The numbering order below does not reflect any recommendation of the merit of any of the designs. They may all be expected to have good overall system efficiencies. Your choice of design is more dependent on the amount of work you want to do and the availability and cost of the various types of tanks.

Design #1. Factory-made, 12 gallon (45 l), stainless steel tanks with single-wall heat exchanger are available from Radco, but they will cost in excess of US$500. These tanks have a 30 foot (9 m) coil of 1/2 inch copper tubing as a built-in heat exchanger. They come fully insulated with an enameled steel outer covering. They look just like a small water heater except for the extra connections. With a tank like this, the installation is easy. Just install the pumps and control, connect the piping to the collector and storage tank, fill the tank with water, and the installation is complete.

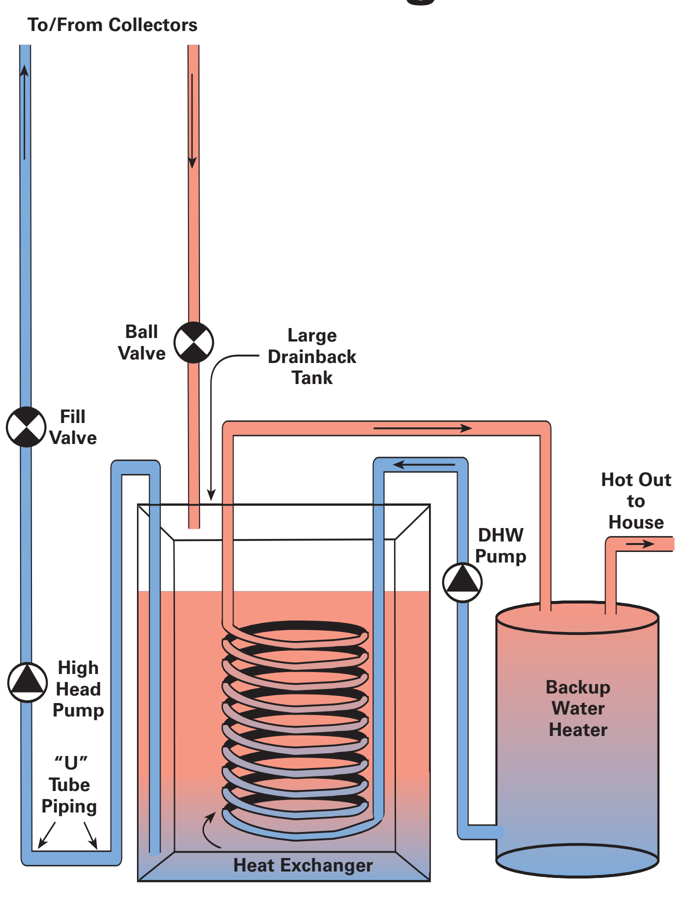
Design #2. Another design uses an immersed heat exchanger or a wraparound heat exchanger integrated with the hot water storage tank. This design requires only one pump in the system. The DB tank in this system can be a modified 10 or 20 gallon (38 or 76 l) electric water heater. The drainback tank may be mounted on top of the regular water heater or on an elevated shelf to lessen the head requirements of the pump. The collector loop water flows through the DB tank and the integrated storage tank exchanger, and is then pumped back to the collector using a high head pump.

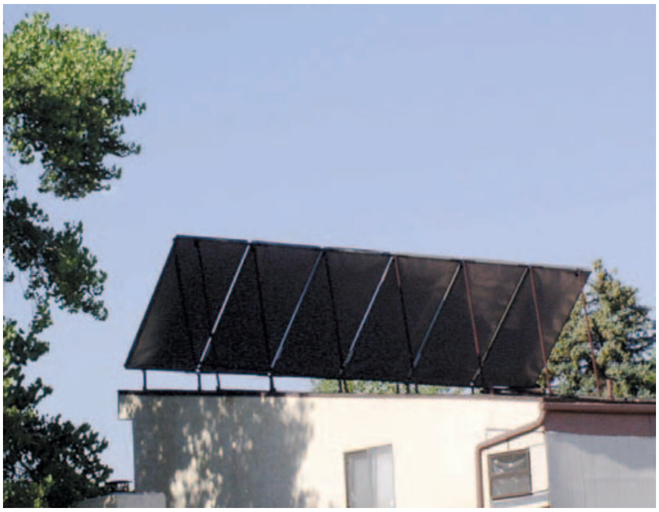
Design #3. As with closed loop systems, you may also use an external heat exchanger. Although external heat exchangers are less efficient, you will have a wider choice of tanks. The DB and storage tanks may both be modified conventional water heaters. External, tube-in-tube single-wall heat exchangers can be readily made by a do-it-yourselfer. See "Homebrew Heat

Drainback Design #3



Drainback Design #4





From the back of this drainback array of six, 4 by 8 foot collectors, the slight slope of the collectors can be seen.

Exchanger" in this issue, and "Heat Exchangers" in *HP93.* The collector loop, water-flow path in this design is very similar to Design #2. This system requires a second pump to circulate domestic water through the heat exchanger. The DHW pump and collector loop pump are both turned on and off at the same time.

Design #4. Large solar thermal systems may use a large unpressurized storage tank as a DB tank. The first consideration should be material. Stainless steel, high temperature plastics, and fiberglass are all good choices for long life. If a tank, drum, or reservoir has a suitable large opening, or one can be easily cut, you can install a coil of copper tubing that will serve as the heat exchanger for the DHW. A second pump will circulate the domestic water through this coil to the hot water storage tank. The water in the DB tank will be circulated to the collectors. If the tank does not have a bottom fitting to connect to the collector loop pump, you can use the inverted "U" tube piping, as shown in the DB Design #4 diagram.

The pump control strategy in this system is different from the systems described above. There is often a demand for hot water when the sun isn't shining. A separate differential control is used to turn the DHW pump on when cold water enters the backup water heater. This will allow the heat in the large DB tank to heat the DHW any time the DB storage tank has a sufficient temperature. These large combination drainback/storage tanks can also provide heat for other needs in a home. More coils in the tank can supply heat for home heating, hot tubs, or swimming pools.

Other tank designs have used a liner made of EPDM rubber or other similar material that will stand up under high temperatures. These tanks need an external support structure that can be made with angle iron and plywood. They are typically rectangular. The support structure is just a large box that the liner lies in. These tanks can be inexpensive for large DB systems, but the liners used in the past have a limited lifetime–usually about ten years maximum. Leaks usually occur where the material has been folded.

High Head Pump Installation

A high head pump is usually required in the collector loop of DB systems. How high depends on the installation. The pump must be capable of pumping the fluid from the DB tank to the top of the collector. As this pump pushes the liquid up through the piping system, the air is forced back down into the top of the DB tank. All DB systems will have a noticeable sound of gurgling upon startup, as the air and some liquid return to the DB tank. You should consider this when deciding whether to run the collector return pipe adjacent to a living space. The sound may be objectionable.

Small hot water circulating pumps that are suitable for DB collector loops have head limits of about 30 feet at sea level. Two pumps in wide use are the Taco 009 (maximum head 27 feet; 8.1 m), and the Grundfos 26-96 (maximum head, 31 feet; 9.3 m). The limit of readily available high head pumps is a consideration in design. Two-story homes with the DB tank in the basement can exceed these head limitations. Many pumps are available for higher head requirements, but you will pay a significant cost in the operation of the higher horsepower motors over the years.

Hot water circulating pumps must be placed below the water level of the DB tank. The pump impeller designs have no suction lift. That is a characteristic of most small centrifugal pumps. Suction lift pumps have impellers that will cause a vacuum on the input side of the pump and "suck" the liquid up the piping. Circulating pumps must be "wet" or primed at all times or they will not pump at all. This requirement may be a consideration in the type of DB tank you choose.

You can minimize the head in a DB system by elevating the DB tank. This can be accomplished by mounting the DB tank on a shelf or other suitable platform. Of course the DB tank must still be within a heated space or freeze-free environment.

Controls

Drainback systems use a differential control as described in many previous articles and in depth in *HP94.* Since DB systems will always have a heat exchanger of some type, the differential temperature of the control should be similar to a closed loop system—on the order of 12 to 18°F (7–10°C) for the turn-on temperature difference and 4 to 8°F (2-4°C) for turn-off. A single control is all that is needed except for a system with a large, unpressurized combination drainback/storage tank.

Options

If you have read the previous articles in this series (*HP94* and *HP95*), you can see that a drainback system has significantly fewer parts and complexity than a closed loop system. You may wish to consider installing a few other optional parts that are not strictly necessary, but can be helpful in monitoring the system operation.

Temperature gauges may be installed on the collector hot return piping, cold supply piping, and the hot pipe to the storage tank. A well-type temperature gauge is often used. It has two parts—the thermometer with a stem, and a fitting (well) that screws into the piping and accommodates the stem of the thermometer, making it possible to remove the thermometer or use it in numerous locations. These thermometers will give you a good idea of the system operation.

A sight gauge mounted on the drainback tank will let you know when you may need to add water to the tank. A transparent flow meter can be installed in the collector supply piping above the high head pump at the drainback tank water level to monitor the flow rate of the collector loop and also serve as a sight gauge.

A valve on the return line from the collectors will allow you to throttle down the return flow. Under some circumstances, fluid returning from the collector may fall faster than it is being pumped up to the collectors. This may cause it to be noisy. The valve will allow you to slow down the return flow to create a smoother, quieter, turbulent-free flow.

A simple system can also be configured using the drainback tank's immersed heat exchanger in series with the home's cold water supply to the water heater. This system was covered in *HP88* and *HP91*. This type of instantaneous design is dependent on the length and size of the tubing (many smaller tubes is better). Instantaneous designs are normally not satisfactory except in situations of very limited hot water usage.

Filling & Startup

Demineralized or distilled water is best for drainback systems. Tap water may be used, but if the water is hard (with many dissolved solids) it can cause problems over time. The water in a drainback system does not fully drain. A thin film of water remains on the inner surface of the riser tubes each time it drains. Repeated evaporation of a film of hard water leaves a mineral deposit that can build up. This deposit acts as an insulator, which reduces thermal efficiency of heat transfer. Very hard water over many years can cause small riser tubes to become partially clogged and potentially retain a column of water. If this happens, the next freeze will likely burst that tube. You can minimize the possibility of this condition (aka capillary retention of water) by using collectors with riser tubes of the recommended minimum 1/2 inch diameter.

All of the drainback tank configurations should have a fill valve installed near or at the top of the tank. You can access the fill valve with a garden hose and washing machine hose to fill if you have tap water of acceptable quality. Or you may use a funnel if treated or distilled water is used. The tank should be filled to the top, but not above the fill valve. Once you have filled the system, turn it on and observe. When you are satisfied that you have no leaks and that the system is operating correctly, turn the controller to the automatic position and put your tools away.

Three, 3 by 8 foot collectors and piping, draining to the left.

Drainback Drawbacks

Drainback systems are not considered as fail-safe as closed loop antifreeze systems. The main reason is the potential for failure to properly drain. Potential causes include the water quality issues discussed above, and malfunction of a sensor or control. These are rare circumstances but as we all know—life happens.

The possibilities include a control locked in the "on" position. This can be the result of a sensor malfunction or a sensor wire shorted or open. It can also be caused by the interior relay of the control freezing in the "on" position. If the control locks on, it will run the collector loop pump at night, and possibly in freezing weather. This can freeze the water in the collectors and cause the tubes to burst.

Another less likely failure mode may occur when you stack pumps in series to achieve higher head requirements. Pumps plumbed in series (outlet of one to inlet of the other) will double the head pressure. Pumps can be stacked in this manner for the head requirements in homes with two stories and the drainback tank in the basement. This can overcome the head limitations of a single pump. The problem with pumps in series occurs when one pump fails and the other continues to pump. The water will not rise to the top of the collectors any longer, but it will rise to the point of the head of the single pump. If the water level rises to an unheated attic or part way into the collector, you have a potential for freezing.

Glycol Drainback

The problems discussed above can be addressed by modifying the drainback system to circulate a solution of water and propylene glycol. This concept moves us somewhat closer to the closed loop antifreeze system, but without the complexity of the pressurized loop. The glycol will afford a safety net level of freeze protection in the event of a system failure.

Even a 30 percent solution of propylene glycol in water will provide fail-safe freeze protection to -10°F (-23°C).

Glycol drainback system designs should incorporate the 325°F propylene glycol made by Dow Chemical. This higher temperature glycol mentioned in *HP89* will not break down the inhibitors in the solution below 325°F (163°C). But adding glycol necessitates the use of a double-wall heat exchanger to prevent mixing with domestic water.

Maintenance

Check the water level in the drainback tank at least once a year. Fill it when needed. Drainback systems lose water over time—it evaporates. Even small drainback tanks in closed systems will lose water. If a DB tank loses enough water, the heat exchanger will no longer be immersed in the drainback tank. A dry heat exchanger transfers no heat. If the tank runs completely dry, the high head pump will likely burn up, since most of them are fluid lubricated.

The slope of the collectors and piping should be checked every year or two to ensure that they have proper drainage. Long runs of near horizontal piping are subject to sagging between supports. Even a small shifting of the collectors, however unlikely, can affect the system's ability to drain properly.

Kick Back with Your Drainback System

We have covered the aspects of SDHW installation that are unique to drainback systems. If you live where it freezes, you need a reliable freeze protection design for your system. The drainback system is less costly and much simpler than the closed loop antifreeze design. If you follow the recommended practices, a drainback system will have reliable freeze resistance and generate hot water year-round, courtesy of the sun.

Access

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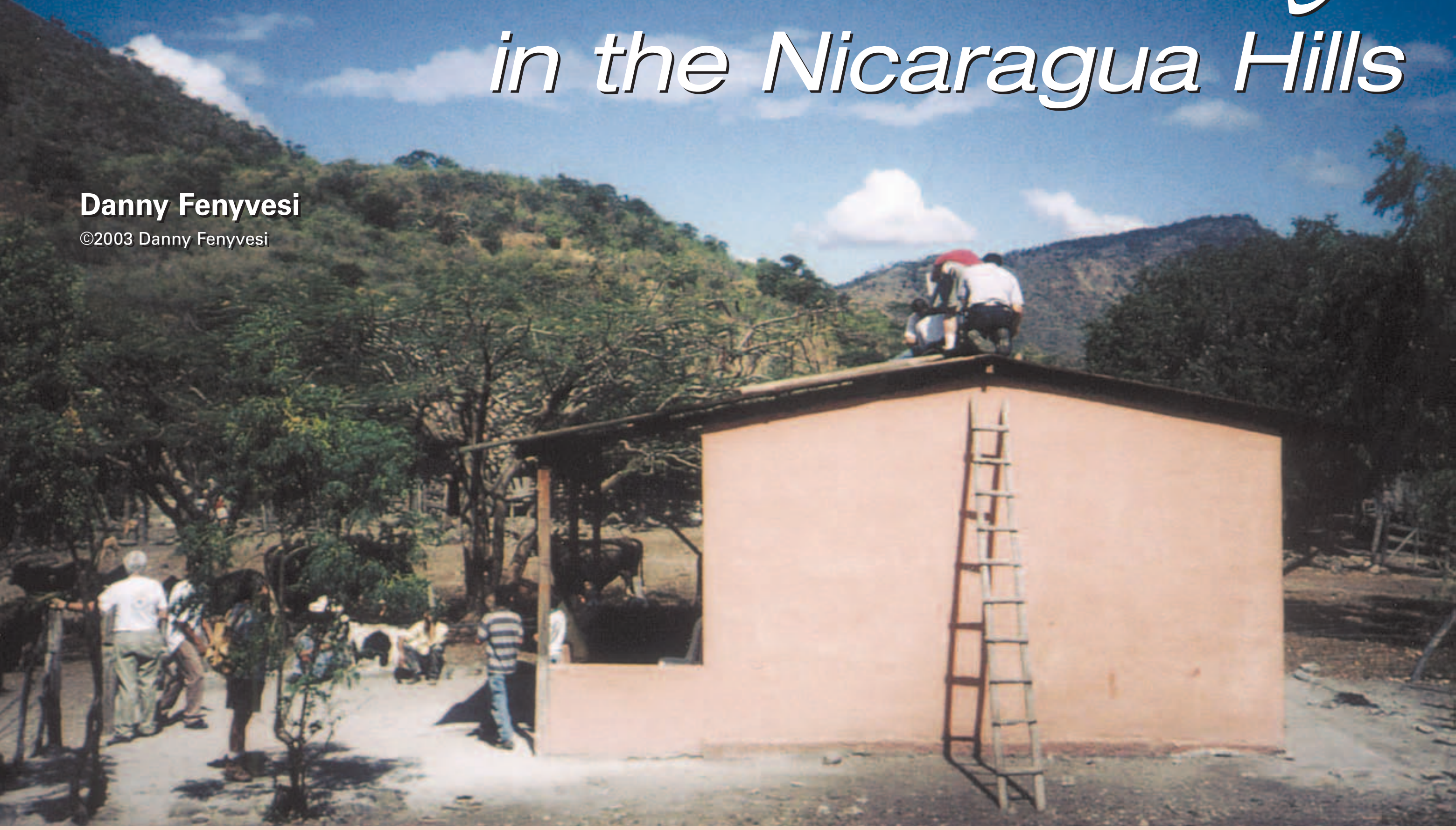
Ken Olson, SóL Energy, PO Box 217, Carbondale, CO 81623 • Phone/Fax: 720-489-3798 • sol@solenergy.org • www.solenergy.org

Radco Products, Inc., 2877 Industrial Pkwy., Santa Maria, CA 93455 • 800-927-2326 or 805-928-1881 • Fax: 805-928-5587 • radcoproducts@utech.net • Drainback tank manufacturer

Solar Electricity in the Nicaragua Hills

Danny Fenyvesi



Grupo Fenix workshop participants install a 50 watt photovoltaic panel for lighting on the health clinic in the little village of Las Pintadas, Nicaragua.

After a spring and summer installing PV in northern California, a fall getting lost in Europe and tinkering with the PV systems of southern Spain (see *HP91*), and a brief winter stint installing PVs in the horse country of Maryland, I decided it was time to get a new perspective in the Third World. A few weeks of searching for options yielded just the people I needed to talk with—Susan Kinne and Dr. Richard Komp of Nicaragua's Grupo Fenix.

Exchanging e-mails with Susan and Richard and reading articles about their group, I learned that Grupo Fenix is a nonprofit organization that has been able to aid the rural poor while educating Nicaraguans and foreigners alike. The objective is to promote renewable energy and bring sustainable technology to the poorest of the rural people.

Grupo Fenix works primarily with engineering students at Universidad Nacional De Ingenieriá (UNI) to design, build, and install solar hot water systems, solar cookers, and PV systems. Grupo Fenix has built a PV panel fabrication shop where they construct panels using donated, broken cells that are re-cut and soldered to make new panels.

Along with its year-round work, Grupo Fenix invites foreigners to participate in solar cultural courses in Nicaragua. Students are able to get a background in solar energy, participate in a rural installation, and get a taste of Nicaraguan culture. As the jumping off point for my two-month volunteer stint with Grupo Fenix, I took their January PV course. After a week of intensive classroom instruction and hands-on workshops, our group left for the village of Las Pintadas to install a donated PV system for its health clinic.

Las Pintadas

A poor village of around one hundred people, Las Pintadas was named for a painted, carved rock that dates back several thousand years (*pintadas* means paintings). The village is located in a remote area of the rugged, pine-topped mountains that border Honduras. During the civil war of the 1980s, the area was center stage for Contra-Sandinista battles. In addition to the death and destruction that war brings immediately, many land mines were planted by both sides, and there have been many land mine victims.

Perhaps the most important criterion for choosing the village for this project was the motivation of the residents. As many foreign aid workers know, projects often fall apart a few months after the aid workers leave because of a lack of follow-up by the aid group, and a corresponding lack of understanding and willingness on the part of the villagers to adopt new technologies.

For this reason, Grupo Fenix requires potential aid recipients to prove that they will maintain the solar projects. Las Pintadas has a progressive, optimistic school teacher, Roosevelt Rodriguez, himself a land mine victim. Having researched solar electricity, he provided the educational support and the energy to unite the villagers behind the project.

Slow Down to Burro Time

Our group of sixteen American students and five Grupo Fenix members left Managua loaded with gifts, tools, and solar equipment. Our trip to the village was a bone-shaking but beautiful ride through the washed-out dirt roads of the tranquil countryside. Seeing hardly any other traffic, we traveled for hours on the flatbed of a 1950s German military truck without a windshield. On the last mile of our ride, we were forced to share the road with a muscular, stubborn burro who refused to let us pass, despite our driver's persistent honking.

When we arrived behind our burro, we were exhausted. But we found ourselves energized by the cool mountain air and the star-filled night of the new moon. Since we were the first foreign group that the village had ever had, our host families were as excited to meet us as we were to be there. For the next two nights, we bedded down in their simple, clay roof, dirt floor homes.

The following day began early. At 5 AM, the crowing of roosters, the oink-oink of pigs, and assorted snorts, hoots, and howls roused everybody. For the locals, who have never lived with electricity and are usually asleep within a few hours of the 6 PM sunset, a pre-dawn breakfast by the light of the moon is the norm.

Tropical Troubles

Many installers in the tropics have learned to install PVs without the traditional terminal boxes. Terminal boxes trap the ever-present humidity that can lead to terminal corrosion. Terminal boxes can also become infested with insects, mice, and other critters, which leads to breakdowns in the insulation and eventual open circuits.

In place of a terminal box, the leads are cut very short and are usually connected to the small, plastic, screw-in, European-style wire connects. In our installation, we used these, and then fed the other end into a large, heavily insulated, insect-proof black cord.

Batteries are another matter in Nicaragua. When Grupo Fenix started in 1996, there was no place they could find in Central America that built deep-cycle batteries. They were all imported, which meant they were expensive and hard to get.

Susan was able to talk a small, local shop that built truck batteries in Masaya, Nicaragua into making 12 volt deep-cycle batteries. These batteries are 70 AH capacity. Although they can't compete quality-wise with the better foreign batteries, they are cheaper, and help to support local workers.

Grupo Fenix uses Solom 8.8x controllers for small systems because it is the smallest controller available in Nicaragua. However, Grupo Fenix's engineers are now designing and starting to build their own charge controllers specifically designed for small systems.

The author in front of the clinic, which has become an evening gathering place for the community due to the electric lights.

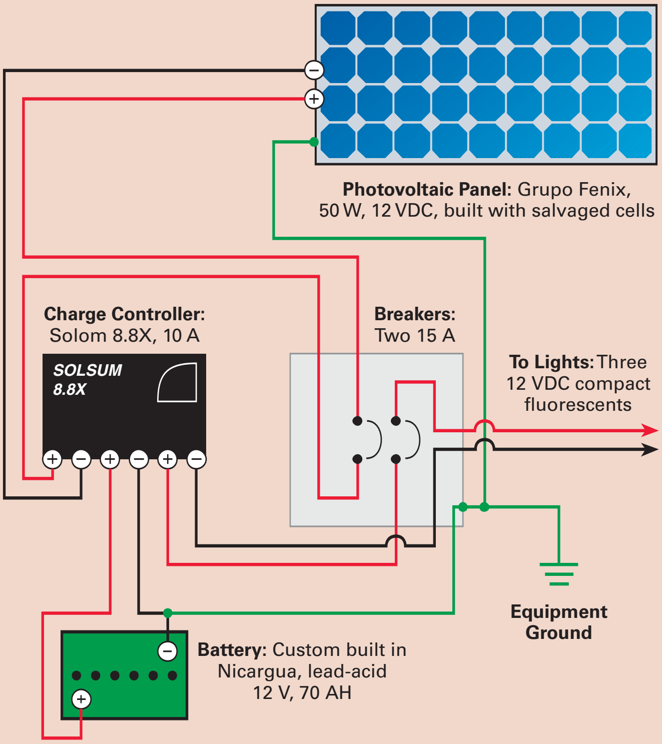
After clearing our heads with strong, locally grown coffee, we broke into two teams. One team would build solar cookers with village women and explain their uses and design. (See the sidebar on solar cooking by Eric Fedus, another Grupo Fenix student from the U.S.) My team began the PV installation.

The Installation

Our first step was installing a 50 watt Grupo Fenix-built photovoltaic panel on the roof of the small, salmon-colored adobe health clinic. Using semiflexible metal straps, our leader, Alexis Martinez, and his assistants, Aín Rodriguez and Maria Teresa Castillo, showed us how they build a makeshift rack. Because the roof is made of thin sheet metal, only a few of us could be on the roof at the same time to watch them bend and twist the rack into a sideways U shape.

The completed rack was bolted to the roof, and the panel was screwed onto the rack. For a lightning ground for the panel and rack, we ran a wire from the panel frame to a $1^1/_2$

The Las Pintadas Clinic's Solar Lighting System



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

All the wires were #14 (2 mm^2) stranded except for the wires from the breaker box to the battery, which were #12 (3.3 mm^2). The small wires from the charge controller to the breaker box were #16 (1.3 mm^2), but this was a short, 1 foot (0.3 m) distance, so the small size doesn't matter. The distance between charge controller and battery is 5 feet (1.5 m), and the total distance from panel to battery is less than 20 feet (6 m).

Although it results in a slight waste of wire, most connections were made in the breaker box, to add a layer of security against insects, mice, and other incidental contact. Both the circuit breaker box and the charge controller are mounted on a 2 centimeter (3/4 inch) board, and the battery sits 1 meter (3.3 ft.) below on a wooden platform. While we were wiring up the PV system, the other half of our group worked on wiring the three DC fluorescent lights—two overhead and one porch light.

The Fiesta

In Nicaragua, as elsewhere in the tropics, it feels like there's no afternoon. The sun goes from its midday position to a brief twilight with startling speed. As daylight rapidly disappeared, we were racing with the sun to complete the PV installation. To place the final wires, we had to hook up a 12 volt bulb straight to the battery to see.

During this time, the villagers, returning from their farm work, gradually clustered around us. Several farmers took a

Aín Salinas, Maria Teresea Castillo, and Alexis Martinez—members of the Grupo Fenix photovoltaic installation team.

meter (4.9 ft.) brass rod sunk into the ground. The panel faced south at a 13 degree angle so that rainwater would run off easily.

A modified, thick, black construction-style extension cord was attached directly to the panel leads and then run down to the area of the circuit breaker box, a distance of about 7 meters (23 ft.). Instead of penetrating the roof for the cord, we slipped the thick cord between the overlap of two of the flimsy sheet metal roofing sections.

For our safety as well as the health of the charge controller, Dr. Komp explained that the order of the wiring must be carefully followed. First, we ran the negative wire from the charge controller to the circuit breaker box where it met a wire that provided an equipment ground for the box. We ran a wire from the battery's negative terminal to the brass ground rod. Then, from the positive terminal of the controller, we ran a wire to the positive terminal of the 12 volt battery.

For the panel wiring, the PV negative is connected to the negative terminal of the charge controller's panel circuit. And the positive from the panel runs to the top of the 15 amp circuit breaker. We then wired the bottom wire of the breaker to the positive terminal of the charge controller. Finally, the load negative from the controller was wired to the negative bus bar in the box. From the bus bar and the top of the 15 amp circuit breaker, the two wires run to the clinic's three, 20 watt, DC fluorescent lights.

Solar Cookers for Nicaragua

Eric Fedus

In Nicaragua, the source of energy for most cooking is still wood. But as the forests have thinned over the years, *campesino* (farmer) families find themselves spending more and more time searching for wood to burn in their clay stoves. Another problem is that the stoves spew smoke inside homes, affecting the health of women. So the women of the village of Las Pintadas were eager to try out the solar ovens. Unfortunately, the day for the tryout happened to be a mostly cloudy day, demonstrating the oven's reliance on sunlight.

Undeterred, the village women eagerly watched and participated as we showed them how to build small sun powered ovens. Our materials were cardboard, tape, glue, glass, cornhusks, a black-painted metal sheet, and aluminum foil. With one larger cardboard box serving as the shell, we placed a smaller box inside and insulated the space in between with cornhusks, a locally available product.

To reflect heat into the center of the box, we glued aluminum foil on the insides of both boxes. Then we placed the black metal sheet inside the oven, glued a plate of glass onto a cardboard cover piece, and the solar oven was complete. These ovens are capable of reaching 250°F (121°C) in full sun—enough to boil water or perhaps cook an egg and a few plantains.

If the women demonstrate that they have learned to use the cookers in the weeks to come, a few of them will have the opportunity to build their own more permanent cookers. An important part of this process will be the follow-up by members of Grupo Fenix to ensure that the women learn the strengths of solar cookers, and continue to use them.

As for myself, I can't wait to build my own solar cooker and try it out at my home, in the New England sun. Now I know that people haven't really tasted a good plantain until they cook it in a solar cooker. Information on solar cookers is available from Solar Cookers International (see Access).

At another Grupo Fenix solar cooker workshop in Managua, Nicaragua, participants pose with their cardboard ovens.

Grupo Fenix instructors, students, and residents of Las Pintadas gather for a celebration in front of the newly electrified health clinic.

great deal of interest in what we were doing, and were soon turning screws and learning the basics of the system. In front of a crowd of excited children and farmers, we turned the breakers on, flipped the light switch, and illuminated the health clinic. Applause and laughter followed, and people scattered to prepare for the party.

We didn't understand what an important event this was to the village until we attended their fiesta. Everybody from the village and quite a few people from neighboring villages gathered around the porch of the clinic. School teacher Roosevelt opened the festivities with a flowery speech explaining the benefit to the community and thanking the visitors for their help, while Susan Kinne translated.

Las Pintadas System Costs

Item	Cost (US$)
Grupo Fenix panel, 50 W	$300.00
CMG custom battery, 70 AH	133.90
3 Lamps, 15 W, 12 V	105.80
Solom 8.8x controller, 10 A	80.50
Installation accessories	80.00
Installation & follow-up	70.00
Total	$770.20

Then a group of young girls performed a barefoot dance, the local pastor gave a lengthy blessing, and there was some heartfelt solar poetry. We pitched in with juggling and a colorful story or two. Next, the ranchero band took over, playing a style of music that can only be described as soulful mountain music, perhaps a bit like an old Bill Monroe ballad.

With my guitar in tow, I was taught countless classic ranchero songs, including some new songs composed to celebrate solar electricity. In return, I tried feverishly to teach the band some American classics and was met with polite contempt. But unexpected enthusiasm greeted "Friend of the Devil," which I played over and over again until the band got it right. Fortunately, the party ended before daylight, and we did get some sleep that night.

Spreading the Light

A few weeks later, I returned to Las Pintadas to work on a second installation. I was excited to talk to the locals and find out how they were doing with the solar powered health clinic. They told me that the newly lighted porch of the health clinic had become a gathering place for reading and talking.

I heard news that some nearby villagers, who had earned good money selling organic coffee beans, were planning to invest in solar electricity for their own homes. I was impressed that there were now more sophisticated questions about the prices of panels and batteries, and the durability of these systems.

However, I did find some confusion concerning the warning lights of the charge controller. People were a bit disappointed that even though there was electricity left in the battery, they had to refrain from using it when the controller's light was red. This confusion originated from the previous experience of the locals running DC televisions off car batteries—they used the batteries until they were dead.

After some conversations concerning long-term battery health, I left the village with the confidence that the locals were up to the job of maintaining the system, and that solar electricity would thrive in the rugged hills of Las Pintadas.

Access

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Homebrew Heat Exchanger

Bert Echt

A single-wall, tube-in-tube heat exchanger can easily be built from readily available parts.

Most solar hot water systems that operate in freezing conditions use a heat exchanger. A heat exchanger is a device that allows a hot fluid to heat a cooler fluid without the two fluids mixing. I am a plumber by trade, but basic soldering skills are all you need to construct your own simple heat exchanger. In this article, I'll show you how to build a simple, single-wall, tube-in-tube heat exchanger for use with drainback solar domestic hot water (SDHW) systems.

Heat exchangers are used in both closed loop antifreeze and drainback type SDHW systems. I have also used them in wood-fired heating systems, radiant floor house heating systems with a domestic water heater, and custom-built spas. For more information on all types of heat exchangers and their use in solar domestic hot water systems, refer to *HP92,* "Heat Exchangers for Solar Water Heating."

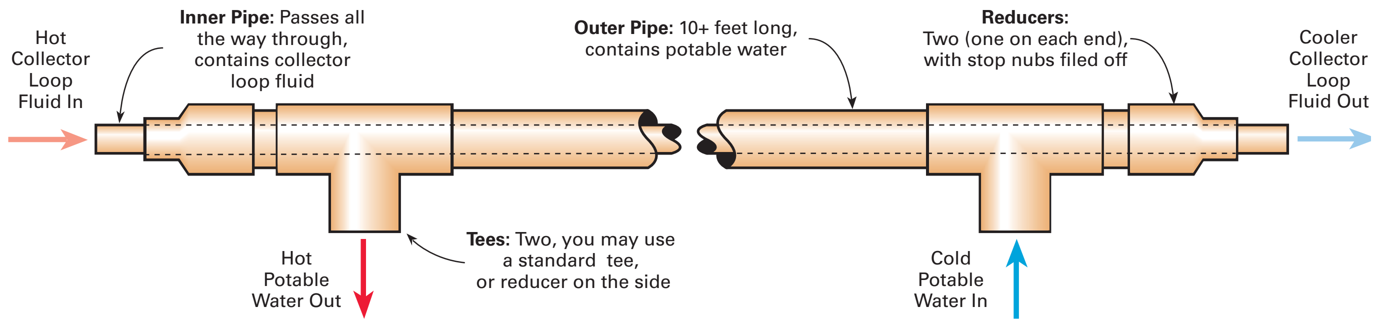
A Pipe Inside a Pipe

The tube-in-tube exchanger described here is simply "a pipe inside a pipe." This is accomplished by a very small and easy modification to a standard copper pipe fitting.

The fitting is called a "reducing coupler" or "coupling" (sometimes called a "bell reducer" because of its shape). But it must have the right kind of "stops." Normally this fitting is used to join two pipes of different diameters, and there are "stops" to prevent the smaller pipe from going too deep into its socket.

Bert Echt ready to solder together a heat exchanger.

Typical Tube-In-Tube Heat Exchanger



Some manufacturers create a ring or tiny shelf all the way around inside the smaller socket—you do not want this kind of stop. Other manufacturers just stamp two little dimples on the outside of the small socket to create two tiny bumps on the inside of the socket. This is what you must look for. Then just use a round file to remove these little inside bumps.

That's the secret! Now the smaller pipe can slide all the way inside the bigger pipe—a pipe inside a pipe. A tee at each end, on the large side of the bell reducer, connects the outer pipe to your cold water source. See the diagrams for different configurations.

Design

The design of a heat exchanger depends on its intended use. Obviously, the longer the pipes, the more heat will be exchanged. For a domestic hot water system, experience has taught me that 10 feet (3 m) is the minimum. To heat a house requires a *big* exchanger. Don't skimp on the exchanger—if undersized, it will be "choked" or bottlenecked, and not enough heat will be transferred. The greater the difference in temperatures (ΔT) between the liquids, the greater the exchange of heat. A ΔT on the order of 20°F (11°C) is typical. The exchanger configuration can be straight (vertical or horizontal), or in a coil if soft copper is used.

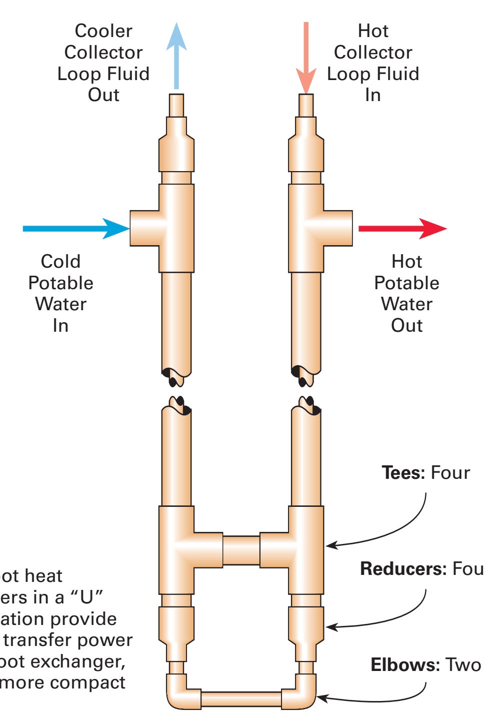
There are other considerations as well. Is the system circulated by thermosyphon or by pump? With thermosyphon systems, larger pipes are needed to make fluid flow easier. I recommend a 1 1/2 inch outside pipe with 3/4 inch inside pipe for thermosyphon systems. With circulating pumps, 1 inch outside and 1/2 inch inside works. The hotter fluid usually runs through the smaller pipe in the center, with the cooler domestic water running between the two pipes. This keeps the outer surface temperature cooler to minimize heat loss.

Single vs. Double Wall

Heat exchangers may be classified as either double wall or single wall. Double-wall heat exchangers have two layers of separation between the two fluids. The space between the two walls is usually vented, so any leak will become visible. Double-wall heat exchangers are usually required by code when a toxic heat transfer fluid such as ethylene glycol is used.

Single-wall heat exchangers only have one wall of separation between the two fluids. A single wall is more efficient than a double wall, since only one layer of thermally conductive material is between the two fluids. However, a failure in that wall will allow one fluid to mix with the other. For that reason, use only potable water (distilled is best) as the collector loop fluid in single-wall exchanger systems for heating domestic hot water. *Never use automotive antifreeze!*

"U" Configuration



Two 5 foot heat exchangers in a "U" configuration provide the heat transfer power of a 10 foot exchanger, but in a more compact space.

Materials & Tool List
for a U-shaped Heat Exchanger

Materials
- ❑ One, 1 inch by 10 foot, type L copper tube
- ❑ One, 1/2 inch by 10 foot, type L copper tube
- ❑ Four, 1 inch by 1/2 inch reducing couplers (with "dimple" stops)
- ❑ Four, 1 inch tees
- ❑ Two, 1/2 inch elbows
- ❑ Insulation, lead-free solder, flux, Mapp gas,

Tools
- ❑ Propane torch
- ❑ Flint box or sparker
- ❑ Abrasive cloth
- ❑ Flux brush
- ❑ Tubing cutter
- ❑ Water spray bottle
- ❑ Leather work gloves
- ❑ Round file
- ❑ Small fire extinguisher

The collector fluid is usually at a lower pressure than the potable water, so if an internal leak develops, the domestic water will move toward the collector fluid, and the pressure relief valve on the solar loop (set at 30 psi) will open. Of course, you should pressure test your exchanger with air at 60 psi for 24 hours, so there will be little chance of leaks.

External heat exchangers are common in small SDHW systems using conventional tanks. Internal coil-type heat exchangers are available with some commercially available tanks, but they are expensive. Large drainback tanks can be easily fitted with an internal coil-type heat exchanger. In smaller systems that use conventional hot water tanks for storage, it is easier to use an external heat exchanger. Standard practice for heat exchangers calls for two-pump, "counter-flow" operation—meaning that the hot fluid flows in the opposite direction from the cooler fluid.

Cost Effective Heat Exchanger

The cost of a 10 foot (3 m), U-shaped (5 feet; 1.5 m long) exchanger for a pumped system is approximately US$50. For a thermosyphon system, the cost is approximately US$100 or more, since larger tubes often come only in 20 foot (6 m) lengths.

These liquid-to-liquid heat exchangers can be easily made from standard copper plumbing tubing and fittings. But you need to know how to solder or "sweat," as plumbers call it. For a crash course, see the sidebar in *HP94*, page 55, "Soldering Copper Pipe."

Heat exchangers are a key element in a solar hot water system. With a few simple tools and some basic soldering skills, you can build your own from this homebrew design. It is efficient, durable, and inexpensive.

Access

Bert Echt, green builder, plumber, licensed master electrician, 63 Strong Rd., Ferndale, NY 12734 • 845-295-9221

Alternators

Brushless

The author prepares to repair a Dunlite BL, 2 KW wind generator that uses a brushless, 3-phase alternator.

Graig Pearen

Several different technologies are used in the generator portion of wind turbines (wind generators). One of the older, more reliable technologies is the brushless DC alternator. Its operation is often poorly understood by the owners, and in some cases, poorly described by the manufacturers. I'm not an expert on brushless alternators, but when I acquired some damaged Dunlite wind turbines, I became seriously interested in how they work.

Basic Theory

When an electric current is passed through a coil of wire, a magnetic field is produced (an electromagnet). Conversely, when a magnetic field is moved through a coil of wire, an electric current is produced in the wire. Both of these actions take place in alternators, motors, and generators or dynamos.

The stationary part of a motor or alternator is called the stator and the rotating part is called the rotor. The coils of wire that are used to produce a magnetic field are called the field, and the coils that produce electricity are called the armature. The coils of wire are sometimes referred to as the "windings."

Electrical energy is generated when a coil of wire is moved through a magnetic field. It doesn't matter whether the coil is moving or the magnetic field is moving. Either configuration works equally well, and both are used separately or in combination depending on mechanical, electrical, and other objectives. The old DC generators (dynamos) used a stationary field and rotating armature. Automotive alternators use the opposite configuration—a rotating field and stationary armature. In a brushless alternator, both configurations are used in one machine.

Construction

A brushless alternator is composed of two alternators built end-to-end on one shaft. Smaller brushless alternators may look like one unit, but the two parts are readily identifiable on the large versions. The larger of the two sections is the main alternator and the smaller one is the exciter.

The exciter has stationary field coils and a rotating armature (power coils). The main alternator uses the opposite configuration with a rotating field and stationary armature. This configuration is required to implement brushless technology without using permanent magnets. Eliminating the brushes eliminates brush and slip ring wear and maintenance. The only moving parts subject to wear in the basic alternator are the bearings.

Alternator Terminology

The parts of an alternator or related equipment can be expressed in either mechanical terms or electrical terms. These two sets of terminology are frequently used interchangeably or in combinations that include one mechanical term and one electrical term. This causes great confusion when working with compound machines such as a brushless alternator, or when conversing with people who are used to working on a machine that is configured differently than the machines that the speaker is used to.

Mechanical

Rotor: The rotating part of an alternator, generator, dynamo, or motor.

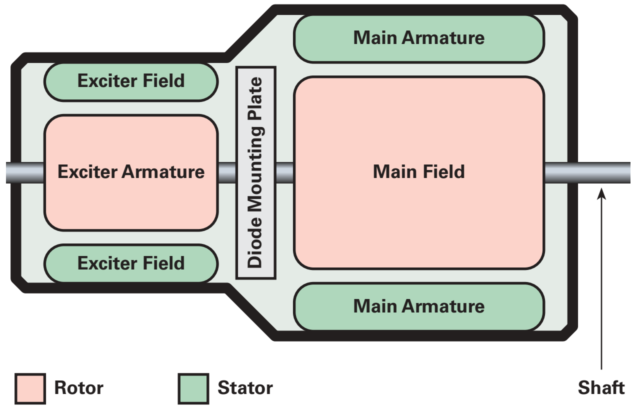
Stator: The stationary part of an alternator, generator, dynamo, or motor.

Electrical

Armature: The power-producing component of an alternator, generator, dynamo, or motor. The armature can be on either the rotor or the stator.

Field: The magnetic field component of an alternator, generator, dynamo, or motor. The field can be on either the rotor or the stator, and can be either an electromagnet or a permanent magnet.

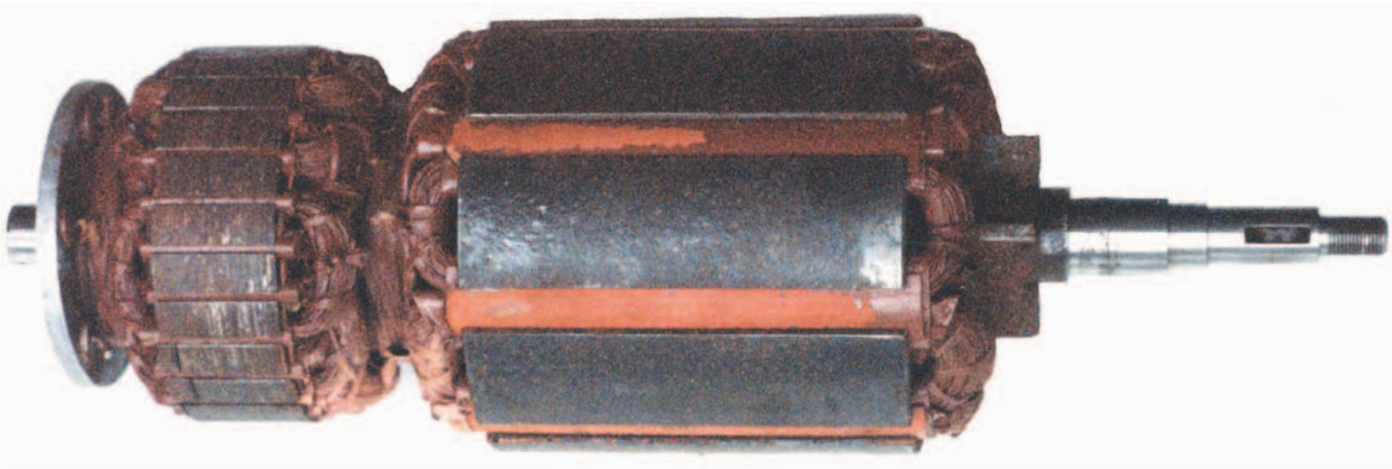
Brushless Alternator Configuration



Although rugged and reliable, brushless alternators are expensive to manufacture and therefore were only used in premium quality wind turbines. The high cost of production puts them solidly in the industrial grade category. With the advent of powerful, cheap permanent magnets, the residential-sized wind industry has switched to the cheaper permanent magnet alternator (PMA) technology. Brushless alternators are also used extensively in large engine-driven power plants and in utility-sized power generation.

Exciter

The exciter field coils are on the stator, and its armature is on the rotor. The AC output from the exciter armature is fed through a set of diodes that are also mounted on the rotor to produce a DC voltage. This is fed directly to the field coils of the main alternator, which are also located on the rotor. With this arrangement, brushes and slip rings are not required to feed a current to the rotating field coils. This can be contrasted with a simple automotive alternator, where brushes and slip rings are used to supply a current to the rotating field.



The rotor of a brushless alternator: The smaller section at left is the exciter armature; the larger section at right is the main alternator field. The diodes are mounted on the aluminum disk at the left end.

Main Alternator

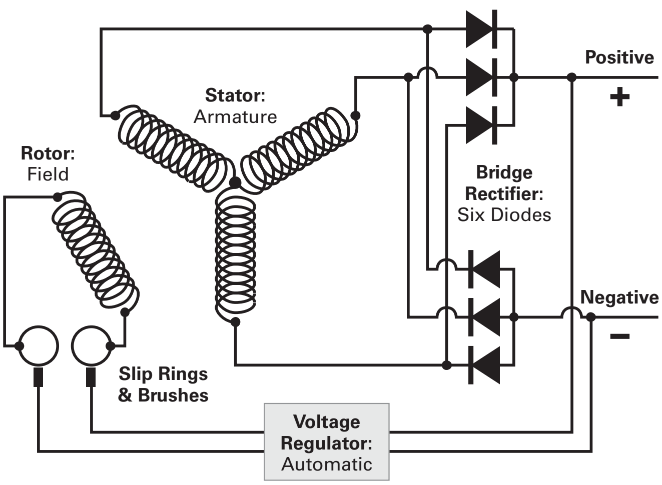
The main alternator has a rotating field as described above and a stationary armature (power generation windings). With the armature in the stationary portion of the alternator, the high current output does not have to go through brushes and slip rings. Although the electrical design is more complex, it results in a very reliable alternator because the only parts subject to wear are the bearings.

Control System

Varying the current through the stationary exciter field coils controls the strength of the magnetic field in the exciter. This in turn controls the output from the exciter. The exciter output is fed into the rotating field of the main alternator to supply the magnetic field for it. The strength of the magnetic field in the main alternator then controls its output.

The result of all this is that a small current in the field of the exciter indirectly controls the output of the main alternator, and none of it has to go through brushes and slip rings.

Automotive Alternator



In a wind generator, this means that the loading can be matched to the speed, unlike in a permanent magnet alternator. Although some of the wind generator's output is used to generate the magnetic field, there is no cogging effect, so low wind start-up characteristics are improved.

Automatic Voltage Regulator

An automatic voltage regulator (AVR) serves the same function as the voltage regulator in an automobile or the charge controller in a solar-electric system. It measures the battery voltage and uses that information to adjust the level of current fed into the field coil. As the battery voltage goes down, the AVR increases the current to the field coils to produce a stronger magnetic field.

The stronger magnetic field causes a higher output from the alternator to bring the battery voltage back up to the set point. Conversely, when the voltage rises too high, the field current is decreased, lowering the output from the alternator.

Variations

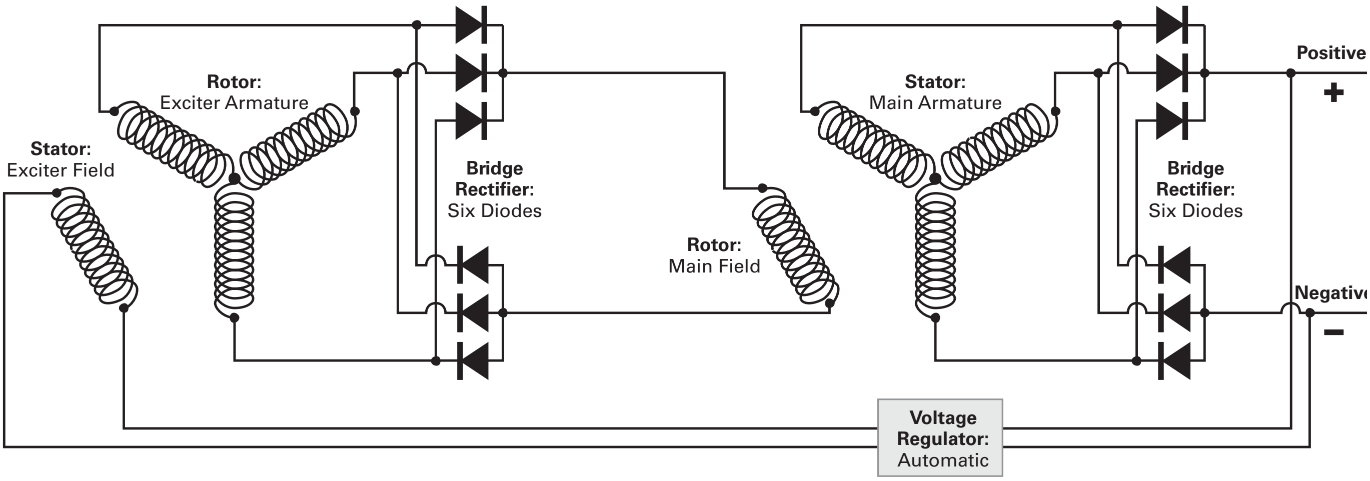
As with any other electronic or electrical device, there can be numerous variations in the design. The Dunlite 2 KW wind machines use an auxiliary winding on the main stator to generate the voltage for the exciter field. These machines rely on residual magnetism to excite the auxiliary winding, while some machines use permanent magnets for this purpose.

On the Dunlite machines, both the exciter and main field coils use eight poles. (Three phases, multiplied by eight poles, is twenty-four coils of wire.) The exciter armature is wound in a three-phase, four-wire wye (star) configuration, and the main armature is a three-phase, three-wire delta design.

Three-Phase Basics

A three-phase alternator has a minimum of three sets of windings, spaced 120 degrees apart around the stationary armature (stator). As a result, there are three outputs from

Brushless, 3-Phase Alternator



the alternator, and they are electrically spaced 120 degrees out of phase with each other. A multi-pole design will have multiple sets of three windings. The more poles there are, the slower the alternator turns for a given voltage and frequency.

More poles increase the complexity of the alternator, and that in part accounts for the higher price of slow speed versions. Other than in single-phase power plants, most alternators, including the automotive type, generate three-phase power. A three-phase AC alternator will not have any diodes in it.

If the output is DC, it will probably have six diodes to convert the output from the main alternator to DC. This is the configuration used in automotive alternators. A three-phase brushless alternator may have four or six diodes on the rotor for the exciter output in addition to the diodes that may be on the stator.

There are two ways that three-phase machines can be wired. One is the delta (triangle) configuration, with one wire coming off each "point of the triangle." The other is the wye (Y) or star configuration. They have one wire from each branch of the Y and a fourth common wire is added from the center point of the Y (the common connection point between the windings). Multiple voltage machines will have additional wires to allow them to be configured for the desired system voltage.

If you ever have to service an old wind turbine with a brushless alternator, this brief description may help you to understand how it works, or at least let you talk the same language as the repair shop.

Access

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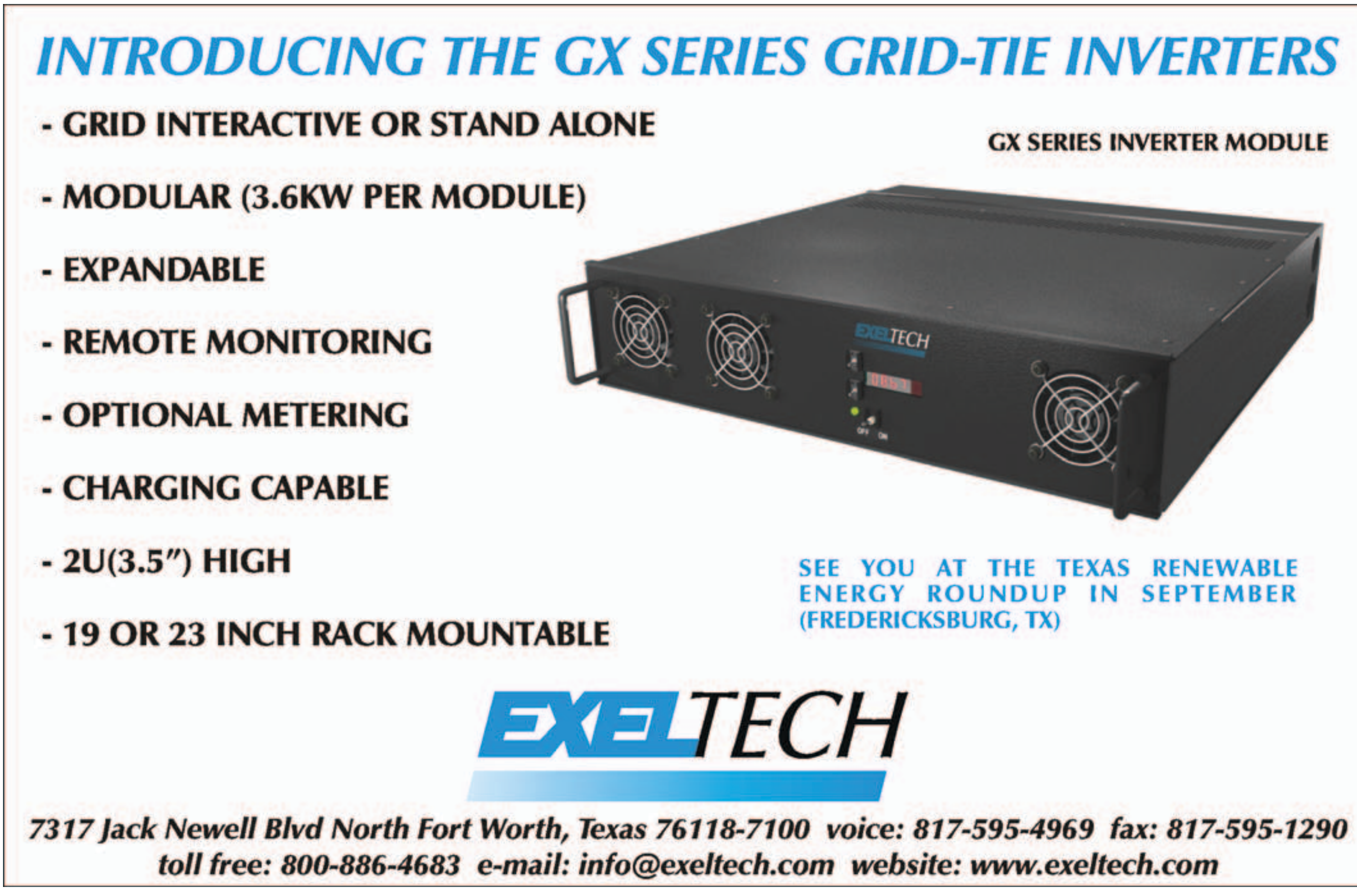
See "Yer Basic Alternator," Bob-O Schultze, *HP20* , available in print or on the *Solar2* CD.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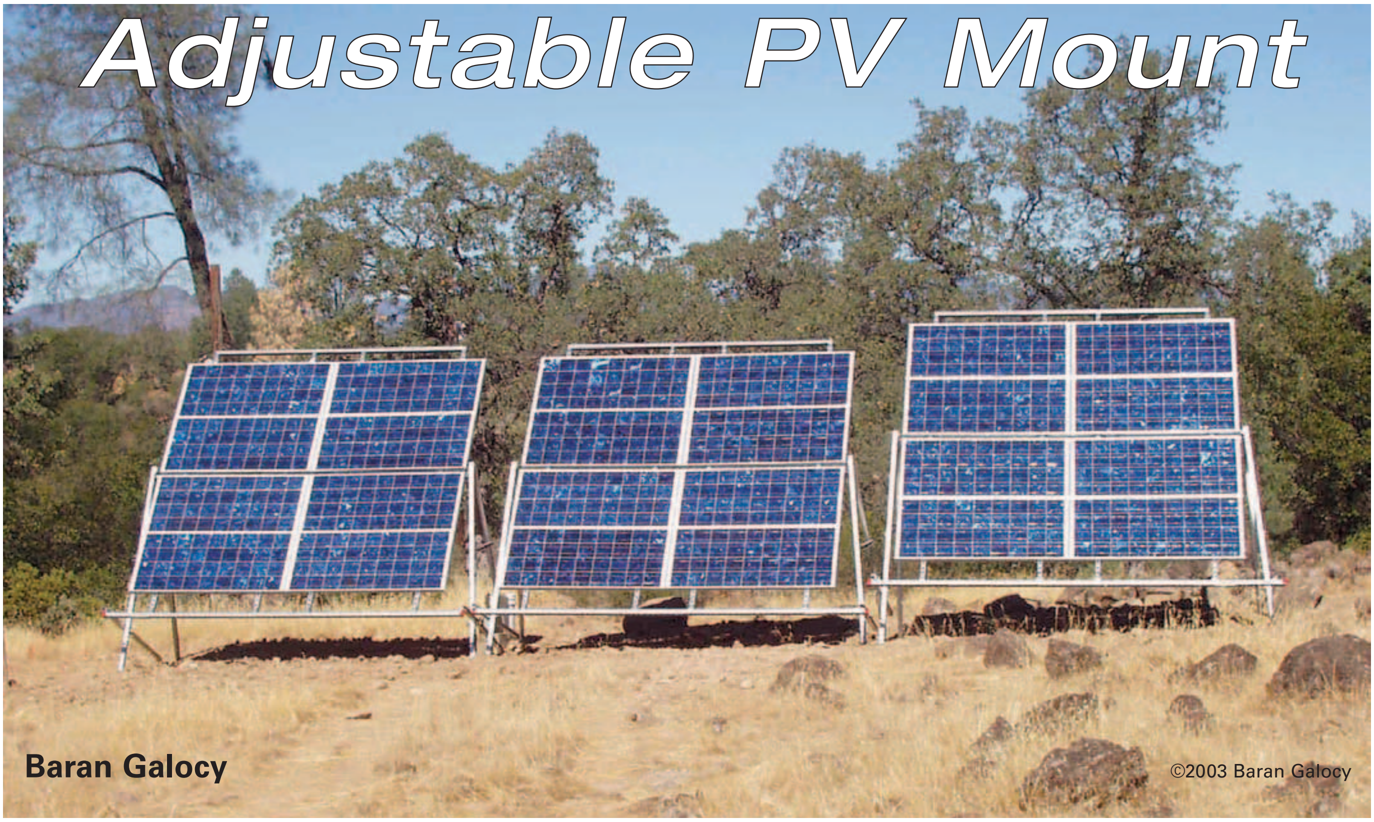


Baran Galocy

Fixed panels on a hot roof don't come close in efficiency or coolness to these arrays out standing in their field.

Nothing is quite so breathtaking as a sail catching wind on the water. These PV arrays bring to mind the same image when resting in their near-vertical position during the winter. Picture a swing set, the center bar oriented east and west, with 100 square feet (9.3 m^2) of solar array balanced on top, but just off center, so that the lower end stays down. You can custom build one of these beauties for under US$500 using common hardware.

This field tested and engineered-for-California design is delightfully simple and efficient. The design specs for this project have been checked by an engineer and approved by my local building department. If you are submitting this design to a building department, you will probably need to provide engineering from a civil engineer licensed in your state.

My Mounting Option

When it comes to mounting photovoltaic panels, only a few options await the installer who chooses not to place them on a roof. First and foremost are pole-mount racks. These include fixed (seasonally adjustable) and tracking (single or dual axis, with various drive mechanisms). Most companies that offer pole-mount racks also have ground-mount racks available. None of these choices suited me.

Many property owners here in the northern Sacramento River valley who are interested in solar electricity also have significant acreage. Most of my ground-mounting scenarios involve vast, open pieces of land. I don't see the need for the expense of trackers here, and some pole mounts require a ladder and a wrench to adjust the arrays.

I wanted to be able to mount large PV arrays that could easily be adjusted for the season by anyone, with no tools or special equipment. Not finding anything that filled my needs, I did what any self-respecting wrench would do—I fabricated a rack with parts from the local supply house, took it to my friendly civil engineer for a stamp, and submitted it to my building department.

I have assembled almost fifty of these racks to date, and found them to be easy to install and operate. I share this knowledge with *Home Power* readers in the hope of hearing from those of you who build, and build upon, this design. By networking and sharing information, future enhancements may be made and enjoyed by many.

Gathering Materials

There are endless choices in materials, and as many variations in design as there are applications. My design criteria was to support as many panels as I could on one rack that could be easily adjusted by one person. Given the hardware and PV panels available, I chose a 10 by 10 foot (3 x 3 m) array that is balanced slightly off center. This design will easily support eight, 120 watt PVs.

The rack's legs are aligned such that, at my latitude, the array naturally rests facing the angle of the sun's winter solstice. Because the array is balanced, it can be easily moved as the seasons progress. Two arms fix the tilt angle of the array. These arms are held in with hitch pins and clips. All of the rack material is hot-dipped galvanized channel with elongated holes, and all of the hardware is stainless steel (SS).

To make things as easy as possible (I'm not getting any kickbacks here), part numbers for Allied Power-Strut material and Fastenal Supply Co. hardware are included in the table. For coastal conditions, all Allied hardware is available in stainless steel, including the strut. To save weight, aluminum strut may be used for the rack framing. Ask your engineer!

Layout & Foundation

The ideal site is level and rock-free with a southern exposure and no seasonal shade. I survey the area with a handheld compass, and I use a Solar Pathfinder to determine if trees or structures will contribute to panel shading. Remember to find true south, which is probably not the same as magnetic south where you live. Also remember to remove your keys, change, etc. from your pockets when using any magnetic compass.

Once I stake out my lines and mark my holes, I'm ready for the post-hole auger. The subcontractor I use has an 18 inch (46 cm) diameter auger bit that goes 4 feet (1.2 m) deep. This is perfect, since that hole can comfortably hold 1/4 cubic yard of concrete, and in my location, 1 cubic yard is required per eight-panel array. The holes are laid out 11 feet (3.4 m) apart in one direction and 5 feet (1.5 m) in the other.

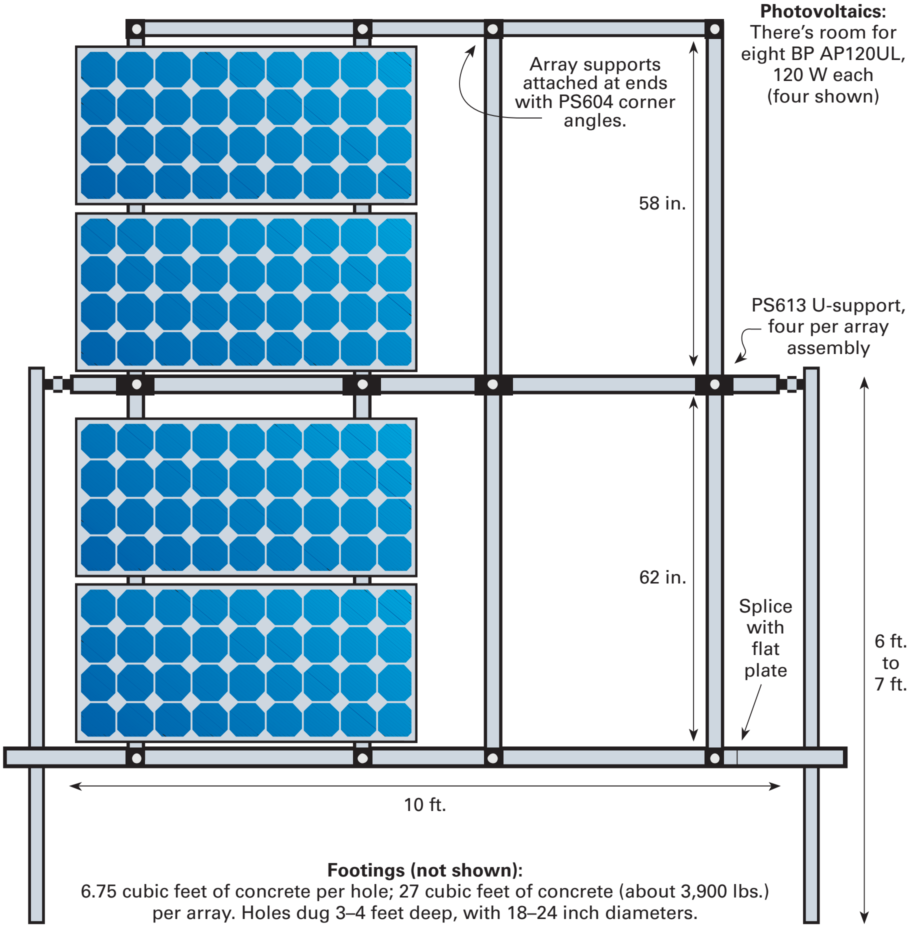
A side view of the array.

An acceptable alternative when hard or rocky soil makes using an auger difficult is to trench two, parallel, 18 inch deep by 18 inch (46 x 46 cm) wide troughs about 5 feet (1.5 m) apart. Assemble the arrays with the feet in the trenches, and ground the arrays to a 20 foot (6.1 m) length of rebar with all-brass ground clamps. Use additional rebar in the trench to maintain the structural integrity of the concrete, as you would with any footer for a new house.

Keep the rebar 2 inches (5 cm) or more from the surrounding dirt, and support the array legs so that they do not touch the bottom of the trenches. Do this with crossbars or set them on concrete "dobies." These are 3 inch (7.6 cm) concrete cubes with wires on one end. They become 3 inch stand-offs that help prevent the channel from premature rusting because of earth contact.

I cannot stress enough how important it is to review your plans with your local building department. Since my job is installing grid-tied PV systems, not doing battle with the building department, I say, "Yes, sir" to their requirements. They approve my plans, and less than US$100 later, I have the permit I need for a utility company inspection.

PV Array's Front View and Detail



Putting It All Together

Each set of two legs is held together by a "T-plate" attached with stainless-steel channel nuts. Before you stand up the leg assemblies, slide a 1/2 inch PVC coupling, glued onto a 1/2 inch PVC sweep into the bottom of one. If you don't do it now, you won't be able to later. Each array needs one sweep to carry the power wires safely protected by one of the rack's legs. The legs are leveled in the holes by additional pieces of Power-Strut laid on the ground between them. These leveling pieces remain until the concrete has set.

The center pivot is supported at each end by a three-hole angle bracket bolted to the T-plate. The angle brackets are attached onto each end of the pivot by two stainless steel channel nuts. Note that with an 11 foot (3.4) leg spacing and 10 foot (3 m) pivot bar, the leg sets will lean in about 6 inches (15 cm) each. This lends stability to the structure.

You now have what undeniably looks like a swing-set frame made from a big erector set. This is the time to level the pivot arms, which should be suspended channel up. If you are installing more than one array, sight down the legs from each end, as well as the pivot arms. If your arrays are adjacent, the view should be that of one continuous pivot arm from either end. Even if one is higher or lower, they should still be in east-west alignment. A string line can come in handy for this operation too.

This brings up another important consideration—on uneven land, should you make all the pivots the same elevation or the same distance from the ground? To some degree, it is a matter of aesthetics. The pivots must be at least 5 feet (1.5 m) above the ground at all points so that the array may rest against the frame in the winter, and not on the ground. If the pivot is more than about 7 feet (2.1 m) high, it tends to be a little more difficult to assemble, and can get squirmy in big gusts of wind. Granted, it is going nowhere, but no one likes to see their arrays shimmy when it's storming.

The next step is to attach the conduit underground, run the ground wires, and call for your preliminary inspection. Trust me—you don't want to have to prove later how deep your holes are. After inspection, it's time to pour the concrete, and let it set for a day. From this point on, things really start to move.

Attach four cross-arms to each pivot arm with the U-supports. This is best accomplished by first securing each bracket onto a cross-arm, and then securing the cross-arms onto the pivot arm with bolts and channel nuts. The brackets should mount onto the cross-arms just off center so that one side (the lower side) is 62 inches (157 cm) long and the other is 58 inches (147 cm) long.

Pivot detail assembly: T-plate, pivot beam, corner angle, U-support, and fasteners.

Detail of the second pivot arm.

For example, on a 120 watt panel (ideal because of its dimensions of roughly 5 feet by 2 1/2 feet; 1.5 m by 0.8 m), the mounting holes are 10 inches (25 cm) from the panel ends, and 40 inches (102 cm) apart. Starting from the middle of the pivot arm, mark 10 inches (25 cm) out in each direction. These are the center lines of the inner cross-arms.

Measure out an additional 40 inches (102 cm) in each direction and you will have the center line of the outer cross-arms. Install two channel nuts in the pivot arm for each cross-arm (about 1 7/8 inch; 48 mm each side of the center line) to bolt the U-support onto the pivot arm with. The cross-arms should be mounted channel side down!

Now is the time to attach the end pieces to stabilize and unify the four cross-arms and complete the rack framing. Refer to the pictures to see how the ends are secured with two-hole angles. The angles are bolted through the elongated cross-arm holes and into channel nuts in the end pieces.

I prefer to cut the north end piece to connect only to the ends of the outer cross-arms—typically about 100 inches (2.54 m). The lower, or southern, end is typically about 134 inches (3.4 m), plus or minus. This is accomplished by fastening an additional length onto a 10 foot (3 m) strut with a four-hole plate or sleeve.

The arrays are leveled with pieces of Power Strut laid on the ground.

Sighting down the arrays, the pivot arms should look continuous.

The grounding technique for attaching copper wire to steel in concrete.

This allows the array to rest against the south legs during the winter.

It is also a safety feature, without which you could experience a well-balanced array swinging back and striking you with some impact. Measure the distances between the cross-arm ends, which should be the same as the marks on the pivot arm, top and bottom. Slide the channel nuts into the end pieces to the measured setbacks and securely fasten four, two-hole angles to the end pieces. Then align the top and bottom ends to the cross-arms and attach with bolts. At this point, it is best to use a ladder to support the heavier end.

Before the panels are mounted, install a second pivot arm beneath the first one, channel side down with six, 1/4 inch (6 mm) bolts, fender washers, and star nuts. The purpose is to distribute the weight and help deflect the load across the pivot arm. The final attachments are the leg-ties and support arms.

Just Add PVs

You have completed the rack framing assembly and are now on the homestretch. Attach your PV panels with stainless steel hardware to the four cross-arms, snugging them up against the U-supports on the pivot arm. The rack framing may be tweaked with a sharp tug from the bottom or top to help align panels. Make sure you have not fastened the

Rack Parts List

Qty.	Description *	Part # **	Price (US$)	Amount (US$)
14	Strut, galvanized	PS-200	$12.00	$168.00
	Concrete, 1 yard		90.00	90.00
24	Top-Grip nuts, 1/2 inch SS	PSTGSS	3.00	72.00
2	Corner angles, 3-hole, SS	PS-605SS	9.25	18.50
4	U-support, 5-hole	PS-613SS	4.50	18.00
2	T-plates, SS	PS-714SS	8.75	17.50
	Misc. clamp, conduit, rebar		15.00	15.00
2	Hitch pins & clips	44155	6.50	13.00
42	Bolts, 1/2-13 x 1 1/4 inch SS	70207	0.30	12.60
42	Washers, 1/4 x 1 1/4 inch SS	71013	0.20	8.40
10	Corner angles, 2-hole	PS-604	0.79	7.90
37	Nuts, 1/4 inch x 20 SS	70710	0.20	7.40
36	Washers, 1/2 x 1 1/4 inch SS	71021	0.20	7.20
46	Split washers, 1/2 inch SS	71071	0.15	6.90
24	Nuts, 1/2-13 SS	70714	0.25	6.00
32	Washers, 5/16 inch SS	71015	0.15	4.80
32	Bolts, 1/4-20 x 1 1/4 inch SS	70007	0.13	4.16
4	Bolts, 1/2-13 x 2 1/2 inch SS	70213	0.50	2.00
4	Washers, 5/8 x 1 3/4 inch SS	71026	0.30	1.20
2	Nuts, 5/16-18 SS (spacers)	70711	0.45	0.90
5	Bolts, 1/4-20 x 2 inch SS	70011	0.15	0.75
			Total	$482.21

* SS = stainless steel

** 5 digit part numbers are Fastenal, PS numbers are Power-Strut.

The junction box prior to the concrete pour—it can also be easily attached to a rear array leg.

A top or bottom end is attached to a cross-arm with a two-hole corner angle and a channel nut.

To extend the front arm, splice on an additional piece of Power Strut with a four-hole plate or sleeve.

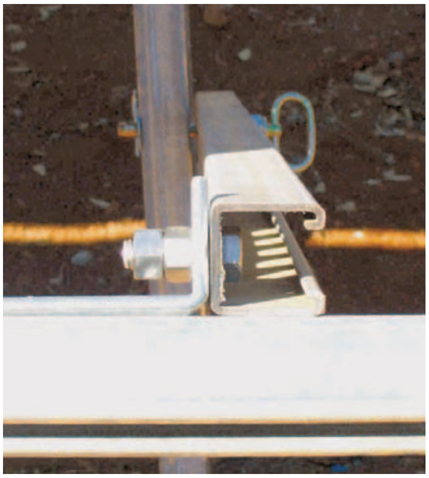
panels securely yet if you try this. In fact, it is best to mount all eight panels loosely, align everything, and then tighten down the assembly.

The support arms are half-lengths of strut, attached to the ends of the bottom end piece with two-hole brackets. They are secured such that they swing freely and can support the rack framing in any position by attaching to the front legs with hitch pins and clips. The leg-ties are scrap channel material that reinforce the legs to help prevent twisting and deformation under severe stress. It is important to note that the support arms and lower legs face each other, back-to-back (channel out), for stability.

Wires may be dressed within the channel itself, and secured with a channel-filler plate, if desired. Instead, I prefer to extend the PVC conduit running up a leg with 3/4 inch Carflex that friction fits over the PVC, and hammers into the the 1 5/8 inch strut channel along its length. I drape it with enough slack to allow for seasonal adjustment, and hammer the other end into the bottom of the pivot. This locks a flexible conduit through which your cables may run. Fill the end of the Carflex with weatherproofing to keep bugs and moisture out. Be sure to ground your PV panels in the manner recommended by the manufacturer or your local building department.

The rack framing and pivot arm assembly.
The array will become plumb when the right arm extension is installed.

The rack's hitch pin and clips are easily accessible for seasonal adjustments.



The Carflex conduit is pressed into the rack's channel.

Finished—all the wiring is neatly tucked away in the PowerStrut and conduit.

A Fine PV Rack

There are several ways to assure proper alignment of the rack. A very simple way is to adjust the arrays on a sunny day near solar noon. You can adjust the setting such that an even shadow is cast upon the ground by the pivot arm and adjacent panels. This is good for frequent adjusters. For those who prefer adjusting four times per year, simply determine the correct solar angles for winter solstice, summer solstice, and fall and spring equinoxes (latitude plus 15 degrees, latitude minus 15 degrees, and latitude). This will determine the maximum and minimum angles, as well as the midpoint. Then mark the front leg and support arm hitch pin locations with an indelible marker.

This design has been a big success in my business. It works for most sites, and is very easy to adjust. One of my clients is a woman who lives alone and weighs less than 100 pounds (45 kg). She has absolutely no problem adjusting her single array. I hope this article has been useful, and that you will enjoy one of the most versatile array designs to hit the streets.

Access

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WBA Engineering, PO Box 493958, Redding, CA 96049 • 530-221-6920 • Fax: 530-221-6988 • wba@wbaeng.com • www.wbaeng.com • Civil engineering calculations

Allied Support Systems, 35660 Clinton St., Wayne, MI 48184 • 800-416-2101 or 734-727-4000 • Fax: 734-721-4106 • kcolligan@alliedsupport.com • www.tyco-alliedsupport.com • Power-Strut manufacturer

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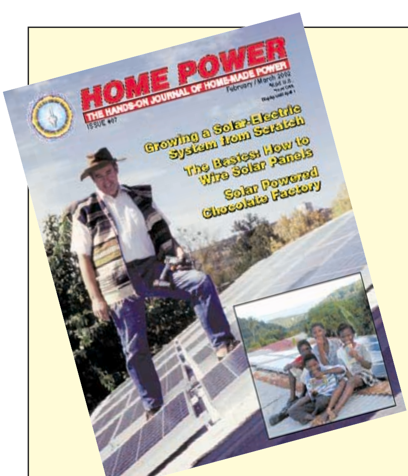

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Thermalstar Technologies

Thermosyphon Solar Water Heater

Ian Woofenden, with data collection by Rose Woofenden

Application: **My family and I put together a stand-alone solar shower at our home in northwest Washington state, using Thermalstar Technologies' simple, unpressurized, evacuated tube water heater. It provides showers primarily for me, but also for the kids when they are willing to withstand the breeze in this outdoor shower and forego the higher water pressure of our indoor shower. Our datalogging session conveniently occurred just after our propane demand heater died, so the whole family used the shower heavily during that time. This solar water heater is a low-pressure unit that will not work in most mainstream applications. It is most appropriate for freeze-free environments, seasonal use, or simple applications.**

Thermalstar's evacuated tube solar water heater.

System: **We datalogged ambient air, collector tube, and tank temperatures using a Hobo logger, three temperature sensors, and a 486 PC laptop. The skin and brains of two adults and five children monitored shower comfort and function.**

Our family has been living with solar electricity for about 20 years. But our water is primarily heated by propane. The complication of pumps, glycol loops, wiring, and installation had kept me from getting out of my editor's chair and putting a solar domestic hot water (SDHW) system on our home. But when I saw Thermalstar Technologies' simple heater, I saw a way to walk my solar thermal talk.

Packaging & Installation

The heater arrived in the back of importer and engineer Andrew Swingler's Volvo stationwagon. Normal shipping is via UPS, but Andrew lives just across the border from me in Vancouver, BC, Canada, and offered to bring the unit down and help set it up. The stainless steel tank and framework are shipped in a cardboard carton. The glass tubes come in a sturdy wooden crate with Styrofoam cradles that keep them intact during transit.

The unit includes a 22 gallon (83 l) insulated tank, a slanted stainless steel reflector, square tubular framework to support the tank, and fifteen simple evacuated tubes. We assembled the tank and framework with common hand tools. It was fairly intuitive and simple. The various stainless steel parts bolt together, and everything fit together well.

After the framework was assembled, we installed the tubes. The tube tops slip up into rubber gaskets inside holes in the bottom of the tank. After a shot of soapy water from a spray bottle, the tubes twist up into the tank with no problem. They then slip back down a bit for the bottoms of the tubes to rest in the plastic cushion at the base of the reflector.

The unit was fully assembled in less than an hour, and we hoisted it up onto the shower structure that the kids and I had built in advance. We fastened it down with eight, 1 inch (2.5 cm) screws through the unit's feet. The next step was plumbing.

Andrew made a simple faucet rig so we can have hot and cold water and also be able to fill the heater tank when we want to. We plumbed a garden hose to this copper plumbing, fitting it with hose clamps. We added a clear plastic tube next to the tank to show us how full the tank is.

Simple Construction & Function

This heater combines a simple storage tank with "evacuated tubes"—double-wall glass tubes. In between the two glass walls is a vacuum. The bottom of the sealed outer tube contains a gas-absorbing, silver-colored material that ensures a high vacuum. The material will discolor if the vacuum is ever lost (rare).

The tubes are similar to the technology used in old electronics-style vacuum tubes and thermos bottles. They are of a continuous glass construction with no metal to glass seal. According to the manufacturer, the "high quality borosilicate glass" tubes are designed to withstand a 1 inch (25 mm) diameter hailstone falling at terminal velocity. The tubes are cylindrical and much stronger than a flat sheet of glass.

Evacuated tubes have had the reputation of being too fragile. The historical fear of breakage comes from the metal to glass seals of the early single-walled heat pipes. Our system's simple tubes are constructed differently. They are an all glass, double-walled design with no metal to glass seal to fail. These are breakable, but not terribly fragile.

In operation, the inner tube is filled with water, which absorbs the sun's heat. The inner glass is coated with a selective surface—a dark material that helps absorb the sun's heat, but does not let much heat reradiate out of the water in the center of the tube. Unlike most other evacuated tube devices, which are called "heat pipes," these units have no metal absorber or heat transfer device.

Zander Woofenden likes to get clean with liquid sunshine.

Features

High Points:

- Simple assembly and installation
- All stainless steel construction
- Simple evacuated tubes (not heat pipes)
- No pumps, glycol, electronics, or wiring
- Very effective solar heater
- Low cost
- Completely passive heating

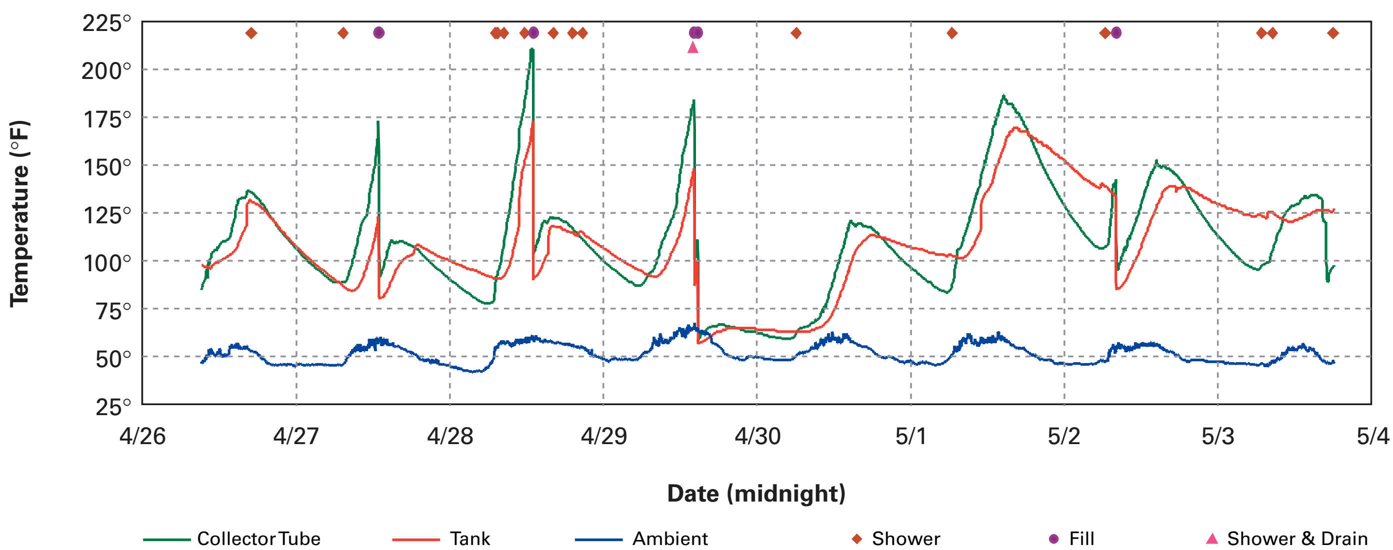
Low Points:

- Maximum internal pressure must be limited to below 5 PSI
- Doesn't interface easily with conventional pressure systems
- Manual fill
- No scald protection
- Needs cold water for mixing

List Price: US$649, including high quality crating suitable for North American delivery

Warranty: A one-year limited warranty, with extended warranty available, covers frame, tank, and evacuated tubes against manufacturing defects.

SDHW Heater Temperatures



They are simply double-wall tubes filled with water, and open at the top. The tops of the tubes, inside the bottom of the tank, allow a free-flowing exchange of water via gravity and thermosyphoning between the tubes and the tank. There is no connection or manifold between the individual tubes at the bottom, and the tank acts as a manifold at the top.

The sun heats the water in the tubes, and since hot water rises, the hottest water goes up into the tank. Cooler water (which is denser and tends to go down) seeps down into the tubes in a continuous cycle that puts the coolest water in the tubes and the hottest water in the tank.

The surface heating area of the system is about 1 m^2 (10.8 $ft.^2$). At full sun, the manufacturer's rated temperature rise is 18°F (10°C) per hour with a full tank and 36°F (20°C) per hour with a half tank. These figures are based on full sun (1,000 W/m^2, perpendicular to the tubes and with zero difference between tank and ambient temperatures), ideal conditions not often found in the real world.

The data my daughter Rose collected showed half the temperature rise of the rated figures, perhaps due to the relatively low ambient temperatures during our test. Recent summer observations showed performance somewhat closer to the importer's claim with a half-full tank. True performance figures will probably be less than ideal conditions would give, and will vary with local conditions.

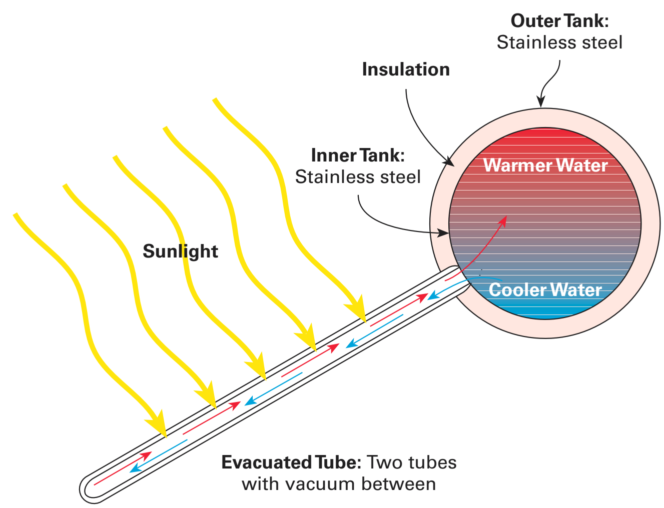
The tank is well insulated with about 2 inches of polyurethane foam, and holds heat surprisingly well. I usually shower in the morning before the sun is on the collector, and normally have to add cold water. The tubes lose little heat because of the selective surface and the vacuum, which make it hard for heat to travel out of the water.

First Use

We installed the unit in early January, a time when not much sun makes it into our clearing past the 130 foot (40 m) Douglas-fir trees. During a few months in the winter, we only get a few hours of direct sun on the shower site, and it's in the mid-to-late afternoon. So it took several weeks before we really could test the unit properly. But I was impressed early on at how quickly the unit heats water. Even with only a few hours of marginal sun, the unit would heat a tankful of our 55°F (13°C) water to useable temperatures (100–120°F; 38–49°C) over two or three days.

This unpressurized solar water heater is an open system, and will not stand up to standard house pressure. It

Thermalstar Operation



Tech Specs

Capacity: 22 gallons (83 l)

Empty Weight: 60 pounds (27 kg)

Footprint: 44 by 50 inches (112 x 127 cm)

Height: 47 inches (119 cm)

Collector Slope Angle: 38 degrees

Number of Tubes: 15

Collector Dimensions: 42 by 43 inches (107 x 109 cm) of exposed area

Individual Tube Diameter: 1 3/4 inches (4.5 cm)

Individual Tube Length: 46 inches (117 cm)

Tank Diameter: 12 inches (30 cm)

provides hot water with gravity pressure only, and has a single opening on the bottom of the tank for filling and drawing hot water, and another opening at the top that acts as pressure relief, vent, and overflow. When we want to fill the unit, we open the fill valve on the shower wall, and turn it off again when the tank overflows. Thermalstar now has an automatic fill apparatus for this unit. This would make the unit more convenient, but might also mean somewhat less control over the tank temperature.

The graph shows ambient, tube, and tank temperatures over an eight-day period in late spring. Unfortunately, we were not set up to monitor solar insolation, but the conditions were generally sunny, though not hot (ambient temperature gives some indication of insolation). Note the decrease in temperature when we filled the unit, and the recovery rate.

Programming

The beauty of this unit is that all the programming necessary is in the brain of the user. This is a two-edged sword, of course, but for folks who like to be hands-on and don't mind working with the changes in the weather, it's great. No set points, no buttons, and no LCD screens. Just fill the thing up and let the sun do the work.

We did add an indoor-outdoor digital thermometer, with the outdoor probe tucked into the tank. Before we use the shower, we can check the temperature and know how much cold we'll need to add. I find that I like my showers between 110°F and 120°F (43 and 49°C). Any hotter than that and I'm mixing in a bit of cold (it doesn't take much). This heater routinely heats water to 140°F (60°C) or more, so it's good to know what to expect when you turn on the tap.

Hot Water!

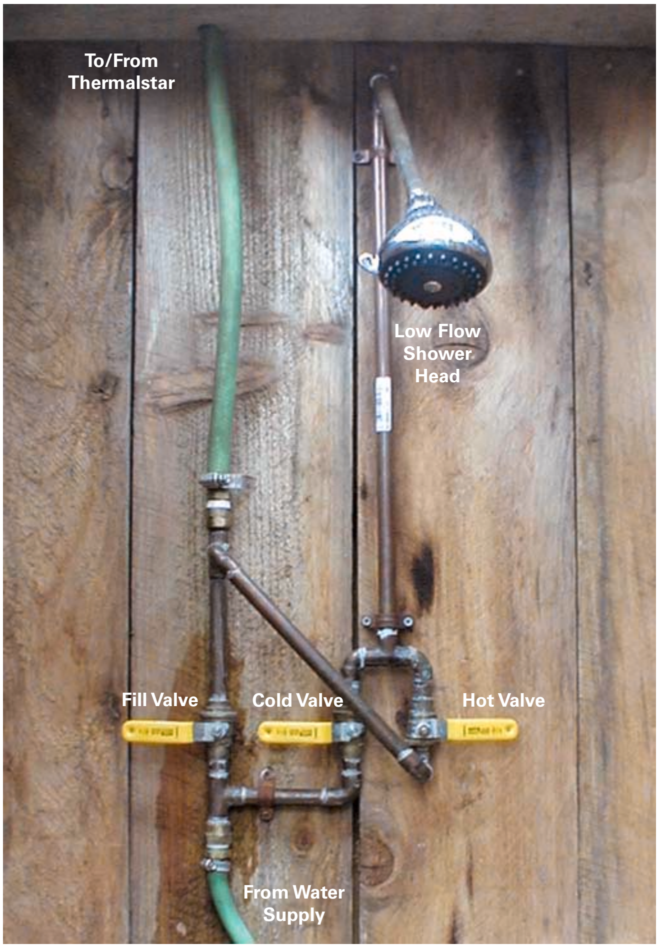
With our very low-pressure system and a wide showerhead, our water usage is not high. The 22 gallon tank takes about 30 minutes to empty. This gives time for several reasonably long showers. Once summer started, I had lots of hot water. Sometimes I splurged and took two showers a day—one under the stars.

If the weather is predictably sunny, I like to refill the tank when it's almost empty, providing that I do it right after my morning shower, so it will have the longest time possible to reheat. But I tend to try to get as much water as hot as possible, so I sometimes fill it too much, too late, and end up with a lot of "lukehot" water. Since it's mostly me using it, I really only need to fill it once or twice a week at most. If the weather is not terribly sunny, it's better to fill it partially so it can get some water hot enough, instead of lots of water not hot enough.

Temperature Extremes

We haven't run this heater through a winter yet. But winters are mild here, and I suspect we will be able to use it much of the year. If we're going to get a hard freeze, it's easy to drain the tank. And if we want to drain the tubes, removing two bolts from the front feet and tipping the unit backwards will accomplish this easily.

One fill/drain port requires creative plumbing.



However, Andrew has assured me the tubes will *never* freeze before the tank due to the natural thermosyphoning effect and the fact that ice will always form at the top of the system. Water is at its maximum density at 39°F (4°C), so the freezing water always rises to the top. The volume of the tank (at least half full) would require subzero temperatures to freeze. These units are common in China, where they use them in heavy freeze areas with the only freeze problems being the water in the send and return pipes.

I am fairly confident that my unit is safe here in the temperate coastal Northwest. But you should use your judgment about what conditions it will be subjected to in your area and how well it is freeze protected with only insulation stopping the heat loss.

At the other end of the temperature spectrum, if the tank is left empty when the weather is hot, the seals could "bake" onto the tubes, requiring a possible gasket exchange, which is easy to do. Stagnating the unit in full sun still isn't a good idea, and will void the warranty if stagnation occurs for more than 30 days.

Recommendations

This is not a product for someone who is unwilling to work within this solar water heater's limitations. It is hands-on with filling the tank, monitoring the temperature to optimize performance and avoid scalds, and determining adequate freeze protection. This unit is not intended for integration into a standard household pressurized water system.

On the positive side, Thermalstar Technologies' low-pressure solar heater is a reasonably priced, well-made unit. If you have a low-pressure application, such as a solar shower for a cabin or camp, dishwashing station, or other situation needing a modest amount of hot water, I recommend this product to you. It's low-tech/high-tech, using high quality materials and sophisticated design in a simple application.

Thermalstar Technologies has these units manufactured in China, where the technology is quite common. Flying into a Chinese city, you can see hundreds of them on the rooftops. I'm glad to hear that thousands of people in China are taking advantage of the sun's heat, and I'm happy to use some of their good technology here in the U.S.

Access

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John F. Robbins

John Robbins' office-powering PV array is near the ground where it is easy to work on, or show off to his neighbors, friends, and clients.

Recipe for a Solar Office: 1 Part Solar 5 Parts Load Reduction

Since the mid-1980s, I've been designing passive solar homes for the midwestern United States. When I decided in 1999 to run my home office on solar electricity, I knew the supply and demand balancing act would be similar to passive solar design. I would have to make my office much more efficient and incorporate lots of electricity storage to get me through a week or more of continuously cloudy weather during winter.

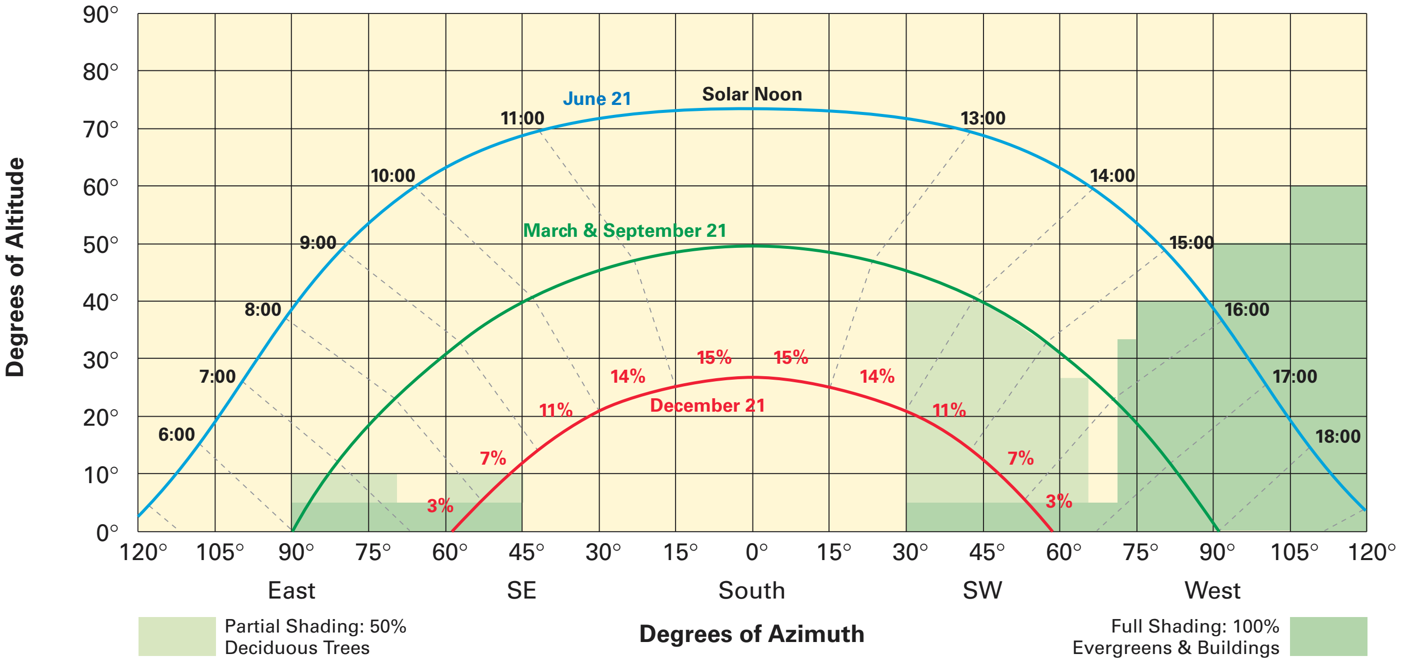
Motivated to be freed from responsibility for my share of the pollution caused by my local coal-burning utility, I would have preferred to convert my whole house to solar electricity. But that goal was unaffordable for me, as it is for most folks I meet. As an optimist, I think progress doesn't need to be an all-or-nothing proposition. I wanted my office solar conversion project to be an educational tool to describe not only how we can make progress in small, more affordable steps, but also how each step can make the next steps easier.

Starting with an Audit

First I needed to know about average sunlight at my general location. Charts and tables in *The Solar Electric Independent Home Book* showed that Cincinnati, Ohio (about 40 minutes north), gets less than 2.5 average daily peak sun hours in winter, and less at the winter solstice. Since my work schedule is typically slow during Christmas holidays, I decided to use 2.5 daily sun hours as my design's worst-case scenario.

Two Solarex SX50 PV modules are supported on a homemade wooden pole mount. A combiner box for the wiring connections is on the back of the pole.

Sun Paths for 40° North Latitude



The December 21 sun path shows estimated hourly percentage of average daily sun hours.

Load Profile: Before

Electrical Loads	Priority 1=Y	Run Watts	Hours / Day	Days / Wk.	Phantom Watts	Avg. WH / Day	% of Total	Surge Watts	Rank by WH / Day	Rank by Demand
Desktop 586-133	1	131	3.00	7	5	498.00	40.2	200	1	3
Desktop 486-133	1	93	5.00	4	5	371.43	30.0	99	2	5
Boom box	1	8	4.00	1	6	145.14	11.7	35	3	11
Clock	1	4	24.00	7	0	96.00	7.8	4	4	12
Answering machine	1	3	24.00	7	0	72.00	5.8	10	5	13
Desktop plug strip	1	0	0.00	7	1	24.00	1.9	1	6	14
Pen plotter	1	50	2.00	1	0	14.29	1.2	150	7	6
Copier (16 copies/week)	1	1,100	0.04	1	0	6.29	0.5	1,100	8	1
Laser printer (16 prints/week)	1	400	0.06	1	0	3.43	0.3	400	9	2
Twin fluorescent tube lamp	1	37	0.50	1	0	2.64	0.2	37	10	7
Single fluorescent tube lamp	1	22	0.50	1	0	1.57	0.1	26	11	8
Circline fluorescent lamp	1	20	0.50	1	0	1.43	0.1	25	12	9
Circline fluorescent lamp	1	18	0.50	1	0	1.29	0.1	25	13	10
Pencil sharpener	0	110	0.01	1	0	0.16	0.0	140	14	4
Total		1,996			17	1,237.66		2,252		
Inverter Priority		1,886								

I used a compass and an inclinometer in conjunction with a sun path chart for 40 degrees north latitude to analyze my solar site. My southeast and south horizons were mostly clear, but my southwest horizon was partially obscured by a maple tree. Even without leaves, this tree's branches would reduce my clear solar access starting about two hours past solar noon during winter.

Next I needed to audit my office to find out how much electrical energy I used. In 1999, I had two pre-Y2K desktop computers with 14 inch color monitors, a laser printer, a high-temperature copier, a couple of old plotters, a variety of lamps, a small boom box, an answering machine, an electric pencil sharpener, and a variety of portable devices that used rechargeable batteries.

With my Watts Up? meter, I observed the energy consumption of each load at peak, on average, and when turned off. Some appliances use energy when they are "off"—we call these "phantom loads." I also kept records for a couple weeks of how long each device was typically on.

I input this data into Ben Root's load calculation spreadsheet, which I downloaded from Home Power's Web site. As shown in the spreadsheet "Load Table—Before," I was using about 1.25 KWH per day, and my peak electric demand was about 2 KW. I modified Ben's spreadsheet so that it ranked devices by consumption and demand. As the process continued, I further expanded the spreadsheet until it was a group of spreadsheets representing steps in my efficiency upgrades. These were all linked to a final spreadsheet that sized the four major solar-electric system components: PVs, charge controller, inverter, and batteries.

Energy Users

In terms of total energy use, which is what determines the size of the solar array, my biggest loads were the computers, boom box, clock, and answering machine. I was not surprised to see the computers high on the list, but I didn't suspect that several low-watt devices would be so highly ranked. It was the fact that they were on 24 hours a day, 7 days a week that made them such big consumers.

Conversely, since many of my high-watt devices were off most of the time, their overall consumption was lower than expected. For example, my 1,100 watt copier consumed 11.4 times less energy than my 3 watt answering machine! I also noted that four of the top six consumers were phantom loads, including the multi-outlet plug strip!

In terms of my peak demand, which would drive inverter, breaker, fuse, and distribution wire sizes, I could easily see that my copier, printer, and computers were

Component Sizing: Before & After

Component	Before	After
Minimum PV, watts	747.0	100.0
Battery bank, AH @ 12 VDC	1,875.0	250.0
Average stored energy, days	9.1	9.1
Minimum charge controller, amps	52.0	7.0
Minimum inverter output, watts	1,886.0	225.0

Load Profile: After

Electrical Loads	Priority 1=Y	Run Watts	Hours / Day	Days / Wk.	Avg. WH / Day	% of Total	Surge Watts	Rank by WH / Day	Rank by Demand
Laptop, 586-133 with 12 inch screen	1	15	7.75	6	99.64	60.3	50	1	8
Answering machine, DC	1	1	24.00	7	24.00	14.5	10	2	10
Subshelf fluorescent lamp	1	22	1.00	5	15.71	9.5	25	3	4
Pen plotter	1	50	1.00	1	7.14	4.3	150	4	1
Subshelf fluorescent lamp	1	22	0.25	5	3.93	2.4	25	5	4
Laptop, 586-100 with 12 inch screen	1	16	0.25	5	2.86	1.7	46	6	7
Business machine, 4 in 1 (32 pg./wk.)	1	24	0.80	1	2.74	1.7	50	7	3
Twin fluorescent tube lamp	1	37	0.50	1	2.64	1.6	37	8	2
Boom box	0	4	4.00	1	2.29	1.4	35	9	9
Single fluorescent tube lamp	0	22	0.50	1	1.57	1.0	26	10	4
Circline fluorescent table lamp	1	20	0.50	1	1.43	0.9	25	11	5
Circline fluorescent table lamp	1	18	0.50	1	1.29	0.8	25	12	6
	Total	251			165.24		504		
	Inverter Priority	225							

ranked highest, but I was surprised to see how much the electric pencil sharpener demanded!

Finally, my sizing spreadsheet showed that I would need at least 747 watts of PVs, 1,875 amp-hours of batteries at 12 VDC, 1,886 watts of continuous AC inverter output, and a 52 amp charge controller. Based on a call to the local solar retailer, Randy Sizemore of Entropy Ltd. in Cincinnati, these four components would cost close to US$7,000, even before labor and all the other stuff that goes with a full installation. This was too much for my budget. So during late 1999 and well into 2000, I worked on reducing my consumption and demand.

Becoming as Efficient as Possible

Since I had started this process in the waning months of 1999 when Y2K concerns about computers were high, and since my computers were each several years old, I started by upgrading computers. Just about any newer computer would be faster and provide more features than what I had. So rather than looking at new equipment, I checked into used computers. Desiring more portability, my first purchase was a notebook computer, a one-year-old, factory-refurbished model with a 100 MHz processor and a 12 inch screen. It was about half the price of a brand new notebook with similar features.

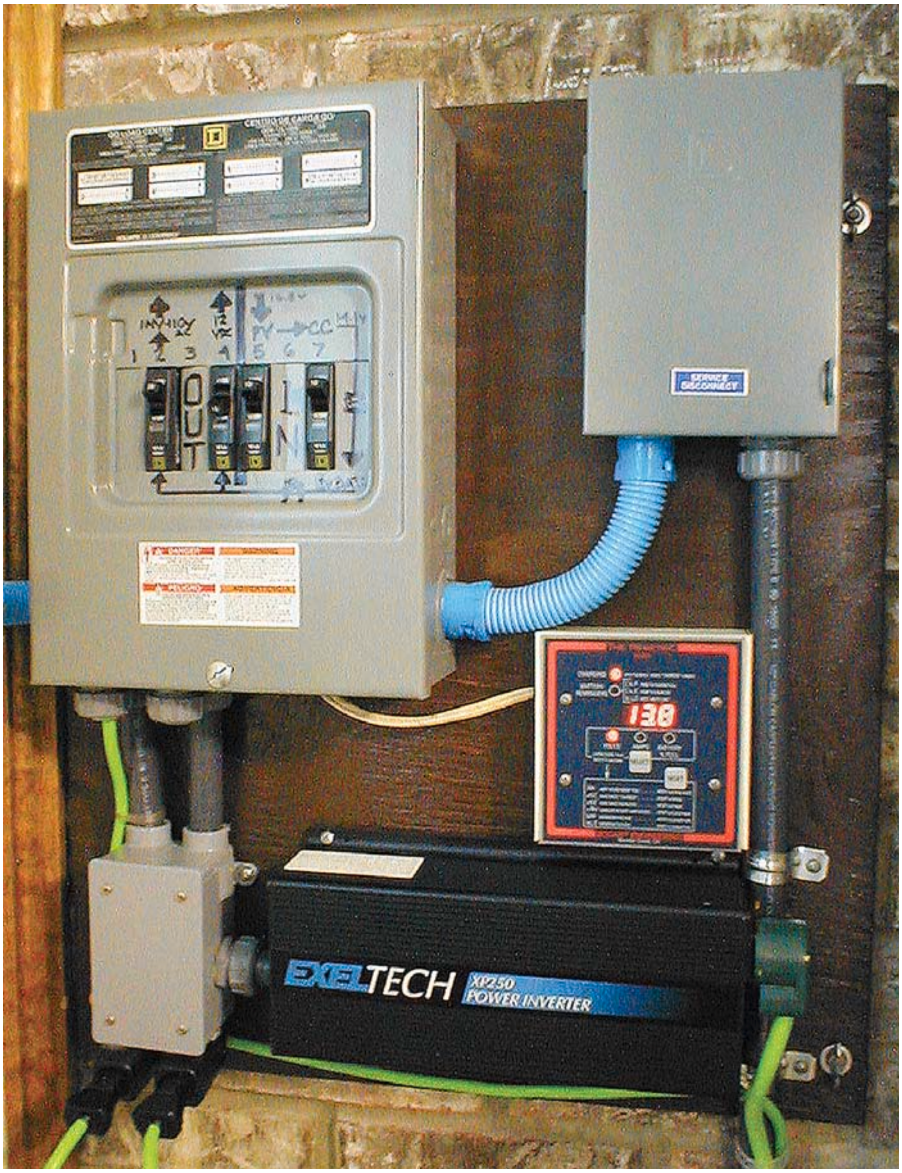
John's current main workstation has two notebook computers, one old printer/copier/scanner/fax on right (now used mostly for faxes), one new printer/copier on left, and one old desktop computer kept for its 5 1/4 inch disk drive.

I did not initially realize that a notebook computer would use dramatically less energy, but I immediately found this to be true! The desktop computers and monitors I had and looked at were all Energy Star rated, so I assumed that meant they all were similarly energy efficient. But when I metered the notebook, I discovered that with optimum power-saving settings and with the 3.5 inch disk drive instead of the CD drive inserted into its main bay, the notebook used one-eighth to one-sixth as much energy as a similarly featured desktop that I almost bought! (With the CD drive inserted, the notebook used significantly more energy than without it, so it made sense to connect the CD only when needed.)

I initially thought that the 12 inch screen would be too small, but discovered that it had about the same display area as the 14 inch monitors to which I was accustomed. I also discovered that while the notebook's battery-charging circuit was a phantom load, this was no more than the constant draw of the old desktop's UPS. I did keep one old 486 computer because I occasionally needed a 5.25 inch floppy disk drive to read old client files.

Almost immediately, I replaced my second desktop computer with another notebook, a pre-owned one-year-old, 133 MHz computer still under warranty. It also used way less energy than the desktop it was replacing. While the two prior desktops together had averaged 224 watts when operating, the two notebooks averaged 31 watts when both were operating!

Next, I traded my 400 watt, black-and-white laser printer and 1,100 watt copier for one of those four-in-one units that color print, copy, scan, and fax. This allowed me to replace 1,500



System electrical panel with breaker box, main fused disconnect box, TriMetric meter, Exeltech inverter, and two, DC output jacks.

Easily accessible along the back of John's main desk, several single-plug subswitches are in-line between devices with phantom loads and the multi-outlet plug strip.

watts of equipment with a single multifunction piece with an average draw of only 24 watts and a maximum surge of 50 watts. The only negative about this was its 4 to 6 watt phantom load.

Then I eliminated the clock and pencil sharpener from my desk, cutting another 114 average watts and 144 surge watts. The clock elimination was easy, since my computers display time, and I wear a solar wristwatch. I decided to do my occasional pencil sharpening manually.

Next I attacked phantom loads. I got rid of the multi-outlet plug strip that was a phantom, and bought several multi-outlet plug strips that are not. I located these strips on my several tabletops. I then bought several single-plug subswitches for the devices with phantom loads. Although this setup brought more wires onto my tabletops, I could now control both operating and phantom loads individually or in groups much more easily than before.

Finally, I realized that my 3 watt AC answering machine would cause an inverter to be on constantly. Even the most efficient small inverters draw up to 10 watts when idling, so I decided to find a DC answering machine. It turned out that I already had one! The plug on mine was also a converter that changed AC to 9 volts DC, consuming 2 watts doing so! So I bought a 12-to-9 volt stepdown converter at Radio Shack and fed the answering machine directly with DC. Now my answering machine draws only 1 watt for its standby power!

This brings us to my spreadsheet called “Load Profile—After,” which shows my office’s energy consumption after my efficiency upgrades. Even though I added more lights, I now use only about one-sixth of a KWH per day, and my peak demand is less than 0.3 KW even if I have every device on at the same time, which never happens. According to my sizing spreadsheet, I needed only 100 watts of PV, 250 amp-hours of 12 volt batteries, a 225 watt inverter and a 7 amp charge controller! Randy at Entropy informed me that I could get not just the four major components, but all the parts for about US$2,000. This was a US$5,000 savings from only about US$1,500 invested in reduced energy use!

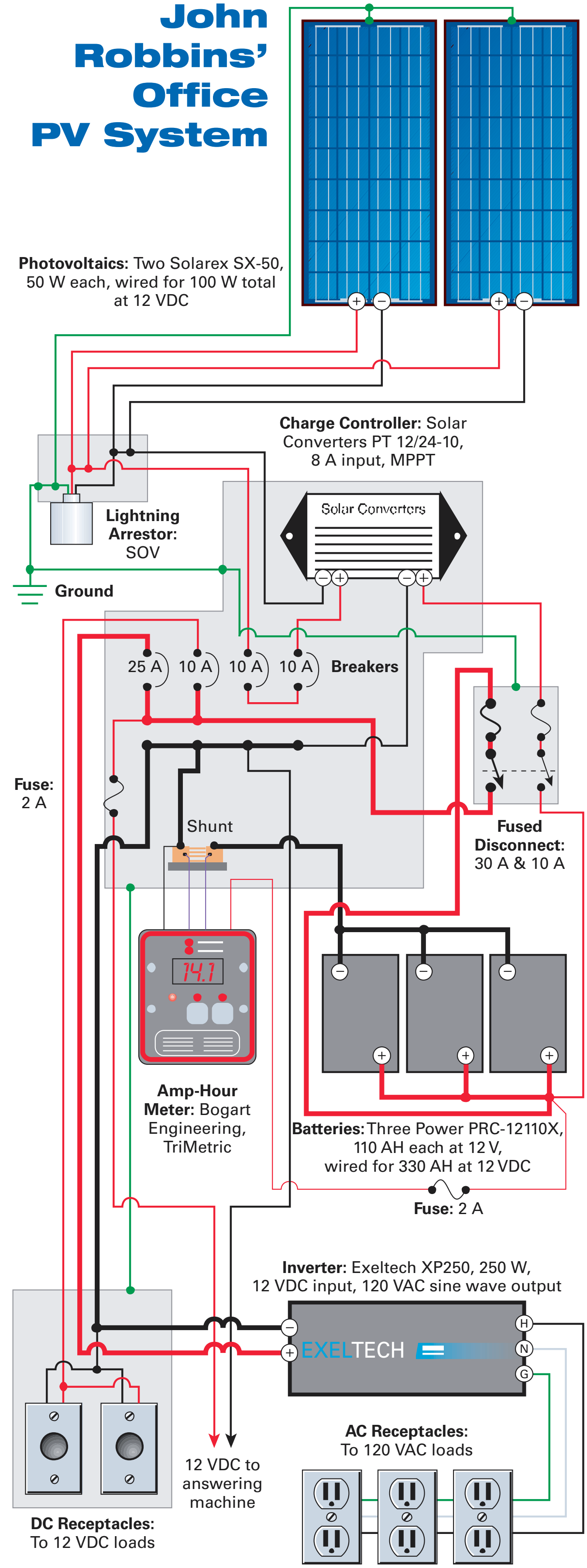
My Solar-Electric System

As a home designer, I don’t like roof-mounted collectors placed askew to the roof lines. Unfortunately, my office roof is pitched 4:12 and oriented about 45 degrees west of south. I had roof-mounted DHW collectors on my last house, and I wanted to avoid climbing, since I’m getting older. So I decided to pole-mount my PVs near the ground.

I also wanted my setup to be as easy to dismantle as possible, since I often do presentations to schools and other public groups. And in case I ever have to move, I want to be able to take my solar-electric equipment with me, since Midwest home buyers and mortgage appraisers typically assign little or no real estate value to this equipment.

Finally, my experience and tools were mostly for woodworking, so although I’d read many articles recommending metal racks and poles, I wanted to use wood. Sized to resist a 100 mph (45 m/s) wind load on the array, a 6 by 6 was selected for the pole. Double 2 by 8s

John Robbins’ Office PV System



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

create an adjustable angle arm that is attached to the pole with through-bolts. The bottom bolt can be inserted in three different hole alignments to permit seasonal altitude angle adjustments of 45, 60, and 70 degrees. I chose these angles to optimize winter production and prevent winter snows from building up. Three parallel 2 by 4 horizontal supports run east-west off the angle arm to hold the PV panels.

For my 100 watts of PV, I selected two Solarex SX50 modules, rated at just under 3 amps each, wired in parallel for a 12 volt system. Total wire distance from the PVs to the batteries just inside the house was about 24 feet (7.3 m), so I decided on #6 (13 mm^2) wire to hold line losses close to 1 percent. On the back of the pole, under the angle arm, a combiner box joins the PV wires with the lightning arrestor and the two feeds from the ground rod and office.

AC is distributed via green, outdoor-grade, 3-wire cord and green-painted, AC receptacles in metal boxes, all anchored to the baseboard.

Electrical Details

I put my system's electrical panel inside the office wall nearest the array. It includes a breaker box, main fused disconnect box, TriMetric meter, inverter, and two DC output jacks mostly for small battery charging. The standard, 100 amp, QO-6 breaker box is set up with four, single-pole breakers. On one breaker bar, the solar electricity is received via a 10 amp breaker, and then routed out through another 10 amp breaker to a Solar Converters, 8 amp, maximum power point charge controller.

From there, the PV input goes out to a 10 amp fuse and the disconnect before heading down to the 110 amp-hour Power AGM batteries. Battery output comes back up to a 30 amp fuse and the disconnect, and then into the breaker box, but on its other bar. A 25 amp breaker feeds an Exeltech, 250 watt, sine wave inverter, and a 10 amp breaker feeds two, DC output jacks. An unswitched feed to the answering machine is protected by a 2 amp in-line fuse.

PV System Costs

Item	Cost (US$)
2 Solarex SX50 PV modules	$530.00
Exeltech XP 250 inverter	400.00
TriMetric AH meter	233.94
3 Power AGM batteries, 110 AH	180.00
DC wiring, conduit, etc.	142.99
Solar Converters controller	122.00
Sales tax, 6%	113.11
Combiner box w/ lightning arrestor	103.78
Breaker box assembly, QO	90.60
Interior distribution	77.39
Rack assembly	76.05
Unnecessary purchases	49.80
Fused disconnect assembly	46.56
Total	$2,166.22

During my design and selection process, I had upgraded to a maximum power point tracking (MPPT) charge controller to deliver a few more amp-hours to hungry batteries after long wintertime cloudy periods. Since my 100 watts of PV provided no oversize factor, the specs indicated an MPPT could add a 10 to 15 percent margin of security.

I selected AGM batteries because they were approved for use in unventilated conditioned spaces. I started out with two batteries, but in the spring of 2002, I added a third battery to expand my storage capacity to 330 AH at 12 VDC, increasing my future security margin. Finally, I selected a sine wave inverter because I'd heard too many tales of noisy fluorescent lamps and other equipment that didn't like modified square waves.

AC is distributed around the office via green, outdoor-grade, #12 (3.3 mm^2), 3-wire cord, anchored to the baseboard. This cord feeds four, green-painted, AC receptacles in metal boxes, also anchored to the baseboards. All the office's existing wall outlets are covered with plastic safety caps to show visitors that grid electricity is not being used.

Although all of the system components are firmly attached, secured, and safely protected, everything except the underground wire and pole outside is relatively easy to disconnect and remove. The electrical panel with all its attached pieces is held with wing nuts onto 1/4 inch (6 mm) threaded posts anchored into a masonry wall. The PVs can be easily disconnected from the combiner box and removed from the rack. The surface-mounted office distribution wires and receptacles are also easily removable.

How Has It Worked?

After some initial tests and a few glitches, on November 19, 2001, I flipped the switch and began running my office on solar electricity. At first, I was very self-conscious and worried about the system, hoping it would work as designed. But all too soon, its smooth and reliable operation became part of my expectation and routine.

My typical daily consumption has ranged from 160 to 250 watt-hours. I've learned to "shed loads" during worst-case wintertime cloudy stretches by not listening to radio or leaving devices on unless absolutely necessary. I've also learned to keep electric lighting to a minimum by working during daylight, since my office is well lit by its two windows.

I often have occasion to talk with friends and neighbors about my system. Utility electricity around here is so poorly priced (cheap) that restraining consumption to the extent I describe makes little sense to most people. Utilities don't charge per amp for new or expanding electrical service, so the idea of driving load reductions and efficiency to offset generation costs is truly foreign. Generation is seen as something utilities are responsible for, so most homeowners around here don't typically buy their own generators. So while I'm often told how "cool" my solar-electric system is, I'm also commonly asked why I bought it!

Most grid-connected electricity consumers seem to be overwhelmed by the huge scale of the grid. Its seemingly ever-expanding scale makes it difficult to see small loads and personal conserving efforts as significant to the whole. When I'm showing off my small setup, I like to describe how I minimize loads and manage consumption both to minimize generation costs and to keep from running out of stored energy. My hope is that understanding the basics of my small system promotes better and maybe different understanding of large grids. I try to explain that if enough people minimize their loads and consumption, it adds up to minimizing utility costs, especially in the future.

Energy Future

Most people will continue to rely on utility grids, but it's naive to expect utilities to expand conventional generation capacity ad infinitum or as cheaply as in the past. Many people expect an eventual transition to solar electricity, but they want it to be affordable. Affordability starts with demanding less through conservation, efficiency, and simply turning off devices and equipment when operation is unnecessary.

Solar electricity is less complex, but more expensive than most people think. Conservation, efficiency, and turning off stuff is not only easier still, but far cheaper than any kind of solar generation.

Once you've done the efficiency work, solar-electric systems can be implemented in small steps and for specific tasks. Sometimes I hear aspiring solar advocates tell me that they can't afford to convert to solar energy, or that everyone in their household or company isn't interested in cooperating or helping with finances. I like to respond that we don't climb stairs in one giant leap. We climb in many small steps.

Like most grid-connected electricity consumers, when I first started thinking about solar energy way back in the late 1970s, I thought that meant simply covering the south side of my roof with panels. I found this was not only unaffordable, but also wouldn't produce all the energy I need.

If I hadn't taken an energy efficiency approach with my office, I would never have seen as many ways to cut my usage so drastically, which would have left me paying much more for my PV conversion, even postponing it until I saved up a lot more money. Load reduction was definitely my cheapest ticket to a faster conversion to solar electricity.

Access

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The Solar Electric Independent Home Book, 1998, US$19.95 postpaid from New England Solar Electric, Inc., 401 Huntington Rd., Worthington, MA 01098
800-914-4131 or 413-238-5974 • Fax: 413-238-0203
nesolar@newenglandsolar.com
www.newenglandsolar.com

See "Doing a Load Analysis: The First Step in System Design," by Benjamin Root in HP58, available on the Solar1 CD and the downloads section of www.homepower.com.

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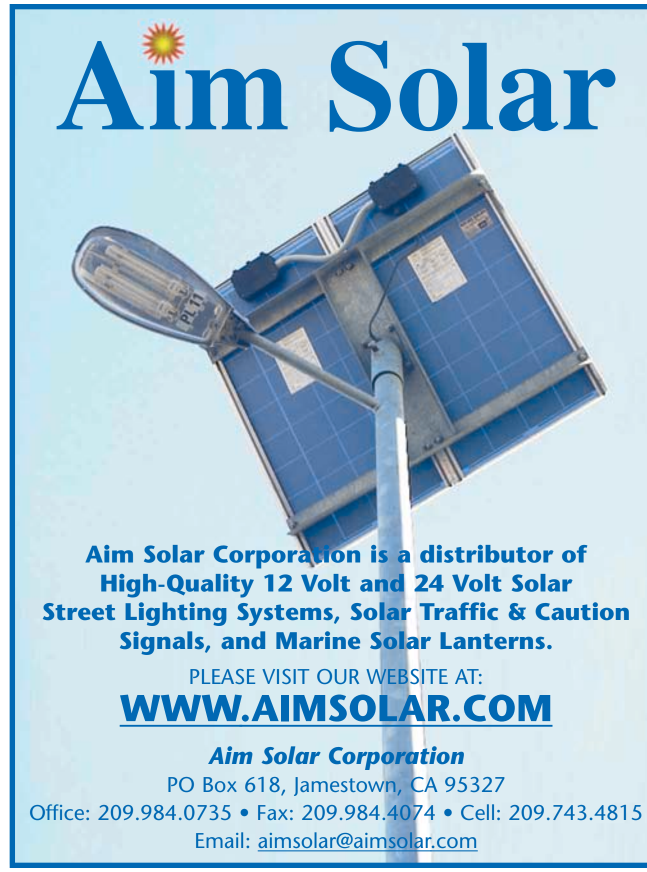
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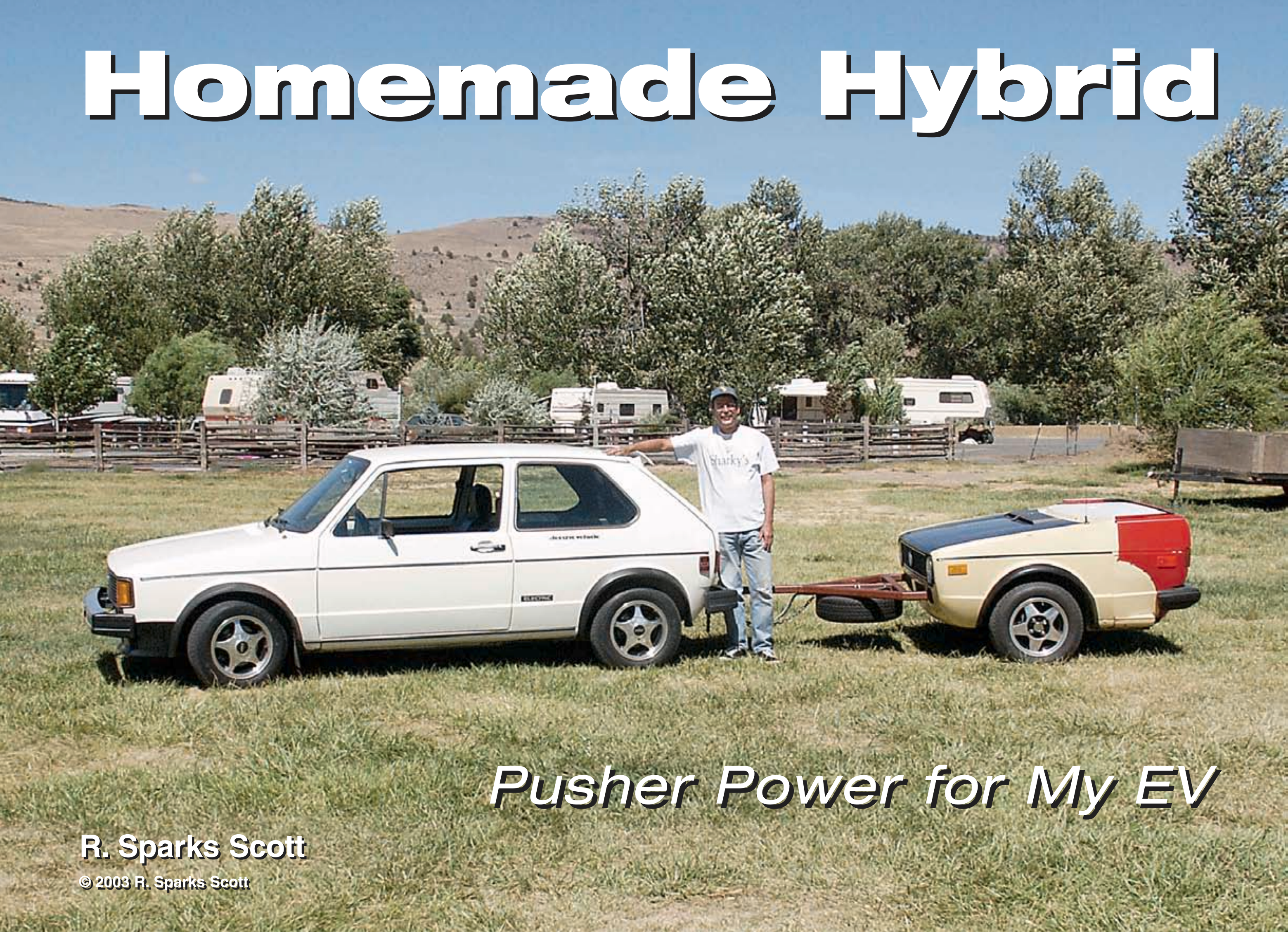
Homemade Hybrid

Pusher Power for My EV

R. Sparks Scott



The author with his '81 electric Volkswagen Rabbit and the biodiesel powered pusher trailer at the SolWest Renewable Energy Fair.

Electric vehicles are great for around-town driving—clean, quiet, and up to the task of keeping up with urban traffic. Longer trips can be difficult. The problem is that they need to be recharged. My 1981 VW Rabbit conversion has a range of approximately 40 miles (64 km) per charge, so a trip of 100 miles (160 km) would require two stops to charge, at about eight hours per stop. Obviously, this is unworkable in terms of convenient traveling.

I could drive my internal combustion engine pickup, but it's kind of worn out, and gets only OK mileage. What's needed is a way to convert the EV into a hybrid for longer distances. Enter the EV pusher trailer, which allows me to have an internal combustion engine (ICE) to drive the EV longer distances when needed, but is detachable for around town use when I want to drive as a pure electric vehicle.

How It Works

My EV pusher is constructed out of the front end of a 1978 Volkswagen Rabbit, powered by a 52 horsepower diesel engine. It has the stock, factory, three-speed automatic transmission, axles, and CV joints, all connected to the wheels as in a regular front-wheel-drive vehicle. Except this vehicle is a trailer that is towed behind the EV, just like an ordinary utility trailer.

Through the use of electronic controls, I am able to operate the ignition, starter, and throttle in the trailer from the driver's position in my electric car. The diesel engine in the trailer pushes the EV forward through ground traction provided by the drive train in the trailer. The electric drive in the EV can be used to provide additional power for economy or performance. Once highway speed is attained, I have several operating modes, some of which are capable of either preventing the batteries from being discharged during driving, or even recharging them as the trip progresses.

Using the pusher trailer, I can cruise at 65 mph (105 kph) continuously, and I have kicked the speed up to 75 mph (120 kph) briefly for passing. Further tests may show that higher speeds are possible. Range is limited only by the availability of diesel fuel, which is pretty common these days. Typically, I see fuel economy in the 27 to 30 mpg (11–13 km/l) range.

Operating Modes

It's possible to operate the pusher trailer in several configurations:

Parallel Mode / Electric Assist. In this mode, I use the electric and diesel drives together. After attaining cruising speed, I can use partial electric and diesel power. This results in the highest fuel economy, but does put a variable drain on the batteries. By calculating driving time and energy used from the batteries, I might arrive at my destination with a partially or fully discharged battery pack. This would be a good option for saving fuel for the times when I know I'll have the time to charge, and a charging facility available.

Parallel Mode / No Electric Assist. In this mode, the diesel engine is driving the car forward, and the EV throttle is backed off until the ammeter shows 0 amps, with no current to or from the batteries. The electric motor does consume a small amount of battery energy, but this is returned through gentle regenerative braking, consuming a little bit of energy provided by the diesel pushing the car forward. The electric motor is on-line, with the clutch engaged and transmission in fourth gear. The electric drive is in "hot standby," ready to assist the diesel in providing power for passing, or conversely, available to provide powerful regenerative braking to slow the car to adjust for changes in traffic speed.

Parallel Mode / Regenerative Braking. This is the mode I operate in frequently, particularly on short trips. The principle is the same as described above, but the EV throttle is backed off even farther, so that the diesel driving the car forward provides charging current to the EV battery pack. This requires that the diesel throttle is opened up enough to account for the

Under the Rabbit's hood—an electric power plant perfect for around town use, with up to 40 miles total distance between charges.

electric car

diesel trailer

Inside the trailer—a diesel power plant including fuel tank, automatic transmission, and "front" wheel drive adds significant range to the EV.

A stock Rabbit automatic transmission makes operation simple. Gear ranges and Park/Neutral are selected by use of a familiar shift lever mounted in the trunk of the trailer.

additional energy that the EV is consuming to charge the batteries. Generally, I keep the charging current to 10 to 15 amps, which doesn't seem to overload the diesel. It is possible to produce charging currents of 200+ amps in this way, but this results in loss of speed due to the additional load. These high currents are useful for recharging the batteries on long downhill grades, and this does help control the speed of the car and trailer without the use of brakes. I should note here that regenerative braking requires a special motor/controller set-up and wiring. Not all EVs or all components are capable of this function.

Diesel Stand Alone. Basically, this is cruise control, with the electric drive shut down and the EV transmission placed in neutral. Since the pusher's throttle is set by a knob on the dash, I can sit back and just steer the car. On a long, straight stretch, with consistent traffic speeds, this mode is the least effort on the driver's part. Although it doesn't provide charging current, this mode can be useful when the batteries have only been used a small amount and charging facilities are available at the destination.

An LPG tank adds power and efficiency by mixing propane with the intake air prior to combustion.

Series Mode. There is one last option with this trailer. For a while, a 3,000 watt AC generator was installed, driven by a pulley from the crankshaft. This was mostly meant to be used to charge the batteries in the EV when the car was stationary, although it could have been used to offset the energy consumption when the car was running. Due to some unresolved vibration and metal fatigue problems, I've removed the generator until some solutions can be worked into its mechanical mounting to the engine.

Since the EV and pusher combination requires about 20,000 watts to power down the road, series mode isn't very useful while the car is in motion. A true series hybrid vehicle would need a whopping big generator, something along the lines of a 30,000 to 40,000 watt unit to produce sufficient power to drive the car, have peak power for hill climbing and passing, and to make up for the losses incurred when changing energy from chemical to heat, then to mechanical, then to electrical, sending it forward to the EV, controlling the current, converting it back into mechanical energy, and then sending it to the road to drive the car forward.

An additional problem with series hybrid operation is that the electric motor in my EV is still only 24 horsepower, and won't develop more no matter how large the generator on the ICE engine is. Added to this is the full-load capacity of the motor, and its ability to be cooled fast enough to keep up with heat production, etc. In all, the parallel modes work out best for me.

Why a Diesel?

Why did I choose a diesel for my pusher? Lots of reasons. They get great mileage, about 50 mpg (21 km/l) for the 1.6 liter VW diesel in a regular car body. The price of diesel fuel generally fluctuates less than gasoline, and they are rugged, with a life expectancy of 150,000 plus miles (240,000 km) between major repairs.

Modern gasoline engines are a rat's nest of emission control devices, all of which require maintenance and steal away power. A diesel engine *is* an emissions control device, in spite of the black smoke that many emit. They are inherently, by design, lean-burn engines, which require nothing in the way of external influences to maintain an acceptable emissions standard.

With the availability of biodiesel fuel based on vegetable oil, the diesel engine has taken on a new life as an environmentally friendly alternative to fossil fuels. Biodiesel has significantly fewer emissions, produces a zero net gain in global carbon dioxide, and is nontoxic. This fuel can be made from waste oil left over from fast food fryers, and has a great potential to make an impact on "big oil" by allowing local small producers or home experimenters to create a community-centered fuel source instead of sending our transportation fuel budget to OPEC.

My pusher is fueled by 100 percent biodiesel purchased from SeQuential Biofuels, a local fuel distributor. I'm hoping to avoid purchasing petro-diesel indefinitely. This allows me to drive my EV over extended distances with my nose planted firmly in the air, since I won't be polluting as much or supporting petroleum companies. Of course, the biodiesel makes the exhaust of the pusher smell like French fries, which isn't altogether a bad thing by itself.

I'm also experimenting with LPG fumigation. Briefly described, this consists of introducing gaseous propane into the air intake of a diesel engine to produce additional power and economy. The propane acts as an accelerant, promoting the more complete burning of the diesel (in this case, biodiesel) fuel during the combustion reaction.

Pusher controls on the dash of the EV.

Pusher Construction

Rather than try to reinvent the wheel, I decided to make use of the appropriate parts of a production vehicle by cutting the front half off of a front-wheel-drive compact car. It would be possible to construct a pusher trailer from scratch, incorporating weight saving techniques and allowing specialized design. However, it made sense to circumvent fabrication of items such as suspension, motor mounts, radiator/battery/fuel system, brackets, wiring, etc. All of this work was already done for me at the factory. With three saw cuts to remove the rear of the vehicle, I was ready to put my pusher together. The car also had reasonably attractive body panels, tightly fitting hood, grille, side markers, and such. The added benefit that the pusher matches my EV's body is icing on the cake.

To provide an enclosed area for the fuel tank and electronics, I purchased the rear clip off of a 1988 VW Cabriolet convertible that had heavy front-end damage. This gave me an operating trunk door, tail and side marker lights, fuel filler, rear bumper, and yet more styling enhancements. The additional cargo space that the rear area provides has been useful during camping trips. The trailer is a patchwork of different colored body panels procured from a variety of different wrecking yard cars. Eventually, I intend to get the body work done and apply some paint to match my EV's color scheme.

Mechanicals

The running gear of the trailer is stock Volkswagen. The engine drives the wheels through an automatic transmission. Of course, some specialized fabrication was necessary to make the throttle operate. Many of the modifications to the car were "found items," either around my workshop, or at the local building materials recycling yard.

The throttle is actuated by way of remote control servo electronics that operate a custom-made servo motor constructed out of the old Rabbit's windshield wiper motor. The servo and electronics are controlled through proprietary electronics, and the desired throttle position is adjusted via a knob on the dashboard of the EV.

Indicator lights for glow plugs, alternator, and oil pressure are remoted to the control panel in the EV, and the coolant temperature and fuel tank level gauges are also remoted to the dashboard of the EV. A large paddle-handle toggle switch serves as an ignition switch, and an interlock circuit shuts down the trailer's throttle when the EV's breaks are applied.

The remote controls are accomplished by means of a 15-conductor cable with AMP connectors at the hitch and another at the dash, which allows the trailer to be disconnected from the car and the control head attached at the tongue for demonstration during events and exhibitions. The Pusher could be used with any vehicle if an "extension cord" with mating connectors was used to extend the control cable to the driver's position where the self-contained control head was located. The cable would not have to be permanently installed in the vehicle to operate the trailer.

While the trailer was in the prototyping stage, it had a worn-out 1.5 liter diesel and a four-speed manual transmission. A Rube Goldberg contraption involving a cast-off power drill and car jack parts actuated the clutch. Operation was unreliable, and the trailer depended upon the EV to tow it up to at least 20 mph (32 kph) before the diesel engine could supply traction power.

After many problems related to the poor condition of the engine, I completely rebuilt a later model 1.6 liter engine and installed an automatic transmission. Now the trailer can supply 100 percent of the power to drive the car forward in case of any failure of the EV's drive systems.

Driving Details

There really isn't much to know about driving with the pusher. The automatic transmission makes it all pretty much, well, automatic. There is a bit of added attention needed by the driver to watch a few extra gauges, and shutting down and restarting the electric drive components in the EV when changing between operating modes are less-than-standard actions for ordinary drivers, but otherwise, no special skills are needed.

The combination of EV and pusher trailer reacts to changes in terrain, true-to-form of the hybrid/electric model. When approaching a mountain pass or long grade, the diesel throttle is increased moderately, and the electric drive is used to provide additional hill climbing power.

My experiences show that performance is quite satisfactory—I am able to watch diesel trucks grow small and disappear in my rearview mirror as I climb a hill. Descending the opposite side of a grade allows the diesel engine to pump energy back into the batteries through regenerative braking, returning most, if not all of the power expended climbing the pass. Of course, additional diesel fuel is consumed to refill the batteries this way, but without the electric assist, the uphill side of the mountain would be a long and very slow climb for a 4,500 pound (2,040 kg) vehicle with such a small engine.

The power of the high-torque, diesel engine and the hefty torque of the electric drive, when combined for a total of 72 horsepower, tend to make the car perform like a mini-rocket launcher on hills, freeway on-ramps, and while passing. This little Rabbit towing a trailer weighing 1,200 pounds (544 kg) has considerably more pep than my gasoline pickup has without a trailer.

An intriguing and as-of-yet unexplored idea is to use the pusher behind my old and painfully slow 1962 motor home. Because the trailer is self-contained, it could be used to provide additional power to nearly any vehicle. I've also had slightly mischieveus thoughts about trying it out on my GE Elec-Trak garden tractor, but probably should fix the brakes on the tractor first.

Public Perceptions

Many people who have seen the trailer are concerned that pushing the car through the single-point hitch will cause handling problems. In fact, the trailer tracks behind the car perfectly, and you can't even tell that it's there. You can't hear it and you can't feel it. The EV outweighs the trailer 3-to-1, and the hitch point is very close to the rear axle. Having 1,000 pounds (450 kg) of batteries in the back of the car helps a lot too, I'd guess.

Another frequent question is what law enforcement thinks about the pusher, but I really don't have an answer for this. The state licensed the pusher as a utility trailer, and I haven't gotten around to flagging a policeman down to see what his opinion is.

The pusher is an instant hit at energy fairs, Earth Day events, auto parts stores, and wrecking yards, drawing a crowd of interested onlookers whenever and wherever it's parked. Past exhibitions include the 2002 SolWest Renewable Energy Fair, the Oregon Electric Vehicle Association's EV Awareness Day, and the 2002 NEDRA (National Electric Drag Racing Association) Woodburn electric vehicle drag races.

While my original plan was to use the EV and pusher for all of my long distance driving, reality has set in, and I have purchased a standard VW Rabbit diesel for this purpose, also running it on biodiesel. The EV/pusher combination gets less than 30 mpg (13 km/l), which is about half of what my biodiesel Rabbit gets. Finding a parking spot for a car with a trailer is more difficult. Besides, the EV uses specialized parts, such as low-rolling-resistance tires, which I don't particularly wish to wear out needlessly.

The stock Rabbit also doesn't attract so much attention, and I spend virtually no time explaining it to every curious traveller. Exhibiting the pusher is fun, but sometimes it's also nice to have a little bit of privacy when you travel. Having a "normal" vehicle means that I don't have to "perform" at every rest stop, although that can be fun at times.

The pusher is still a valuable addition to the EV, and I use it to transport the car to events both near and far. Most of the time, I am the only EV owner who arrives under his own power. Most others trailer their vehicles, or use a tow bar attached to an SUV to pull their "clean air vehicle" to an event, which seems like a conflict of purposes in my view.

In all, the pusher allows me to gain additional utility from my electric vehicle, and makes it possible for me to use only renewable fuels to transport the EV to shows and events, closing the loop between ideology and practice in my EV lifestyle. Most of all, it's fun to drive!

Access

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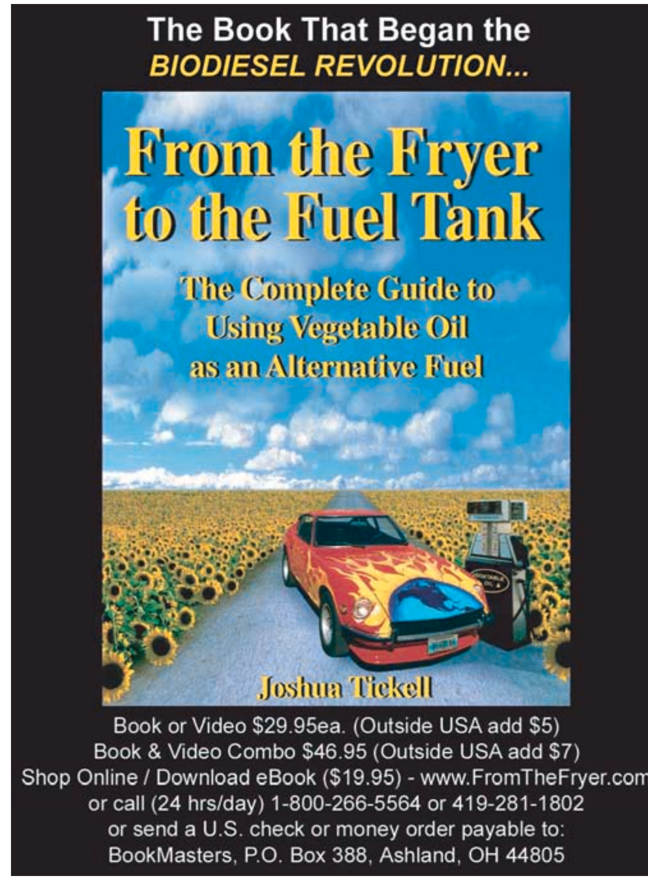
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And be looking for the 2003 Oregon Tour of Solar Homes magazine! It is chock full of great information.

What the Heck? 9

Load Center

Two load centers—the one on the right is for the building wiring and the one on the left is for the DC circuit of a PV array supplying some of the building's electricity.

Note that most breakers are not approved for DC electricity. Make sure you use a DC-listed load center and breakers on that part of a PV electrical system. (See "Code Corner," *HP68* for more info.)

Used in: PV and electrical systems of all types; conventional homes and buildings

AKA: Panel, breaker panel, breaker box, mains panel

What It Is: The central point of distribution and overcurrent protection of an electrical system

What It Ain't: A place you go to get loaded

For convenience and safety, all overcurrent devices (breakers, see "What the Heck?" in *HP 93*) that protect home and building wiring should be in a central location. The enclosure that holds the breakers is called a load center.

Loads are the energy consuming devices in any electrical system. Lights, electric motors, and appliances consume electricity—they are all loads. All of the wiring supplying the electrical loads in a building comes together at individual breakers in the load center.

The number of overcurrent devices in a breaker panel is dictated by the total electrical consumption of the building and, to some extent, the type of load. A single breaker may protect many electrical receptacles or lights. Or in the case of a clothes dryer, range, or other large appliance, a single breaker may protect a single appliance or receptacle. The *National Electrical Code* and local regulations give guidelines on the number and type of devices served by one breaker, and this dictates the size of the load center. A load center that contains more than six breakers is required to have a main breaker to disconnect all the downstream breakers at once.

–Chuck Marken, AAA Solar Supply Inc. • info@aaasolar.com

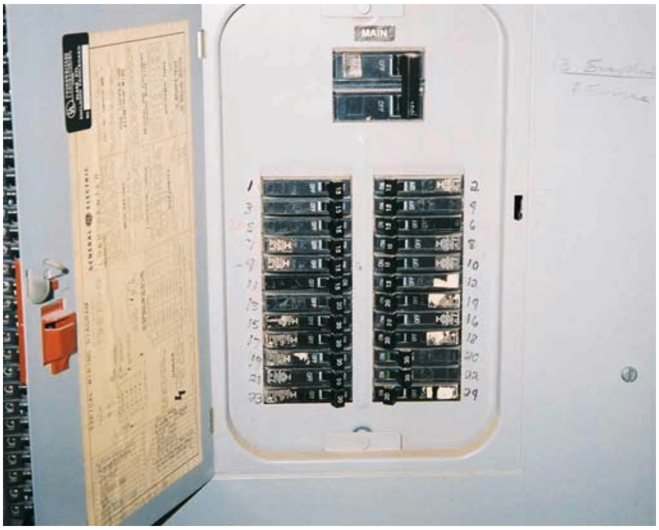
Location, Location, Location!

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

The location of the balance of systems (BOS) components (everything other than the PV array) in a PV system can be as important to a PV designer/installer as the location of a new house is to a homeowner. These location considerations are governed by serviceability, safety, and convenience requirements.

First Disconnect

The AC utility service to the typical residence comes in either on an overhead or underground feeder. Before this service feeder gets into the house, it usually must go through a billing kilowatt-hour meter and then the service entrance disconnect. In many jurisdictions, the local code allows the main disconnect to be immediately inside the home where the conductors first enter the building, as allowed by the *National Electrical Code (NEC)*. See *NEC* Section 230.



A load center with an AC service disconnect.

In other locations, and the number is increasing, the service entrance disconnect must be located on the outside of the house, while the load center, minus the disconnect, is installed inside the house. In all cases, this disconnect must be "readily accessible." It must not be in locked compartments. No ladders can be required to access it. And no building material must be removed to get to it.

These requirements were established many years ago to allow fire response personnel to quickly and safely shut off electricity to a burning building when they might need to cut holes in walls, ceilings, and roofs. In life threatening situations, time is of the essence.

An AC service disconnect, with the meter yet to be installed.

PV Disconnect & Wire Run

The *NEC* in Section 690.14 requires that the main PV disconnect be in a similar location. It therefore must be readily accessible where the DC PV source or output conductors first come into the building. If the attic is reached by fixed stairs (not pull down), then the disconnect can be mounted there. Disconnects in bathrooms are not allowed. Other readily accessible rooms are acceptable as long as there are no locked doors.

Although commonly done in the past, many inspectors are not allowing PV conductors from a roof-mounted PV array to penetrate the attic and be run through the walls to the first floor or the basement to the main PV disconnect. These "always energized" conductors pose a danger to fire response personnel, and may be a fire hazard since they are in locations where potential short circuits might start fires.

Good working clearances, with the equipment not mounted over the batteries.

The 2005 *NEC* may allow a compromise installation. If the conductors are installed in a metal conduit or raceway, they may be routed inside the house to the DC disconnect located at some distance from the point of first penetration. The disconnect will still have to be readily accessible, but this allowance, if adopted, will permit more design and installation flexibility. The metal conduit/raceway provides for added fire protection (doesn't burn), mechanical protection (difficult to accidentally cut), and ground-fault detection (in the event of an internal ground fault).

Working Clearances

A PV system, like other electrical systems, will have to be serviced periodically, and the *NEC* recognizes this service requirement. Equipment that may have to be serviced while energized must be installed with certain clearances around that equipment. This equipment may include the batteries (watering and tightening terminals), DC PV disconnects and combiners (changing fuses, testing, and tightening terminals) and charge controllers (set point adjustments). Yes, some of these things may be accomplished by somehow turning off all power to the device, but others, like changing set points on a charge controller, must usually be done while the equipment is up and running.

Section 110.26 of the *NEC* establishes the following clearances: A clear workspace is required around all equipment. This space must extend side-to-side the width of the equipment or 30 inches (76 cm), whichever is greater. For systems with 150 volts or less to ground, the depth of the working space must be 3 feet (0.9 m) from the front of the equipment. If the system voltage is above 150 volts to ground and there is a grounded surface (including concrete, tile, and brick) to the rear of the clear area, the depth of the working space must be 3.5 feet (1.1 m). A surface that is not grounded requires only the 3 foot depth even when the voltage is above 150 volts.

The required height of the working space is 6.5 feet (2 m) or the height of the equipment, whichever is greater. In existing dwellings, where the circuits operate at 200 amps or less, the height requirement may be reduced to an unspecified value with inspector approval. Other equipment in the working clearance area may project no more than 6 inches (15 cm) beyond the front of the equipment to be serviced.

Generally, these requirements mean that inverters should not be mounted above battery boxes. The area above battery boxes should be clear 6.5 feet (2 m) from the floor. A horizontal layout of components usually meets the requirements where the electronic components are mounted side by side, with the batteries in a group off to one side of the other components.

Disconnect Locations

The handles of disconnects including circuit breakers and fused disconnects may be no higher than 6.5 feet (2 m) above the floor or mounting platform when the handles are in the up position.

Most circuit breakers and disconnect switches are labeled indicating that they must be mounted in a vertical position on a vertical surface. This means that the handle must move up and down, not sideways. This ensures that the internal arc-suppression devices (which rely on heated arcs to rise vertically) work properly.

These location and clearance requirements are some of the more frequently ignored requirements in the *NEC*. There are others, but we will save them for another column. One last thought—don't forget to locate the PV modules in the sunshine.

Access

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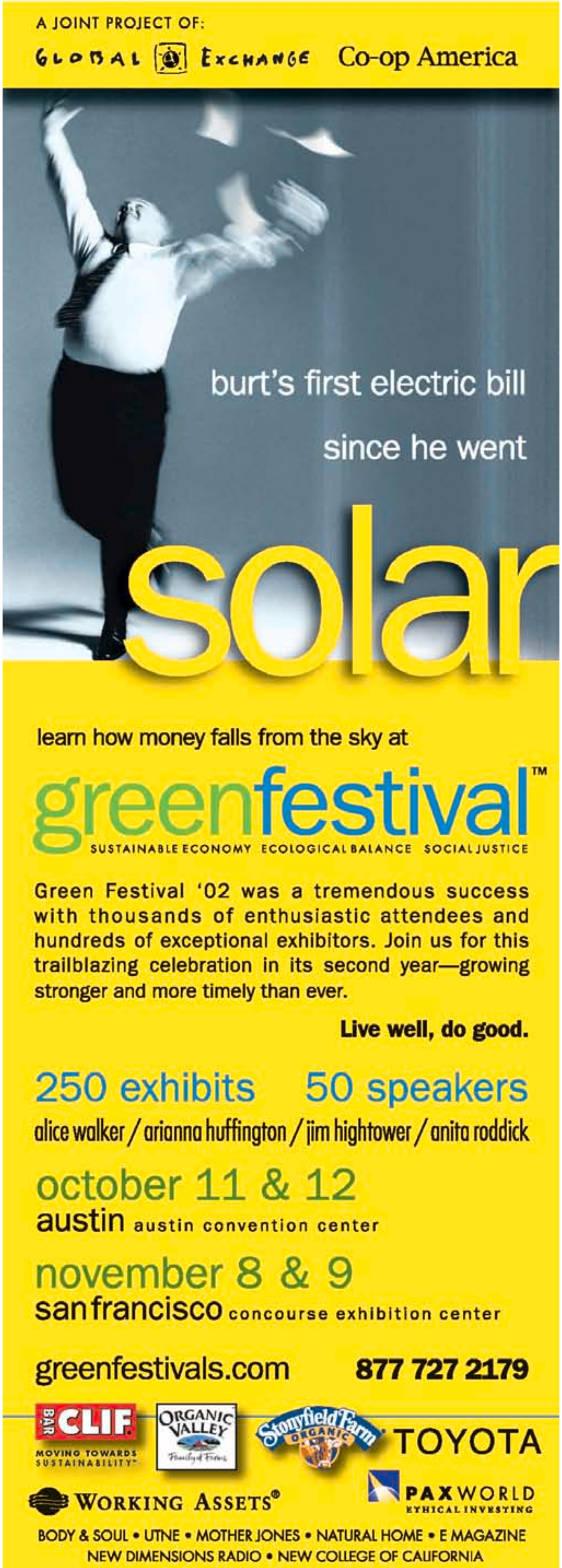
The 2002 *NEC* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA), 11 Tracy Dr., Avon, MA 02322 • 800-344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301 • custserv@nfpa.org • www.nfpa.org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RE Industry Matures

Don Loweburg

Looking back over the last twenty years, the PV industry has changed dramatically. There have been changes in the manufacturing companies, the technical hardware, and the installation companies.

Early module manufacturers primarily supplied the space program. Those manufacturing companies were high tech and specialized. Today, module manufacturers represent some of the largest global corporations. Many come from the established energy sector, such as Shell Solar, BP Solar, and RWE Schott. Others are divisions of diversified electronics corporations such as Kyocera and Sharp. In some cases, manufacturing companies (such as RWE Schott and Kyocera) have set up their own distribution channels.

Manufacturing Changes

Beyond these changes in ownership, organization, and business model, there have been major changes in manufacturing. Early modules were hand assembled. Today, most major manufacturers use high-speed robotics, both in cell manufacture and module assembly.

Early inverter manufacturers were generally small operations at their inception, morphing into larger companies primarily through corporate acquisition. Today, some module manufacturers, such as Sharp, are also beginning to produce inverters, indicating a transition towards total system integration and branding.

We have seen the beginning of this trend in the form of system kits. Most of these kits are rather unimaginative compilations of off-the-shelf components. In many cases, they simply replicate what independent installers have been doing for years. A true systems approach incorporates a higher degree of integration than kits have, and offers advantages to both the customer and the installer.

Technology Changes

Major changes have also occurred in module and inverter technology. The average PV module output has increased from around 40 watts to more than 150 watts during the last twenty years. In the same time frame, module efficiency (crystalline silicon) has increased from around 11 percent to 15 percent today.

Early inverters used SCRs (silicon controlled rectifiers) or Darlington transistors. They produced crude square waves, and had efficiencies pushing 80 percent. Today, inverters typically feature sine wave output, use FET and IGBT (field effect transistor and insulated gate bi-polar transistor) output devices, and have efficiencies exceeding 90 percent. Grid-connected inverters are available in off-the-shelf sizes ranging from under 2 KW to more than 200 KW. Most inverters now incorporate microprocessors and digital circuitry.

Other areas of technical improvement include engineered racking systems, and most recently, plug-and-play terminations on PV modules. Another change that has occurred is that all major components, modules, inverters, and array combiners are UL or equivalently listed. In fact, the standard itself (UL 1741) was developed in collaboration with the PV industry, and includes specifications addressing utility concerns about islanding. And finally, maximum power point tracking (MPPT) charge controllers are now available, and their price can be expected to drop.

Installation Changes

Just as there have been significant changes in the manufacturing and technology side of the PV business, so have there been major changes in the installation and sales of PV systems.

Twenty years ago, large PV systems were generally installed by manufacturers. To some degree, this pattern still prevails, with all major manufacturers still maintaining in-house engineering and installation capability. However, now there are also companies specializing in large system installation. They offer customers a turnkey solution, often with financing included. Two examples that come to mind are Powerlight and World Water. Companies like these generally have in-house engineering and project management, while contracting for outside labor.

In the consumer market, the systems were generally small and off-grid in the early years. These systems were often installed by do-it-yourselfers. Many of these people began installing for friends and neighbors and ended up creating full-time businesses. This is my personal background, and I suspect many established wrenches share it. At first, it was as much a labor of love as a job, and many of us had other employment. Training was pretty much on the job, supplemented with technical workshops sponsored by distributors and manufacturers.

Training

The consumer market in many areas in the U.S. is developing and expanding, especially the grid-connected market. Existing installing companies are growing, and many new companies are entering the business. With this expansion of business comes the need for more trained and knowledgeable installers. For many business owners already in the business, employees can be trained on the job (OJT).

Other sources of trained workers are schools offering workshops, classes, and training in renewable energy technologies. Organizations such as Solar Energy International (SEI), Midwest Renewable Energy Association (MREA), and San Juan College have offered training for years. Additionally, the IBEW electrical union has training programs for their members. Manufacturers and distributors continue to offer updated workshops and training for their installers as new products become available.

As the PV industry grows, we are seeing an increase in the number and kind of training opportunities, from OJT to formal college degree programs. This is an expected and welcome development. It does, however, raise concerns about the coherence of the varied trainings offered, and the consistency of the knowledge held by new installers who go through various training programs.

Installer Certification

One way to help build coherence is to establish third party certification for installers. The NABCEP (North American Board of Certified Energy Practitioners) certification program formally presented at MREF and ASES this past June offers that opportunity. This voluntary certification program can be seen as a way to raise the bar and establish a consistent and well-defined understanding of the requirements for a safe and efficient PV installation.

The primary instruments of NABCEP certification are a fieldwork experience requirement and an examination. The cost of certification is US$250. Eligibility to sit for the examination is determined by a mix of work and education prerequisites that are designed to encompass a wide variety of backgrounds. Regardless of an applicant's educational background, engineering, contracting, trade school, or other recognized training, a minimum of one year installing experience is required.

The content of the examination covers technical, design, and safety issues. An installer who passes this test and receives NABCEP certification will be qualified to install PV systems. There was strong consensus among the board members and the various committee members working on the program that the level of the test be fair. The test and prerequisites are not meant to exclude any potentially qualified applicant.

Full information is now available at www.nabcep.org. Information available includes a candidate's handbook, an outline (task analysis) of critical and important skills that define the knowledge base of a good installer, a study guide, and application information. Updates on test sites and exam dates will be available on the Web. The first exams will be conducted at six locations on October 25, 2003.

Ezra Auerbach, President of NABCEP, leads a directors' meeting in Austin, Texas (ASES 2003).

A Growing Industry

Just as all other aspects of the industry have changed, the installation infrastructure should also change. Establishing minimum standards and certification for the installation of PV systems is consistent with the other changes occurring in a growing PV industry.

Few would favor square wave over sine wave inverter output, or unreliable over reliable equipment performance. Just as technical and hardware advancements clearly benefit the PV industry, installer certification will benefit everyone in the industry—from customers to manufacturers to government agencies administering funding.

Probably the greatest beneficiary of certification will be established installers. What better way to distinguish your experience and knowledge than to be certified? In a rapidly growing industry, there clearly is a need to separate the qualified installer from the unqualified.

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Have Your Say —Now!

Michael Welch

For a long, long time, energy activists have been looking for ways to turn our nation's dismal energy policies around. Watching our leaders promote dirty energy technologies instead of dealing with the real environmental, social, and economic problems that our energy policies contribute to has been frustrating and disheartening.

Mainstream and lesser known environmental groups, individual activists, and renewable energy users have provided only stopgap measures, and have not been successful with the big picture of overall policy. We must take things into our own hands, so governments and the media will finally deal with the real problems, rather than focusing on nonsolutions.

There is little doubt that a massive overhaul is needed to bring energy policy back in line with the public good. For example, tax breaks for RE add up to US$0.4 billion, plus US$0.1 billion for energy efficiency. Fossil fuels get US$10.2 billion, and nuclear energy gets US$1.5 billion.

Apollo Project

Every now and then, bright rays of hope show up. In *HP94*, I briefly reported on the New Apollo Project, an effort started by Washington State Representative Jay Inslee. The program is an alternative to the energy plans that Congress has been working on, and would focus government on a more appropriate national energy policy (see www.house.gov/inslee/energy_apollo_rallydems.htm).

The idea is to take a clue from the Apollo space program, which included an all-out effort to put a human on the moon, winning the U.S. vs. U.S.S.R. race for space. Another similar effort was the Manhattan Project, which developed nuclear weapons, purportedly to help end World War II, and to ensure that other countries would not have and use them before us.

Whether or not you agree with the goals or like the end results of those all-out efforts is beside the point. Those programs provide an example of what can be done if our government applies itself and its resources to get a big job done. What we are after is a massive, nationwide undertaking to increase energy efficiency and conservation, and to promote cleaner and renewable sources of energy.

In June, a new organization and initiative with a similar name, Apollo Alliance, was started. It has comparable aims to Inslee's plan. I like and support both of these efforts. Inslee's program is internal to Congress in the form of introduced bills and amendments to the energy bill. Apollo Alliance is seeking to unite key activists from labor, environmental, and civil rights communities to support clean energy and good jobs programs. They are focused on informing and influencing the electorate in this direction via public information campaigns.

Results Are Our Responsibility

The results of these efforts are what count. Nothing about national energy policy will get better until voters involve themselves. Most U.S. citizens do not take the time to contact our representatives. So we forfeit our political power to the corporate campaign funders and lobbyists that are well paid to constantly be in the faces of our elected officials. It is critical for us to take the time to let our representatives know how we feel.

Late on July 31, the last day before Congress recessed for the summer, the Senate agreed to consider last year's energy bill instead of the one they had been working on this year. Then with only 14 votes against, that bill was quietly passed. This one is not better than the one they had been working on, though some nuclear plant subsidies are left

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out of it. Now the energy bill goes to a conference committee to reconcile differences between the House and Senate versions.

Please contact your representatives in Congress *right now* to let them know that you support nothing less than a massive project to come up with a new national energy policy similar in scope to the Apollo and Manhattan Projects. The project must:

- Preserve regulatory protections for consumers and the environment.
- Improve owner incentives and auto industry fuel standards to encourage high-mileage and low-emissions automobiles, like hybrids and EVs.
- Improve factory and manufacturing facility energy efficiency through tax incentives and development grants and funds.
- Increase the use of and standards for energy efficient appliances.
- Increase the availability and convenience of mass transportation.
- Switch the energy focus to hydrogen produced from renewable sources.
- Improve the climate for renewable energy development by increasing subsidies and incentives, while decreasing subsidies for dirty and unsafe technologies.

Through this massive redesign of our energy policy, we can slow the increasing dependence on foreign oil, create local jobs in industries that are clean and safe, slow global warming, and end the pollution from fossil fuels and nuclear plants.

Access

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Inductance

Opposition to Change in Current

Ian Woofenden

Derivation: From Latin inducere, *to lead, bring in, induce.*

When you connect the positive and negative leads of a generator, battery, or other energy source to each other with nothing but wire in between, all the charges try to flow at once, with nothing but the size of the wire to stop them. This rush of charge (high current) is called a "dead short" or "short circuit," and it's not pretty. It can lead to melted wires, damaged equipment, and fires.

Electrical loads in a circuit provide a form of regulation. They control the flow of charges. In DC circuits, loads present what's called "resistance" to the flow. In simple terms, this is like squeezing a hose down to a small opening, which restricts the flow. A resistor in a DC electrical circuit slows the flow of charges, only allowing them to travel at a certain speed. At the same time, these resistors and their electronic buddies are doing some form of work, which is the point of the circuit in the first place.

In AC circuits, there are a couple of additional electrical effects besides resistance that regulate the flow of charges in a circuit and assist in doing useful work. These are capacitance—storing energy in an electrostatic field, and inductance—storing energy in a magnetic field. These effects are present in DC when the circuit is being energized and de-energized; but they are present all the time in alternating current (AC) circuits, since the voltage and current are constantly changing.

In my last column, I explained that when charges flow through a coil of wire, it sets up a magnetic field. Conversely, a magnet passing by a wire "induces" a voltage in the wire. This can lead to a flow of charge, which we call "current." In AC circuits, the voltage goes to zero and reverses many times per second, so the charge flow stops and reverses as many times as well. The magnetic field around the wires builds up to its peak when the charge flow is fastest, and drops down to nothing when the current goes to zero (charge flow stops).

When that magnetic field is increasing, there's a reverse effect that the magnetism puts on the movement of charges in the wire itself. This counter-voltage or electromotive force (cemf) tries to slow the charges down. When the charge flow decreases and the magnetic flux collapses, it has the effect of trying to keep the charges flowing. Inductance is like electrical inertia. It opposes change in charge flow speed.

Imagine a flywheel attached to a belt drive. When the belt goes one way, it spins the flywheel up. When the belt direction changes, the flywheel opposes the change, but then slows down and is spun up the other way. The flywheel stores some of the energy and bounces it back in an alternating pattern that echoes the source alternation, but is offset from it.

In the same way, the magnetic field around a coil acts as a sort of shock absorber, in both directions. It removes energy from the circuit when the charge flow rate (amperage) is increasing, and returns it to the circuit when the charge flow rate is decreasing.

"Inductors"—also called coils or chokes—are simply coils of wire wrapped around a solid or air core. Different wire and core materials and different configurations give different levels of "inductance"—the strength of the reverse voltage generated when current through the inductor changes.

Inductance is measured in "henrys"—named after American physicist Joseph Henry, who along with Michael Faraday, discovered induction. The abbreviation for the unit is "h." One henry is the inductance when charge flow that is changing at the rate of 1 amp per second produces a cemf of 1 volt.

Induction is used in various ways in electrical equipment. Motors use induction as a basic part of their design. Transformers rely on induction as they convert from one voltage to another. Induction ovens and cooktops induce electric currents in the cooking vessels, which heat up, cooking the food. Inductors are used in all sorts of electronic devices.

The basic trick to induction is that changing the magnetic field surrounding a wire or through a coil of wire sets up a voltage in any conductors nearby, including in the wire or coil itself. Taking advantage of this natural phenomenon is critical to electrical and electronics design. Next time: Capacitance.

Access

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

"Basics of Alternating Current Electricity: Part Two—Phase and Power," by Richard Perez in *HP53*.

"Getting the Buzz Out: Electromagnetism for Beginners," by Chris Greacen in *HP35*.

River Rescue

Part Two

Kathleen Jarschke-Schultze

Last issue: A tree that Bob-O was felling in Betchawannaland had injured him. He had called in his own rescue using our telephone/radio. Help had arrived. His broken leg had been stabilized, and he was carried up the mountain to the rescue vehicles. By this time, it was several hours after the accident.

Anticipation

My friend Betty Ann and I waited for a "broken" Bob-O to be transported to us at the junction of McNeil Creek Road and Salmon River Road. From there, I would drive him for three hours to the hospital. CB radio traffic on the road channel had dropped to a minimum. People calling their mile markers on the river road made short, terse transmissions. When an emergency was in progress, channel 18, the road channel on the river, was used. To switch to another channel brought the possibility of missing a vital transmission. Everyone listened intently for news and any hint that they could help in the rescue effort in some way.

As we stood beside my car waiting, Betty Ann kept reassuring me that everything would be okay. A helicopter flew overhead towards Bob-O in Betchawannaland. A few minutes later, someone called me on the radio. Bob-O was going to be flown down to meet me at the road junction. That would save about an hour. Fine with me. The sooner I laid eyes on Bob-O, the better I would feel.

Complication

It took another half hour to carry Bob-O to where the helicopter had finally been able to land. They loaded him in, with local EMT Nixie at his side. The helicopter was a small Bell Ranger, and with the two of them and the pilot, it was a tight fit. Nixie hated flying, but figured she was the EMT and needed to stay with her patient until she could turn him over to me. Bob-O and I had almost completed our EMT training, so I knew I could handle it from there.

Once the helicopter was airborne, Bob-O called me on his 2-meter ham radio. They weren't coming down to me. They were going straight to Rogue Valley Hospital in Medford, Oregon.

The helicopter was from a logging company working elsewhere on the Salmon River. They had heard about the accident and came to help. They were like that. In any emergency in the woods, if a helicopter was nearby, they had orders to perform a mercy flight, no matter whether it was an employee, a Forest Service worker, or a local resident. The pilot's orders were to pick up the injured and fly directly to Rogue Valley Hospital. Do not pass Go; do not collect $200. Just get there as soon as possible. Rogue Valley is *the* trauma center between Redding, California, to the south and Eugene, Oregon, to the north.

I watched the helicopter fly overhead. I waved. "I'm right behind you, Baby," I spoke into the radio. I hugged Betty Ann good-bye and drove up the South Fork. As I passed Indian Creek, Sarah called on the radio. She would look after our dog, Amelia Airedale, until I returned—however long that would be.

I got to Starveout, and ran across the bridge to the cabin. I grabbed the checkbook and some clean clothes out of a laundry basket, petted the dog, and left.

Consternation

Meanwhile up in the helicopter, Nixie and Bob-O were having their own drama. Nixie was terrified. She sat holding Bob-O's leg up and the splint straight. The vibration of the helicopter had caused his leg to start bleeding again. Blood seeped from the splint over her hands. She looked Bob-O in the eye. "Bob-O," she said tensely, "if you have AIDS, I will kill you."

Bob-O assured her that he did not. Now the only thing to frighten her was the altitude. She started breathing hard. Bob-O borrowed her stethoscope and took her vitals. She took it back and recorded his vitals. And so it went for the whole flight. They ministered to each other.

Operation

By the time I arrived at the hospital three hours later, Bob-O had already been in surgery for over an hour. Nixie met me, and we sat in the waiting room. Nixie's husband Larry showed up to drive her back home. They stayed with me another hour till we heard Bob-O was out of surgery, and then they took off.

I had to wait some more before I could see Bob-O. He was awake, but very tired. Because of Bob-O's asthma, the anesthesiologist had used a spinal block rather than a general anesthetic. He also let Bob-O know his displeasure with the fact that Bob-O had lain on the sidehill eating the remnants of his lunch waiting for rescue. That was another compelling reason not to use a general anesthetic.

Bob-O had broken both the tibia and fibula bones right at the boot line on his right leg. It was a compound fracture, with the bones poking through the skin. The surgeon put an external fixation device on Bob-O's leg. He drilled four stainless steel pins into the bones, evenly spaced along the length of his calf. A single long rod was clamped onto these, holding them in place.

This device was a real sheet shredder. It looked like a Yagi or old-style TV antenna sticking out of his leg. Once home, I had to use a length of black PVC pipe rising up and over the foot of the bed to make a half circle tent to keep the bedding off the leg Yagi.

The oddest thing was that while Bob-O's left leg was, and still is pristine, his right leg has suffered several wood cutting mishaps. There are scars from two prior chainsaw misadventures. The worst one, across the bottom of his knee, happened up at the old Black Bear commune.

They were brushing the area around the ranch in the spring. The chainsaw bucked back at him and hit his leg. His buddies carried him into the main house and laid him on the long wooden dining table. Geba, a midwife, had experience with stitching skin, so she stitched up his leg and they treated it with herb poultices. It healed very well and remains today only as a scar and a good story.

Hospitalization

I stayed with Bob-O in his hospital room for eight days. He was on some pretty powerful antibiotics because the bone ends had stuck out of his leg for such a long time. From the time of the accident until he saw a doctor was five hours. That was with a coordinated rescue and helicopter mercy flight where nothing went wrong. In EMT training, you are taught that if you can stabilize an injured person and get them to a hospital within an hour of the injury, you have a really good chance of saving that person's life. They call it the "golden hour." There is no such thing as a golden hour on the river.

One of the nurses, who had never met us before, immediately sized up the situation, "Oh, a logging accident." We accused her of reading Bob-O's chart. She explained. Bob-O's injury was severe, but very localized. If he had been in a car accident, the rest of him would have been roughed up more. We were impressed.

Proposition

Our good friend, Karen Perez, came to visit us at the hospital. I told her that Bob-O was done working in the woods. He wasn't fast enough to dodge that tree, and the metal in his leg wasn't going to make him any faster. His surgeon concurred with me. It was official.

Karen and her husband Richard had a proposition for us. Some friends of theirs were putting a house near them up for sale. Richard and Karen knew we were looking for land to buy. They had an amazing project going with a renewable energy magazine, and needed to devote more of their time to it, and less to running Richard's installation business. If we bought the house, they would hire Bob-O to run Electron Connection and would hire me to work for *Home Power*. (Eventually, we purchased the installation business from them.)

Bob-O and I looked at each other. We would have a house and two jobs—jobs that were good for the earth and its people. In four years, Bob-O's son Allen would have to leave the river to go to high school. So we were destined to leave that place sooner or later. Well, when opportunity knocks, we've been known to throw the door open wide. We went for it.

Revelation

Sitting in the hospital room, Bob-O and I thought the worst had happened to us. Bob-O was hurt, and unable to return to his job. I had no job and no real prospects for one on the river. Just when we thought we were playing a spent hand, we were dealt aces.

So when it seems like your luck has gone, and when good things go bad, just wait and keep your heart open. It could be the best thing that ever happened to you.

Access

Kathleen Jarschke-Schultze is appreciating Bob-O, her diamond-in-the-rough, at their home in northernmost California. c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 •
kathleen.jarschke-schultze@homepower.com

RE happenings

INTERNATIONAL

Free instructions, photos, drawings, & specs to build solar cookers & water systems with local materials, purchased with local currency. Sunstove • www.sungravity.com

El Paso Solar Energy Assoc. bilingual Web site. Info en Español on energy & energy saving. Free download of PV Systems book • www.epsea.org/esp

Green Empowerment promotes community-based RE projects internationally. Info: www.greenempowerment.org

Solar On-Line (SóL) Internet courses. Year-round. PV Technology & Opportunities: A Qualitative Overview; PV Systems Design: Basic Course; PV Systems Design: Professional Course; Hands-On PV System Installation; Solar Homes; Healthy Buildings; & Solar Energy for International Development. SóL, PO Box 217, Carbondale, CO 81623 • 720-489-3798 • info@solenergy.org • www.solenergy.org

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

CANADA

Nov. 13–15 '03; Can. Solar Industries Assoc. annual forum; Ottowa. Discussions & presentations on strategies, plans, & practical means to ensure solar capitalizes on Canada's Climate Change Objective of reducing greenhouse gas emissions. Info: CanSIA, 613-736-9077 • www.cansia.ca • rmcmonagle@cansia.ca

Alberta Sustainable Home/Office, Calgary. Open house last Sat. every month 1–4 pm, private tours available. Cold-climate features, environment, conservation, RE, recycling, efficiency, self-sufficiency, appropriate technology, autonomous & sustainable housing & communities. 9211 Scurfield Dr. NW, Calgary, AB T3L 1V9 • 403-239-1882 • jdo@ecobuildings.net • www.ecobuildings.net • www.ecodeveloper.com

Vancouver EV Assoc. Call for meeting info. PO Box 3456, 349 W. Georgia St., Vancouver, BC V6B 3Y4 • 604-878-9500 • info@veva.bc.ca • www.veva.bc.ca

CHINA

Apr. 7–9, '04; REAsia 2004, Beijing. Marketing RE in Asia. Info: Vivian Li, Grace Fair Intl. Ltd. Room 1311, Tower A, Zhongyun Bldg., Wangjing New Industrial Zone, Chaoyang Dist., Beijing 100102, China • ++86-10-64390338 • Fax: ++86-10-64390339 • vivian@gracefair.com • www.gracefair.com

COSTA RICA

Feb. 16–21, '04; RE for the Developing World—Hands On, Rancho Mastatal, Costa Rica. Solar electricity, hot water, & cooking; other RE technolgies. Info: see SEI in COLORADO listings. Coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

FRANCE

Oct. 20–21, '03; STORE: STOrage for RE conference; Aix en Provence, France. Storage technologies for RE. Office du Tourisme, 2 place du Général de Gaulle BP 160, 13605 Aix En Povence Cedex 1, France • Fax: 33 (0)4 42 161 179 • gestioncongres@aixenprovencetourism.com

GERMANY

Oct. 9–11, '03; Hydrogen Expo, Hamburg. Exhibits, technology, & commercialization. Info: Hamburg Messe, + 49-211-687858-11 • info@h2expo.de • www.h2expo.de

May 11–14, '04; Wind Energy Intl. Trade Fair; Hamburg Fair Site. Info: Hamburg Messe und Congress GmbH, PO Box 30 24 80, 20308 Hamburg, Germany • +49 40 3569-0 • www.windenergy-hamburg.de

INDIA

Oct. 16–17, '03; Green Power 4; Hyatt Regency, New Delhi, India. Sustainable energy development for improved quality of life. Info: World Council of Power Utilities, +91- +11- 2554 2551/ 5158 9329 • ipis@vsnl.net • www.indiacore.com/Conf/9-oct2003-cpu-green-power/

NICARAGUA

Jan. 6–16, '04 (again Jul. 18–29); Solar/Cultural Course. Managua. Lectures, field experience, & eco-tourism. Taught in English by Richard Komp & Susan Kinne. Also, Micro-Irrigation Course: Feb. 22–29, & RE Fair: Apr. 1. Info: Barbara Atkinson • 215-942-0184 • lightstream@igc.org • www.grupofenix-solar.org

SINGAPORE

Nov. 18–19, '03; Sustainable Energy Asia, & Energy Efficiency Asia. Conference. Info: Christina English • (65) 6227 6252 • cenglish@iirx.com.sg

SPAIN

May 16–19, '04; SCELL-2004: Intl. Conf. on the Physics, Chemistry & Engineering of Solar Cells; Badajoz, Spain. Will disseminate research results on materials science & technology related to solar energy conversion. Info: Formatex Research Center • Fax: +34/924/258-615 • scell-2004@formatex.org • www.formatex.org/scell2004/scell2004.htm

WALES

Nov. 14–16, '03; Intro to RE; Centre of Continuing Education, Univ. of Wales, Aberystwyth. Also Jan. 16–18, '04; Mar. 12–14; Jul. 9–10. Info: Green Dragon Energy, + 44 (0)1974 821 564 • dragonrg@talk21.com • www.greendragonenergy.co.uk

U.S.A.

Oct. 4, '03; National Tour of Solar Homes. Check for tours local to you. Info: Cindy Nelson, American Solar Energy Society • 303-443-3130 • cnelson@ases.org • www.ases.org

Oct. 4, '03; National Tour of Solar Homes & Green Buildings, in northeast U.S. Info: NESEA, 50 Miles St., Greenfield, MA 01301 • 413-774-6051 • nhazard@nesea.org • www.nesea.org

Videos. Appalachia: Science in the Public Interest; Incl. Solar Dry Composting Toilets, Solar Hot Water Systems, PV, Solar Space Heating, Solar-Powered Automobiles, Quilted Insulated Window Shades, & more. Broadcast-quality tapes available. ASPI Publications, 50 Lair St., Mt. Vernon, KY 40456 • 606-256-0077 • aspi@a-spi.org • www.a-spi.org

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

State & Fed. incentives for RE info. North Carolina Solar Center, Box 7401 NCSU, Raleigh, NC 27695 • 919-515-3480 • www.dsireusa.org

Energy Efficiency & RE Clearinghouse Fact Sheets: Insulation Basics, Financing an Energy Efficient or RE Home, PV: Basic Design Principles & Components, Cooling Your Home Naturally, Small Wind Energy Systems for the Homeowner, & more. www.eere.energy.gov/consumerinfo/factsheet.html

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

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

Federal Trade Commission free pamphlets: Buying an Energy-Smart Appliance, Energy Guide to Major Home Appliances, & Energy Guide to Home Heating & Cooling. Energy Guide • 202-326-2222 • TTY: 202-326-2502 • www.ftc.gov

Solar curriculum for schools. 6 week science curriculum or individual sessions. Free! 30 classroom presentations & demos. Florida Solar Energy Center • 321-638-1017 • www.fsec.ucf.edu/Ed/sw

ARIZONA

Tax credits for solar in AZ. ARI SEIA • 602-258-3422 • www.azsolarindustry.org

Scottsdale, AZ. Living with the Sun; free energy lectures, 3rd Thurs. each month, 7–9 PM, City of Scottsdale Urban Design Studio. Dan Aiello • 602-952-8192; or AZ Solar Center • www.azsolarcenter.org

CALIFORNIA

Oct. 3–5, '03; Understanding Grid-Connected Solar Electric Systems: A Course for the Homeowner or Small Businessperson. Arcata, CA. Info: Office of Extended Education at Humboldt State University • 707-826-3731 • www.humboldt.edu/extended

Solar Living Institute workshops: Oct. 4, Hydrogen Energy; Oct. 4–5, Women in Solar; Oct. 6–10, On-grid PV Design & Res. Site Install.; Oct. 10–12, Straw Bale Construction; Oct. 18, Save Money with Solar Hot Water; Oct. 25–26, Solar Electric 101; Oct. 25, Will Solar Save Money?; Oct. 25, Find Your Dream Job in Solar; Nov. 1–2, Solar Electric 101; Nov. 9, Biodiesel; Nov. 14, Commercial Apps for PV; Nov. 15, Solar For Electricians. Info: Solar Living Institute, PO Box 836, Hopland, CA 95449 • 707-744-2017 • sli@solarliving.org • www.solarliving.org

Nov. 15–19, '03; EVS 20, International EV Symposium & Expo; Long Beach. Info: www.evs20.org

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

Rebates for PV & wind. CA Emerging Renewables Buydown Program, CA Energy Comm. • 800-555-7794 or 916-654-4058 • renewable@energy.state.ca.us • www.consumerenergycenter.org/erprebate

Energy Efficiency Building Standards for CA. CA Energy Comm. • 800-772-3300 • www.energy.ca.gov/title24

Solar e-Clips, free weekly e-mail newsletter. CA solar energy news & info. Subscribe: www.californiasolarcenter.org

COLORADO

Sep. 29–Oct. 4, '03; Sustainable Resources 2003; Boulder; Intl. forum connecting people with hands-on solutions to world poverty. Info: www.sustainableresources.org

Carbondale, CO. SEI hands-on workshops & online distance courses. PV Design & Installation, Advanced PV, Solar Water Pumping, Wind Power, Micro-hydro, Solar Hot Water, Biodiesel, Alternative Fuels, Solar Home & Natural House Building, Advanced Straw Bale Construction, RE for the Developing World, Politics of Energy, Utility Interactive PV, Women's PV Design & Installation, Women's Wind Power, Women's Carpentry, PV Distance course, & Solar Home Design distance course. Solar Energy International (SEI), PO Box 715, Carbondale, CO 81623 • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

DELAWARE

Oct. 16–17, '03; Solar Hot Water & Radiant Heating Workshop; Delaware Technical CC, Terry Campus, Dover. Design & construction specifications course for solar radiant heating systems. Info: Peter Biondo, USA Solar • 928-282-5140 • info@usasolar.net • www.usasolar.net

IOWA

Prairiewoods & Cedar Rapids, IA. Iowa RE Assoc. meets 2nd Sat. every month at 9 AM. Call for changes. IRENEW, PO Box 355, Muscatine, IA 52761 • 563-288-2552 • irenew@irenew.org • www.irenew.org

KENTUCKY

Mt. Vernon, KY. Appalachia: Science in the Public Interest. Projects & demos in solar electricity, solar hot water, gardening, sustainable forestry, more. ASPI, 50 Lair St., Mt. Vernon, KY 40456 • 606-256-0077 • solar@a-spi.org • www.a-spi.org

MASSACHUSETTS

Greenfield Energy Park. Ongoing energy demos & exhibits. NESEA, 50 Miles St., Greenfield, MA 01301 • 413-774-6051 • nhazard@nesea.org • www.nesea.org/park

MICHIGAN

Urban Enviro workshop, Ferndale, MI. Third Wed. 7–9 pm. Sustainability, energy efficiency, RE, & consumer issues. Free. Mike Cohn, 22757 Woodward #210, Ferndale, MI 48220 • 313-218-1628 • ECadvocate@aol.com • www.hometown.aol.com/ecadvocate

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

MINNESOTA

Oct. 14–18, '03; St. Paul MREA PV Installation workshop. Info: see MREA listing in WISCONSIN

MONTANA

Oct. 4, '03; Photovoltaics & the NEC; Great Falls. Continuing ed. seminars for electricians. Also Oct. 25 in Bozeman & Oct. 26 in Billings. Info: Montana RE Assoc. (MREA), johnw@ncat.org • www.montanagreenpower.com/mrea/AboutMREA.html

Whitehall, MT. Sage Mountain Center: one-day seminars & workshops, inexpensive sustainable home building, straw bale & cordwood constr., log furniture, PV, more. SMC, 79 Sage Mountain Trail, Whitehall, MT 59759 • 406-494-9875 • cborton@sagemountain.org • www.sagemountain.org

NEVADA

Jan. 19–22, '04; 2004 Intl. Builders' Show; Las Vegas, NV. Incl. energy efficiency in new home design, construction, & marketing. Info: Karin Victorio, NAHB Research Center, 400 Prince George's Blvd., Upper Marlboro, MD 20774 • 800-638-8556 x6277 or 301-430-6277 • Fax: 301-430-6180 • kvictorio@nahbrc.org • www.nahbrc.org /evha

NEW MEXICO

Sep. 29–Oct. 3, '03; Natural House Building workshop; Kingston, NM. Build with earth & straw. Hands-on sessions: straw bale, adobe, pressed block, rammed earth, cob, & natural plaster. Info: see SEI in COLORADO listings.

Oct. 15–17, '03; Solar Energy Systems Symposium; Albuquerque. Forum on solar technologies as they relate to national security, strengthening U.S. solar industry, markets, & the significance of R&D. Info: Sandia Solar Projects, PO Box 5800, Albuquerque, NM 87185 • 505-844-4383 • Fax: 505-844-6541 • pvsac@sandia.gov • www.sandia.gov/pv

NEW YORK

RE Loan fund: low interest financing: NY Energy $mart Program, NY State Energy R&D Authority • 518-862-1090 ext. 3315 • rgw@nyserda.org • www.nyserda.org

NORTH CAROLINA

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

OHIO

Oct. 11–12, '03; 3rd Athens Area Sustainability Festival; Athens County Fairgrounds, Athens, OH. Showcases recycling, solar & wind, watershed restoration, organic farming, alternative transportation, heritage preservation, citizenship, local currency, community development, etc. Music, theatre, poets, storytellers, film makers, food vendors, educators, etc. Info: Ivars Balkits, PO Box 58, Amesville, OH 45711 • 740-448-1016 • isbalkits@hotmail.com

Nov. 15, '03; Wind & Solar Workshops; Dublin Community Center & Glacier Ridge Metro Park, Dublin, OH (near Columbus). Info: Green Energy Ohio, 7870 Olentangy River Rd. #209, Columbus, OH 43235 • 866-473-3664 • christina@greenenergyohio.org • www.greenenergyohio.org

OREGON

Oct. 4, '03; National Tour of Solar Homes participant, John Day, OR. See EORenew below for contact info.

Oct. 4, '03; Central OR Tour of Solar Homes & Green Building Fair, Bend area. Open houses & fair in downtown Bend w/ booths & displays on RE & sustainable bldg. Info: info@3estrategies.org • 541-312-4451

Nov. 1, '03; EORenew Annual Meeting & Program, John Day, OR. Info: EORenew, PO Box 485, Canyon City, OR 97820 • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10 weeks, 14 interns per quarter. Aprovecho Research Center, 80574 Haxelton Rd., Cottage Grove, OR 97424 • 541-942-0302 • apro@efn.org • www.efn.org/~apro

PENNSYLVANIA

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

PV grants for Penn. available through the Sustainable Development Fund • sdf@trfund.com • www.trfund.com/sdf

Philadelphia Million Solar Roofs Partnership • 215-988-0929 ext. 242 • www.phillysolar.org

RHODE ISLAND

People's Power & Light: buyers' groups for green electricity & bio heating oil. Also info & programs to promote sustainable energy. Info: 401-861-6111 • info@ripower.org • www.ripower.org

Coventry, RI. Apeiron Institute for Environmental Living. Ongoing workshops & demos on sustainable living. Apeiron Inst. • 451 Hammet Rd., Conventry, RI 02816 • 401-397-3430 • info@apeiron.org • www.apeiron.org

TEXAS

El Paso Solar Energy Assoc. meets 1st Thurs. each month. EPSEA, PO Box 26384, El Paso, TX 79926 • 915-772-7657 • epsea@txses.org • www.epsea.org
Houston RE Group: Call for meetings:

HREG • hreg@txses.org • www.txses.org/hreg/

VIRGINIA

Info & services on practical solar energy apps in VA. VA Solar Energy Assoc., the VA Solar Council, & the VA SEIA. Info: VA Div. of Energy • 804-692-3218

WASHINGTON STATE

Oct.11, '03; Intro to Renewable Energy, Guemes Island, WA. Solar, wind, & microhydro for homeowners. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Oct. 13–18, '03; PV Design & Install Workshop, Guemes Island, WA. System design, components, site analysis, system sizing, & a hands-on installation. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Oct. 20–25, '03; Wind Power Workshop with Mick Sagrillo, Guemes Island, WA. Design, system sizing, site analysis, safety issues, hardware specs, & a hands-on installation. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

WISCONSIN

MREA workshops. Solar Water & Space Heating: Oct. 11 in Custer; Make Your Own Window Quilts: Oct. 25 in Custer; Intro to Masonry Heaters: Nov. 8 in Custer. Also Wind System Install, PV Install, Straw Bale, Sustainable Living, & others. MREA, 7558 Deer Rd., Custer, WI 54423 • 715-592-6595 • mreainfo@wi-net.com • www.the-mrea.org

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

Wrong Way

Lately, I have heard that Congress is considering an energy bill that would give oil and gas companies billions of dollars in tax breaks and other incentives. They are also said to be reconsidering drilling in ANWR, and opening more federal lands to oil and gas exploration.

This is totally outrageous. These companies have more than enough capital to invest on their own. They don't need any public money. This money would be better spent on installing billions of watts of solar and wind power generation capacity, and for jump-starting the hydrogen fuel economy. If this is done, we eventually won't need any more oil and gas exploration.

The present government of the U.S. is definitely going in the wrong direction in respect to the development of future energy and fuel resources. Hydrocarbon resources are limited, and will eventually be used up. The sun and wind are going to be around for as long as humanity exists on this planet.

It is utterly ridiculous to invest in short-term resources, when you will have to invest eventually in long-term resources anyway. The way things are going, it appears that a radical crisis will be necessary to get us turned around. Let us hope it is not too radical.

Home Power is a user's technical journal. We specialize in hands-on, practical information about small-scale renewable energy technologies. We try to present technical material in an easy-to-understand and easy-to-use format. Here are some guidelines for getting an article published in *Home Power*.

Informational Content

Please include all the details! Be specific! We are more interested in specific information than in general information. Write from your direct experience—*Home Power* is hands-on and how-to! Articles must be detailed enough that our readers can actually use the information. Name names, and give us actual numbers, product names, and sources.

If you are writing about someone else's system or project, we require a written release from the owner or other principal before we can consider printing the article.

We're moving in a new organizational direction for *HP* articles. We're trying to keep the main body of our system articles light, with more human interest for newer, nontechnical readers. The more technical system information is included in sidebars and tables for the super nerds who need to know.

We hope this approach produces more balanced articles that will reach a broader audience. So, try to include the system's technical details in either tables and/or separate information boxes that run as sidebars in the magazine.

Article Style & Length

Home Power articles can be anywhere between 350 and 3,000 words. Length depends on what you have to say. Say it in as few words as possible. We prefer simple declarative sentences that are short (fewer than twenty words) and to the point. We like the generous use of subheadings to organize the information. We highly recommend writing from within an outline. Check out articles printed in *Home Power.* After you've studied a few, you will get a feeling for our style.

We edit all articles for accuracy, length, content, organization, and basic English. You can help by keeping your sentences short, simple, and to the point. Our editing crew will make your text shine.

Photographs

We can work from high resolution digital pictures; or good photographic prints, slides, or negatives. If you are unable to submit photos from a three megapixel camera, or better, we prefer 4 by 6 inch color prints with no fingerprints or scratches. Do not write on the back of your photographs, since the ink can transfer to the front of the next photo. Please provide a comprehensive caption and photo credit for each photo. Include some vertical format photos—you might even find your system on *HP*'s cover. People are nice in photos; a fuse box is only so interesting, even to solar nerds.

Digital photos should be at least 280 pixels per inch (ppi) at the final printed size. This means that a column width photo should be 1,000 pixels wide or more. A full page width photo should be at least 2,300 pixels wide. Basically, set your digital camera at its highest resolution, and crop thoughtfully. We prefer Photoshop files, but we can handle the following formats in descending order of preference—EPS, TIFF, and JPEG.

Art, Schematics, & Tables

System articles must contain a schematic drawing showing all wiring. Our art department can make gorgeous diagrams, charts, and schematics from your rough sketches. If you want to submit a computer file of a schematic or other line art, please e-mail us first.

For system articles, we require a load table listing all loads, with wattage and run time. We also require an itemized cost table listing each system component and its cost. We prefer to have the tables come to us in Excel format. But we can use them from any word processor or spreadsheet format if they are saved as "text only," with tabs as the delimiter between data.

Computer Talk

We can take text from most word processors. Save all word processor files in "TEXT" or "ASCII TEXT" format. This means removing all word processor formatting and graphics. Use the "Save As Text" option in your word processor.

If you want to send files larger than 5 MB (such as digital photos), use removable media and snail mail it to us. We prefer CD-ROMs, DVDs, or Zip100 disks. You can also FTP your large files to us at ftp.homepower.com, to the "incoming" folder. Please e-mail us after you have sent files via FTP.

Putting It All Together

We get many more articles submitted than we can print. The most useful, specific, organized, and complete get published first. Here are the basic components of a great *Home Power* article:

- Clearly written, well organized, and complete text, with a strong introductory paragraph, subheads for each major section, and a strong closing paragraph
- Photos (plenty) with comprehensive captions
- Cost table
- Load table
- Other tables, charts, and diagrams as appropriate
- System schematic
- Complete access information for author, installers, consultants, suppliers, and manufacturers

Contact us if you have any questions.We prefer receiving e-mail at submissions@homepower.com.We hope to see your article published in *Home Power*!

Access

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Preaching to the World

Dear *Home Power*, Every other month, I look forward to the new issue of the magazine. Here are people who think the same way I do: renewable energy sources should be used in every way imaginable. We need to live in harmony with Mother Nature and not use our resources faster than the Earth can create them.

I live in the Texas panhandle. I was originally born and raised in Los Angeles, but I love this area of Texas. The people are among the friendliest I've ever encountered (sometimes too friendly for this boy from LA!). Unfortunately, their friendliness does not extend into the realm of contemplating renewable energy sources.

The mentality of this area is similar to most of mid-America: They are fiercely nationalistic. They are skeptical of conservation because they feel it is a threat to their freedom, and therefore to their nationalistic tendencies. They view social programs with disdain primarily because they see such aid as an insult to their own self-sufficiency. I have patients who actually refuse to cash their Social Security checks for this reason.

I love renewable energy. I hate having to fill up my automobile with gasoline, the profits of which support overseas regimes that are unfriendly to the U.S. I hate the fact that we invaded and now occupy a sovereign country for (in my opinion) no other reason than our gluttonous desire for fossil fuels.

A month ago, I decided to do something about this. I wanted to write a letter to our local newspaper, but I knew that if I mentioned "conservation" or "war-for-oil" that I would be ridiculed. I decided to create a letter that I felt would show that renewable energy is in accordance with my neighbors' nationalistic tendencies. In the letter, I mentioned that the panhandle of Texas would be a perfect spot for the construction of wind generators, because of our nearly constant 15 mph wind. I added that farmers in the area could supplement their income at times, like winter, when no other income is being produced. I mentioned that such construction would add jobs and broaden our economy.

I suggested that farmers could grow crops that grow well in this area, like cotton and sunflowers, which would in turn produce biodiesel and decrease our dependence on foreign oil. I pointed out that this would contribute to our self-sufficiency and help our "war on terror." I ended the letter with the observation that "The Constitution of the United States says that one of the reasons for government is to '...secure the blessings of liberty for ourselves and our posterity.' Liberty, by definition, can never be obtained as long as we are dependent on others for our prosperity."

After the letter was published, I heard nothing but praise for it. I touched a chord in these people who are right wing conservatives. It made me think much more about renewable energy, and why it is not embraced as much as I (and we) would like it to be in this country. We have marketed it as clean energy, sustainable energy, etc. All of that is true, but as I have experienced, most people do not care about this. My suggestion is simple: *Market renewable energy in a way that people will listen.*

We are still in a wave of patriotism in this country that we probably won't see for another generation. Let's use this to our advantage. We need to make it very clear that every time we use the air conditioning when we are not at home, fill the tank in a car, or purchase an automobile that gets poor gas mileage, that we are, in part, fueling terrorism. We need to draw a parallel between gasoline use and funding terrorism. We need to show that terrorism is threatening our freedom. We need to show that we can cut our inadvertent funding of terrorism by becoming self-sufficient.

I am writing this hoping that I can target the manufacturers, distributors, and dealers of renewable energy equipment. To expand your market, you need to market to people who would not normally buy your products. You need to show that renewable energy encourages freedom. You need to show that renewable energy creates jobs. You need to demonstrate that wind generator produced electricity is actually cheaper than natural gas generated electricity. The farm lobby needs to try to get laws passed that mandate that all diesel fuel sold in the U.S. be of a biodiesel blend of at least 5 percent. This would greatly expand a very small industry and add hundreds, perhaps thousands of jobs. That's right, we can actually create jobs at a time when our president is bleeding 60,000+ jobs per month from the country.

When you get resistance, just wrap yourself in the flag and demonstrate that any intolerance of renewable energy ideas is un-American and unpatriotic. Even the most conservative individuals listen to this.

Another thing that I learned by getting my letter published was that many people will not easily change their minds. However, if you show that your new ideas are in accordance with their ideals (nationalism, self-sufficiency, and keeping costs down), they will stop being roadblocks to progress. Some might even become allies. Lee Shuwarger, O.D., Canyon, Texas • 806-655-0835 • leeshu@amaonline .com

Recycling CFLs

Regarding the letter from Sue Drouillard and Michael Welch's response in *HP96* (CFL Questions) concerning mercury in CFLs: I just noticed that IKEA, the Sweden-based multinational home furnishings retailer, not only promotes and sells CFLs and lamps that accept them, but also takes old CFLs back for recycling. It's great to see a big chain embrace the "cradle to grave" concept for something they sell. Maybe some other retailers will follow this lead.

Hats off to Sears too. I just purchased a front-loading washer from them. Their best model (42072/4 with "Ecowash cycle") was far more efficient than anything else I could find locally here on Vancouver Island, and it is a great machine. A few years ago, we also purchased from them a high efficiency refrigerator that used non-CFC refrigerant.

This was at a time when most corporations were dragging their feet about bringing in the new refrigerant. Thanks for the great mag. Jim Palmer, Courtenay, BC, Canada • palmerj@island.net

Look at Your Appliances

Fantastic magazine! I read it cover to cover in about four days. I was reading about phantom loads and recalled measuring the crankcase heater in a central air conditioner that I recently replaced. It was 50 watts—1.2 KWH per day, 438 KWH per year, or about US$60 at US$0.14 per KWH. Then I measured a 1972 air conditioner that uses a capacitor to keep the compressor windings warm. It was 2.2 amps at 241 volts! This is 530 watts, and an astounding 12.725 KWH per day, or 4,644 KWH per year. At our local rate of US$0.14 per KWH, this is US$650 per year! It is very common to use this sort of system to keep the compressor warm; crankcase heaters are much less common.

I installed a replacement unit that uses 7.5 amps (1,807 W) to run the air conditioning system, and no phantom load. The old unit was 12.3 amps (2,965 W) when running. This is a 60 percent savings in electricity. I recommend only 12 SEER (seasonal energy efficiency ratio) or higher efficiency units to all of my customers now. This will save them 20 percent in electrical cost compared to the least efficient unit sold today. If the customer lives in an extreme site, then 14 SEER and 16 SEER units are available to save another 40 percent on the electricity bill.

Also, look carefully at your refrigerator and second freezer. How much are they costing you? One person wanted me to repair a deep freeze that they inherited from a relative. I said I would have to wait until summer was over, and when I inquired later, they said, "I threw it in the trash and my electric bill went down $35 per month!" Think about it—does your second freezer really save you US$100 per year that it costs you to run a new Energy Star efficient freezer? If it is a 12-year-old unit, it might cost you over US$300 a year to run it! Fred Golden, Garden Grove, California • cfgolden@pacbell.net

Older Hot Water System

I have a solar thermal system that is approximately 20 years old. It is an antifreeze, closed-loop system with heat exchangers for my swimming pool, hot water, and forced-air furnace. I frequently see applications for swimming pools and hot water, but I'm wondering why I never see information for space heating using this type of system. I'd like to add on to my current system to include a second furnace, but cannot find a source for fluid to air heat exchangers that would fit into a furnace plenum. I'd like to see what people are doing for solar space heating in a future *Home Power*. prazak@aol.com

Hi, Quite a few systems like yours are still in operation today, but they are not as popular as they were twenty years ago. The reason you don't see more space heating systems like this is that there are more efficient options in many situations. Every heat exchange is a loss of efficiency. When the glycol solution heat is exchanged to the tank water, then the tank water heat is exchanged to the immersed furnace coil, and then exchanged in the finned coil liquid to air heat exchanger in the duct… Well, it works fine, but you must have a tank full of water that is 110 to 120°F minimum.

Compare this to a radiant floor system or air collector system that can operate effectively below 100°F, and the advantage is significant. You will find mention of this "bulk storage" (large water storage tank) type space heating system in the solar drainback installation article in this issue. Drainback systems were more popular for bulk storage systems because there is one less heat exchange, since the large tank is also the drainback reservoir. You will be seeing more solar space heating articles in the future.

Solar contractors and HVAC contractors use finned coil, liquid-to-air heat exchangers on a regular basis. One common type used in air conditioning is called an "A" coil because of its shape. You may have to wait a while (manufacturing delay) for a finned coil that will fit your duct exactly, but if you modify an existing coil slightly, you should be able to find one on the shelf. Chuck Marken • chuck@aaasolar.com

Diesel Doubts

I just received my first copy of *Home Power*, and was generally very pleased with your fine magazine. I did become concerned, however, with your article "It's Your Choice: Alternative Fuels." In particular, you talk about the fuel characteristics, including the environmental emissions. It is noted that these emissions are compared to typical gas car emissions, but I believe that the biodiesel or vegetable oil emissions must be compared to a petroleum diesel car at best. Diesel emissions are much more dangerous than gas emissions, and their danger lies in the combination of toxics and ultra-fine particle emissions. This cannot be measured by measuring total particulate matter, carbon monoxide, hydrocarbons, or oxides of nitrogen.

I would strongly urge no one to use a diesel vehicle for transportation, and strongly encourage those interested in clean air and healthy living to do a lot more research into the toxicity of these diesel emissions. The fact that biodiesel is an alternative does not make it good for people or the environment. I hope people can focus on more positive alternatives. Mark Miller, Plenty Belize • plentybz@btl.net

Hi Mark, First, you are correct about the table. The other fuels are compared to gasoline, but the biodiesel emissions are compared to petroleum diesel. This was misleading in the source material, and the error was repeated in the article. My apologies.

Second, you are concerned about the dangers of ultra-fine particles absorbing toxins from the atmosphere (including the exhaust of other vehicles around you) and carrying them deep into the lungs. This is a serious problem with petroleum diesel, but not many studies on it are readily available. I was able to locate one study that directly compares ultra-fine particles from petroleum diesel with biodiesel. This study found that these dangerous particles account for 44 percent of the total particulate emissions from petroleum diesel, but only 2 percent of the particulates from biodiesel. Since overall particulates are also greatly reduced by biodiesel, the difference in actual particle count would be even *greater. The study was done on rapeseed oil biodiesel, so more study should be done on biodiesel from other sources, but the initial results are highly encouraging. The full study can be found at www.chemsoc.org/networks/learnnet/green/docs/biodiesel.pdf*

Finally, I'd like to add that so far, we have not found any single perfect fuel. All of them have strong and weak points. Each user must first look at practicality: what is available, affordable, and able to do the job required. Then the user must sort his or her own priorities: carcinogens, greenhouse gases, ozone depletion, renewableness, petroleum independence, or other issues. This is why we need to have many alternatives available, so users can choose the best option for their own needs. Shari Prange • electro@cruzio.com

More Efficiency Coverage

Great magazine! I can't think of anything I don't like. The do-it-yourself, hands-on flavor is by far the most important aspect of your magazine for me. Please don't ever change that. Also the articles on safety, such as John Wiles' column, are important.

I'd like to see even more coverage of energy efficient appliances, both large and small. For example, what is the best dishwasher (besides me) out there? Are there any in which the electric hot water heater can be turned off? Does anyone make a gas clothes dryer that doesn't use a glow bar (either pilot or electric ignition)? How about more trivial things like a VCR that won't lose its time and programming when unplugged?

I'm also interested in a fuel cell powered car and making my own hydrogen for it, but that is not in my immediate future. But I do appreciate and enjoy your coverage of that. Also I wanted to say that the work you do is *so* important. Keep up the good work! Thanks! Paul Johnson • pauljohnson@crosswinds.net

CFL Problems

I'd like to respond to a comment in *HP96* in the Solar Decathlon article. I think that several factors may help explain the "continued use of incandescent lightbulbs for most residential lighting in America."

1. Start time. When you enter a room, you need light. When the switch is flipped, the light should be close to full brightness.
2. Light quality. The warm tones of incandescent are what the public expects and will compare CFLs to. Many CFLs have harsh tones by comparison and will be judged unacceptable.
3. Noise. Lights should be seen and not heard. Four CFLs make our bathroom sound like a beehive.
4. Packaging. (or the pig-in-a-poke problem) Packaging should indicate color in a comparative way that the public can easily understand. It should also clearly and obviously indicate if a bulb is "quick start" (and the startup time), and whether it is dimmable or not. Good, informative packaging will help eliminate customer frustration.
5. Cost. CFLs still cost more to buy. (The only dimmable CF flood I've found costs over US$20, plus US$7 for shipping.)

I have had negative experiences in each of these categories. Perhaps there are resources out there that would help, but I have missed them, and I imagine the average consumer has also. Keep in mind that the average consumer will not approach issues like these from the perspective that energy conservation is worth sacrifices like loud buzzing or harsh light tones. Solve the issues, and America's residential lighting won't be an "embarrassment." Steve Welch • swelch@paonline.com

Hi Steve, The last 14 W spiral CFLs I bought at Home Depot were US$2 each, have a warm pleasant color, start instantly, and do not make noise. I have used CFLs for the last ten years, both on and off-grid, and the problems you cite have not bothered me for the most part. Slow startup is an issue with some CFLs, but instant-on models are commonly available. I have never personally had a CFL that buzzed on sine wave electricity, although many do so on modified sine wave inverters.

The light quality of the new CFLs is much better than a few years ago. Last time I tried to buy a cold white CFL, I was confounded by only being able to find warm yellow ones. I actually don't like the color of regular 120 VAC incandescent bulbs, since I am used to the bright white light of 12 V halogen bulbs. I am also continually annoyed by the tendency of incandescent lightbulbs to burn things near them by the time you get a high enough wattage to give decent light. The cost is still high for anything but the standard spiral 14 to 25 watt CFL bulbs, but it's still worth it for the life cycle savings, even when operated from the utility grid instead of solar electricity.

However, most Americans don't care what my experience has been, nor should they. The incandescent lightbulb has become the standard by which everything else will be judged, and to make inroads, CFLs must be of similar quality. Aside from getting people to realize that the first cost of a CFL will pay back in energy savings in a year or so, I believe that your #4 comment is the crux of the problem—the average consumer cannot tell the good CFL from some of the not so good ones. This is analogous to having a choice between a Honda Civic or a Yugo—and the salesman won't tell us which is which.

A partial answer is to look for Energy Star certified CFLs. They must have a startup time less than 1 second, an electronic ballast (these are less likely to buzz or flicker than magnetic ballasts, and are more efficient), a color temperature between 2700K and 3000K (incandescent bulbs are about 2700K, cold fluorescent tubes are between 4500K and 6500K), and a color rendering index of at least 0.8 (incandescent bulbs are about 0.9, sunlight is defined as 1, old fluorescent tubes were from 0.4 to 0.7). They must also clearly state whether they are dimmable or not (and I guess the 2 mm high writing on the side of mine qualifies as "clearly"). The Energy Star Web site at www.energystar.gov/index.cfm?c=cfls.pr_cfls gives info on CFL bulbs, including a list of all Energy Star compliant ones.

I agree with you that while substandard bulbs are still in the market, or even while people remember the bad CFL they bought a few years ago, better labeling of CFLs is necessary. Things are *improving (all lightbulbs now include info on lumen output), but we still have a ways to go. Zeke Yewdall • yewdall@colorado.edu*

Efficiency Works

We have been interested in energy conservation more and more through the years—then we had the big energy shortage here in the West. My family decided it was time to really get serious about saving energy. Three years ago, we quit using our electric dryer altogether. We had dried clothes on our solar dryer (clothes line) in good weather for several years. We live on the wet side of Washington State, so drying clothes without a dryer year-round can be a bit of a challenge. We use our wood stove to heat our home and cook on during winter, so it was a logical next step to dry our clothes on a rack near the stove. It takes a bit of planning ahead, but it works well for us. Laundry is done in cold water for the most part. We bought a water heater timer (US$40) and installed in spite of some people saying that it would cost more in the long run. We have it run the water heater for two hours each day just before dawn. We have fluorescent lights in all the places where they work well.

All our work paid off when the utility came and changed our meter. They said that it had obviously become slow and needed to be replaced with a new one that would register all the energy they thought we were using. They said the same thing the next month when our bill was still low. They seemed puzzled when we reminded them that the meter had just been replaced the previous month. Our usage has remained low, although it has gone up some due to our teenage daughter's love for long hot showers and cooking with electricity during the summer (when we don't use our barbecue).

Our bill runs between US$40 and US$50 each month all year. It has been as low as US$35. Our monthly electricity usage has gone from nearly 1,500 KWH per month to 500 KWH or less. We do not have gas or other energy coming into our home—it's an all electric "good-cents" home built about 35 years ago. We hope to have a solar water heater in the near future. We have been pleasantly surprised at how a few changes and no large investments saved so much energy. kworkwoman@juno.com

Inevitable Energy

It's nice to see information about the use of solar electricity. The general public actually knows very little about this amazing technology. Your magazine is very informative and helpful to those who have an interest in this energy source. The destructive energy sources that exist now are taken for granted by those who have a lack of information about their destructive side effects. It amazes me just how much people do not know or chose not to think about the negative aspects of energy production as it exists today.

The term alternative energy (referring to solar electricity) should be changed to inevitable energy. Otherwise, our future will surely suffer from the negative side effects of energy production that are causing a worldwide series of problems. These are not little problems, folks—this is now a global problem, and it's time to take a look around! Your magazine helps get the word out and it makes us solar energy loners realize that we are not so alone in our quest for clean energy and self-reliance!

I have used solar electricity now for thirteen years, and cannot even imagine going back to the old unlearned ways that offer only temporary convenience before they harm our world more. It's time to look around and notice the problems that we are creating for future generations of your children. Imagine if we each had a pollution-producing generator in our home, and the toxic, life-threatening gases were filling the home for this convenience of electricity—would it be worth it? Well, it is only a matter of time before the world's atmosphere fills up with these toxins—it is only a bigger space than your home. Not really complicated, huh?

I think that if your magazine would help spread the word about the nuclear threat and coal pollution that this would be the ultimate endeavor to educate people, and bring about thought as to what we are really doing to ourselves. Perhaps just getting people to actually think about the advantages of solar energy is a giant step, but somebody has to do it, so keep up the good work, *Home Power*! Oh yeah, I am writing this letter from my solar powered computer in my solar powered home and would like to express the pride of owning a system that I built. I am also proud to *not* be contributing to the worldwide pollution problem. The Humble Hermit • doug@tcip.net

Have Phone System to Donate

First I would like to say thanks for a great magazine. My wife and I have lived off-grid for about five years and love it. We have learned so much from *HP*.

I work for a small independent telephone company; we provide dial tone to 98 percent of our 175 customers through a wireless local loop system called DIVA. We are in the process of upgrading to another wireless system and phasing DIVA out by the end of 2003. DIVA is no longer being manufactured, and the company is out of business.

We would entertain the idea of giving this system to say, a party in a third world country that has no working phone system. DIVA is a voice only system, which means that you cannot transfer data, (fax or Internet) over it, but the voice quality is good. The majority of our customers are off-grid, so we power the equipment at the customer's home with a 32 watt solar-electric panel and a sealed 100 amp-hour battery. The solar-electric equipment would not go with the DIVA system. One thing to keep in mind is that there needs to be a way to access dial tone wherever the radio switch controller (RSC) equipment is installed. Interested parties may contact Andy or Rich at sptele@chaffee.net

Evaluating Batteries

Hello to all you good folks in the NW, I have come into possession of a pile of salvaged batteries from our local electrical utility company, and have no idea of their condition. They are YUASA sealed gel cells, 17 AH, approximately 7 by 7 by 3 inches, and weigh 14 pounds apiece. I have 108 of them and was wondering how to go about a large-scale evaluation on them to determine their individual usefulness. Any advice you could provide would be greatly appreciated. Thanks in advance for your help. Rob Klipper, San Antonio, Texas • klipper@uthscsa.edu

Hello Rob, There is really only one way to determine if a battery is in good health—charge each one up and then discharge it while measuring the number of ampere-hours it contained. This must be done to each battery individually—lots of work. Richard Perez • richard.perez@homepower.com

Synchronous/Asynchronous

I would like to comment on the hydro article that appeared in *HP96.* There is a sidebar about induction generation on page 19. In this the author is confused about the terminology. An induction generator is an asynchronous machine. A synchronous machine is one that is self-excited and is what is normally called a "generator." It runs in exact "synchronization" with the utility grid. An induction generator must run slightly faster than the grid frequency/speed. This is the case so that current can be "induced" in the rotor of the machine and create an opposing magnetic field to the one the grid supplied, and in this way generate electricity. This difference in speed is called "slip."

A synchronous generator does not require any inverter or batteries to operate as a stand-alone system. All it needs is an electronic governor to properly load the generator. The same could be done with the induction machine. It would require capacitors to provide excitation, and a different type of controller, but this is commonly done. Paul Cunningham, Energy Systems & Design • hydropow@nbnet.nb.ca

Thin Film?

Hi Richard, I attended your Successful Solar Businesses seminar this spring and now have my Oregon contractor's license and a new career at 58! My motto is: "Energy Independence for our Freedom!" (both personal and national). I have some good prospects for installing grid-tied PV panels this summer as well as solar hot water panels. Local plumbers and electricians have expressed willingness to subcontract the installation procedures that require a professional license.

A question has come up regarding thin film solar-electric modules. My impression from dealer conferences is that most dealer-installers steer away from it, that some major manufacturers are getting out of the business, but that D.O.E is still promoting it. What is your opinion on the risks or advantages of installing thin film PV? Your reader and grateful fan, Al Walker, Energy Independence Co.

Hello Al, The biggest promise held by thin-film PV is much lower cost. Until thin-film PV realizes this promise, it's unlikely that it will gain acceptance in the marketplace. Technically, the issue is longevity. Conventional crystalline modules have demonstrated long lifetimes, but thin-films need decades in the sun to prove their staying power. Until this happens, most dealers will install the proven technologies since thin-films now cost about the same as conventional modules. Richard Perez • richard.perez@homepower.com

Helping the Planet

I began subscribing with *HP1*. I continue to marvel at the many, positive changes that have taken place in only a few short years. Going from a black and white magazine, starting out on paper that turned yellow with the first hint of direct sunlight, to a prestigious, bright, wonderfully appointed, internationally acclaimed journal is testament to the deep, binding dedication of the founding crew delivering an idea that has been literally devoured by a growing, like-minded readership. Clearly from reader input and author contributions, *HP* has directly/indirectly affected many lives and will continue to do so. *HP* could as easily stand for "helping the planet." Best to you, Harry Rakfeldt, *HP6, HP69* • www.syn-lubes.com

Thanks for your kind words, Harry. It's a reminder to us that our work is valuable, but also that our work is totally dependent on contributions from readers like you. We're looking forward to your next article submission, and I encourage others who are walking the talk to send us their stories. Ian Woofenden • ian.woofenden@homepower.com

Captivating Content

Above all else, I like the format of your magazine—the way articles are not split up into different sections of the magazine, and the wonderfully large page numbers on every single page regardless of whether or not there is advertising on that part of the page.

The content is quite captivating most of the time. I like how all of the articles that I have come across tell you what happened in a general sense and then include all of the nitty-gritty details for people interested, to glean all of the knowledge and experience gained from the writers' accomplishments and mistakes. I also like most of the small how-to articles on different sorts of things—the things that don't take a large cash outlay to try.

Since I am connected to the grid, I would also like to know about more of the best off-the-shelf products that we can buy, especially in the area of appliances that use less energy without going without most of the modern day conveniences. strawdog@telus.net

RE Foundation

I want to share a vision with *HP* readers, since I am not necessarily the best qualified to see this through. The vision is to establish a foundation with the mission of purchasing and installing sustainable energy generating capacity, to be leased to folks who sell electricity. This idea came as a revelation after years of living with an apparently insolvable question—rather Zen-like!

We have a new "run of the river," very low impact hydroelectric system that my husband, Peter Fox Sipp, is this month filing with the U.S. patent office. The initial construction costs for this (not necessarily small) energy source would make it prohibitive for the average consumer to buy. My question: Who is my customer?

The "answer" of a foundation came one day when my husband said that he *had* to find his copy of a biography of Henry J. Kaiser. I watch closely when Pete is in such a state; magic usually follows! When he found the book, we read aloud about how Kaiser started out—how he built roads, dams, and later ships. Kaiser had workforces in the tens of thousands, and he had to keep the workers healthy. Dr. Sydney Garfield developed the original "HMO" for Kaiser. Reading about Garfield and Kaiser taking this healthcare system to the public after WW II gave me a burst of clairvoyance!

Garfield & Kaiser went to borrow funds to build a new hospital. The banker laughed, declaring that he'd never lend a penny for a hospital. Garfield's efficient system would likely have paid the loan, but being turned down, Kaiser established a foundation that built the Kaiser Permanente hospitals, and then leased them to the Kaiser health plans.

In a flash of association, I saw that sustainable energy generating capacity is very much like the hospitals in this equation, only to heal our society and Earth instead of individual patients. Born was the idea of a foundation that provides the vehicle for philanthropic support to purchase and install sustainable energy generating capacity (in environmentally sound and optimal conditions), and then lease the capacity to electricity producers—such as merchant operators, public utilities, electric co-ops, or even large energy corporations. Corporations that won't use capital to buy these systems may, nonetheless, be happy to operate capacity installed with foundation funds. The leases would pay to install more capacity. The foundation would be a nonprofit with support from sources committed to a sustainable future. The costs could be carried over the projected (long) life of the systems, while the leases allow electricity generated to be sold in the market at competitive rates.

Long-term, the market price for these generating systems may come down; short term, more people will learn that sustainable energy is reliable, and that it creates healthy jobs as well as improving our environment. With homage to Henry J. Kaiser and appreciation for Pete's inspiration, I invite anyone who is interested in developing this concept to be in touch! Mary Fox Olson, PO Box 7586, Asheville, NC 28802 • 828-678-3583

Troubleshooting

Richard Perez

Let's face it, things break. They fail, they malfunction, and they quit working. If you installed your own renewable energy system, the person who needs to troubleshoot and fix whatever breaks is you. Here are some observations about finding out what went wrong—troubleshooting.

Troubleshooting is more of an art than a science. It is a process of identifying exactly which component or components in a device failed. While the techniques used to troubleshoot electrical equipment are different than those used to troubleshoot mechanical gear, the process is the same—identifying what went wrong and is causing the malfunction.

Troubleshooting Heritage

I began learning how to troubleshoot in my early teens. My father, a career Air Force officer, was director of maintenance for the Strategic Air Command's 100th Bomb Wing at Pease AFB in Portsmouth, New Hampshire. To say that he was into troubleshooting and maintenance would be a huge understatement. He had established a well-equipped home shop in our basement and encouraged me to use it to build and fix things. By the time I was old enough to have a driver's license, I was doing all the troubleshooting and maintenance on our vehicles and home appliances. I learned how to troubleshoot from an expert—my father. This skill served me very well in later life.

In the early 1980s and before getting into publishing *Home Power*, I spent three years operating and maintaining a 100 KW television transmitter for the local CBS TV station. This ancient beast was made by General Electric in 1953, and contained more than 600 vacuum tubes. It was always breaking, and it was my job to find out what was wrong and fix it. This antiquated TV transmitter honed the troubleshooting skills my father had taught me to a razor's edge.

Since then, I have been applying these troubleshooting skills to our home power system. While the PV/wind system we have lived with for decades is very reliable, things still do occasionally break. And when they break, it's a long way to town for either parts or expert advice. So I've learned to do what most home-powered folks do—fix it myself.

Attitude

Troubleshooting is a mental activity, and begins long before applying a wrench to the piece of equipment. It is largely a matter of attitude—you are either your own best friend or your own worst enemy. Here is a list of positive mental attitudes that can make you an effective troubleshooter, and a list of negative mental attitudes that will render you utterly dependent on outside help.

Positive Attitudes:
- Assuming nothing
- Thoroughness
- Patience
- Self-confidence

Negative Attitudes:
- Making assumptions
- Skipping steps
- Impatience
- Self-doubt

Mechanical Example

Perhaps the best way to illustrate these attitudes in practice is to tell you about my latest troubleshooting experience. While this experience concerns a mechanical device, not an electrical one, the art of troubleshooting is the same.

Two weeks ago, our back-up engine generator wouldn't start. This Honda ES6500 is about eight years old and has only 1,280 hours on it. It has needed repairs in the past, requiring two trips to the Honda shop downtown. Once was for a leaky rear main engine oil seal that had dried out due to disuse, and the second was for an oil pump replacement.

The dried out oil seal taught me to start the generator at least once a month to prevent the seals from failing. And so, even though it was July and the sun was providing more than enough electricity for us, I tried to start the generator.

When I turned on the engine's electric starter, all that happened was that the engine turned partly over once, followed by a clicking sound. What was wrong? I immediately thought that the engine starting battery was dead. A quick check with a digital voltmeter showed that while the battery was low in voltage (12.22 VDC under no load), it was far from dead.

Richard, ready to shoot trouble.

To check the battery's voltage, I had to remove the rubber protective cap over the battery's positive pole. There I discovered that the positive terminal had been corroded by acid schmaze (my word for a smeared haze of acid), and was not making good contact with the positive cable.

After cleaning the positive terminal and the cable's connector, I tried to start the engine again. All that resulted was a clicking sound and the engine wouldn't turn over at all. I connected the engine starting battery to the huge battery in our 12 VDC PV system and allowed it to be fully recharged. Then I went into the house for a cup of coffee and some hard reflection.

I was in the grip of the most common negative troubleshooting attitude. Often when a device fails, it is assumed that the least understood, most difficult to fix, and most expensive part of the device is the problem. I thought that the engine had a major mechanical problem, that it had dropped a connecting rod or valve, and that it was hard frozen. I had succumbed to self-doubt and jumped to a paranoid conclusion—that the part I understood the least and couldn't fix was the problem.

As the coffee cleared my brain, I reminded myself of the troubleshooting lessons my father had taught me. I chided myself for skipping steps—this time by assuming that something (anything, any component) is working properly, so it's unnecessary to check it. I reminded myself that most failures are caused by simple, obvious things. I realized that I hadn't really thought the problem through, that I had assumed the worst. I gathered up my self-confidence and returned to the generator.

This particular generator has a common main shaft for the engine and the alternator. I removed the cover plate from the back of the alternator and gained access to a huge nut at the end of the main shaft. Holding my breath, I put a socket wrench on the main shaft and tried to turn it. It rotated, and with immense relief flooding me, I realized that the main shaft wasn't frozen, and that the engine probably had no major problems.

All that had happened was that the starter's dogs had jammed on the flywheel. Normally, the rotation of the starter would be able to overcome the friction of the dogs on the flywheel. But the low battery voltage caused by the bad positive cable connection wouldn't spin the starter with enough strength. I figured I was home free and patted myself on the back—I'd get this generator started yet.

As I was getting ready to give it another try, I noticed that fuel was dripping from the carburetor—bad sign. I was mystified. What had this fuel leak to do with the bad battery connection and stuck starter dogs? I turned off the fuel petcock and allowed the spilled fuel to evaporate before even considering starting the engine. I returned to the house for another cup of coffee and more reflection.

A Combination of Problems

As I sipped more caffeine, I reminded myself that when equipment fails, it is often a "combination of ingredients" problem. Sometimes the failure of one component will cause another to also fail, and sometimes a piece of gear will have two or more unrelated problems. I decided that the carburetor leakage problem was unrelated to the starting problem, and returned to the generator to examine the carburetor.

I noticed that the carburetor had two small-diameter, rubber venting tubes attached to it. These tubes were about a foot long and ran from the carburetor to the bottom of the generator where they vented, open-ended, to the outside air. I wondered if the carb was leaking due to interior pressure build-up, and decided to examine these tubes. I discovered that mud dauber wasps had built a cozy home for their larvae in each of the tubes.

A quick run-through of both tubes with a short piece of stiff wire cleared the larvae and their mud packing. I turned on the fuel petcock and was gratified to see that fuel was no longer leaking from the carburetor. I was now ready to try to start the generator.

I hit the starter switch and held my breath. The freed starter dogs engaged the flywheel and the engine turned over. It immediately roared to life and I whispered a prayer of thanks to my father's ghost.

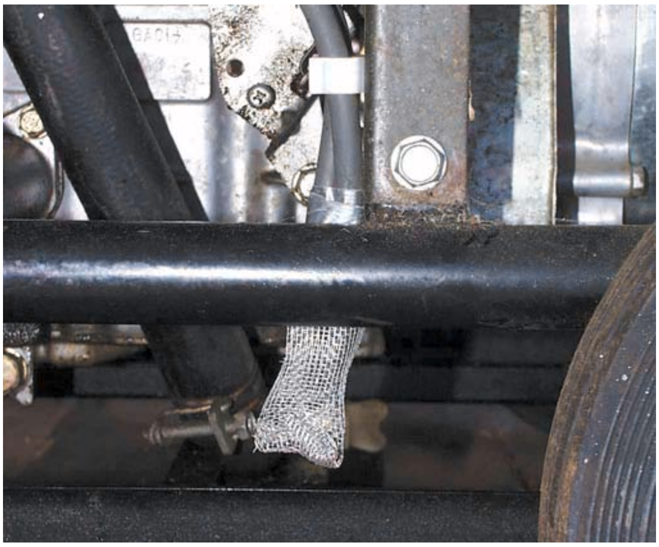
By applying his lessons in troubleshooting, I had avoided having to manhandle the 350-plus pound generator into the truck, spending two hours hauling it to town, and paying for the Honda mechanic to fix what was, after all, a simple combination of problems.

Shoot the Trouble

The art of troubleshooting is not difficult. It just demands a good attitude and observance to procedure. Assume nothing. Check the obvious things first and skip none of them. In my experience, fully 80 percent of the problems, especially in electrical gear, are simple-to-fix things such as mechanical connections.

Give the problem device a good and thorough visual inspection. Better than half of the problems that I have found and fixed revealed themselves upon close visual inspection. Have confidence in yourself—you can find the

A screen deters mud dauber wasps.



problem with patient and thorough investigation. Don't succumb to the paranoid fear that the problem is something that you don't understand and can't fix. Give it a try. If you don't succeed, you can always have an expert fix it.

Troubleshooting is made far easier if you are familiar with your equipment. Don't be a hands-off user! Regularly observe your gear and how it's working. The more familiar you are with how things normally work, the better you will be able to recognize what is wrong when things go wrong. Familiarity with your system will enable you to notice when devices are beginning to operate poorly and catch problems before they become outright, and possibly expensive, failures.

Finally, do your maintenance. Maintaining equipment not only keeps it running well, but it gives you the experience and confidence to troubleshoot that gear when it breaks. Let your troubleshooting experience add to your scheduled maintenance. For example, I will now keep a closer eye on the terminals of the engine's starting battery and keep them free of corrosion. And the venting tubes on that engine's carburetor are now swathed in a bulb of fine metal screen—mud dauber wasps will have to look elsewhere for a home for their larvae.

Installing an RE system and making your own electricity is an exercise in independence and self-reliance. Doing your own troubleshooting and maintenance makes you even more independent and self-reliant. Give it a shot!

Access

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DC Fan Speed Control

Homebrew Hot Water Collectors

Hi Folks, I am looking into homebrewing collectors for domestic hot water here on Vancouver Island, BC, Canada. Shipping large items, especially across the border, is quite expensive. I have a few questions I hope you can shed some light on. Most of these questions revolve around "more area vs. more efficiency."

1. Low-iron glass seems to be widely used. Here it is very expensive and hard to get. If the purpose is to increase output, why not use standard tempered glass and increase area?
2. Heat loss limits efficiency. What about using regular glass and increasing insulation and adding reflective foil insulation? Which is more effective on radiant heat loss?
3. What about reducing radiant losses by using low-e glass, which is readily available (reflective coating facing in)? One glazing layer or two?
4. Any other glazing suggestions?
5. On the absorber plate, is there that big a difference between painted and selective coated surfaces? What about chemically etching the surface?

Thanks for your ideas and your contributions to a great and inspiring magazine. Jim Palmer • palmerj@island.net

Hi Jim, Good questions. You can build a fine collector using regular tempered glass and a black painted absorber. Under optimal test conditions, a selective-surface-absorber collector with low-iron glass can have efficiencies of about 70 percent. Both of these features increase performance on the order of about 10 percent, although the selective surface has a wider range of performance variability. A black painted collector with standard tempered glass will have a top end around 50 to 55 percent. You can make up the difference by increasing the square footage of collector surface area. Most manufacturers in Mexico build a regular tempered glass, painted absorber collector because of the supply problems with the more efficient, costlier materials.

Low-e glass (unless improvements have been made) is not a good option because it cuts down on light entering the collector, and this impediment far outweighs any gain. Thanks, Chuck Marken • chuck@aaasolar.com

Ram Pump

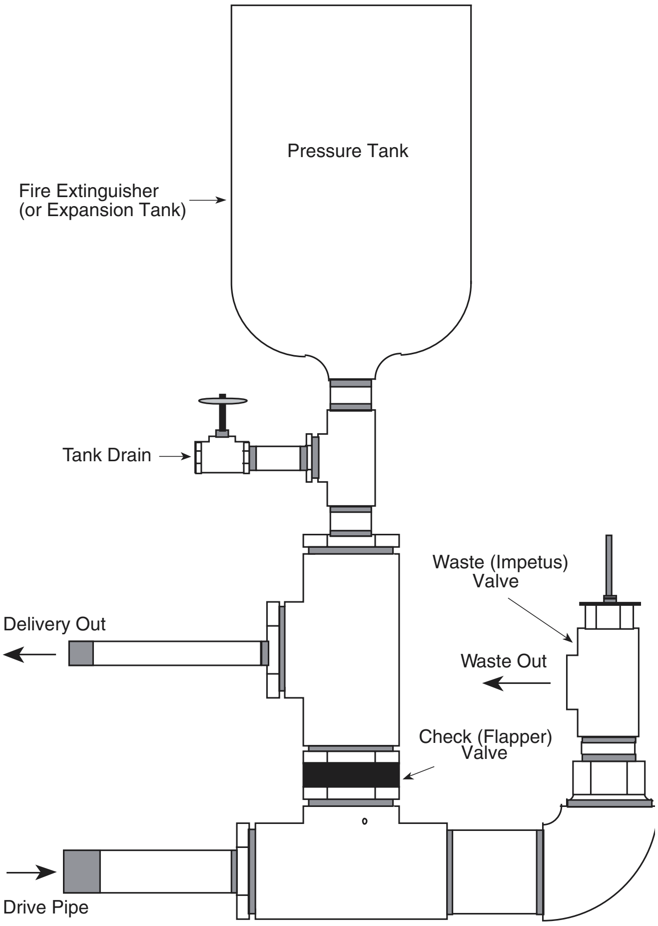
Dear *Home Power,* I live in northeast Scotland. I was very interested in an article you had in your magazine on how to build your own ram pump using basic plumbing fittings and a fire extinguisher (*HP41*). My water supply at present is fed to our house by a #2 Blake Hydram pump, which requires between 2.5 and 5 imperial gallons per minute falling 6 or 7 feet to enable it to pump to a height of 137 feet. This has worked reasonably well until now. The water supply has reduced to 2 imperial gallons per minute and the pump is 50 years old and has seen a lot of wear and tear. I can still manage to get it to pump to around 75 feet.

I endeavored to fabricate my own pump using your detailed instructions. Using the same flow rate and working fall, I got it to pump to a height of just under 60 feet. Do you think that the output I have obtained is reasonable and I'm expecting too much, or have I done something wrong somewhere? The only feature that differs in the pump I put together is that I used an expansion tank rather than a fire extinguisher.

I would appreciate any advice you could offer, since my house is becoming one of the driest places in Scotland. Regards, Ian Black • blackgowanlea@aol.com

Hi Ian, I am really surprised to hear that you can only reach 60 feet with that pump, whereas the Blake was pumping to 137 feet. Actually, I am more surprised that you got that much pumping height from such a low drive head, even with the Blake. It must be a very nice pump.

Something may be amiss with the homebuilt pump. That pump successfully moved water to a height of 150 feet, but also had a drive head of greater than 20 feet at the time. Here are two things to check. First, the design of the waste (impetus) valve leaves much to be desired. If you are using the original design for this, I would not be surprised if it was trying to close a bit crooked since there is not enough of a guide for the stem. That would leave a small gap, and possibly reduce the amount of power the pump has. Also, the flapper valve inside can be a problem. We found that



it would cup into the hole when it closed, losing efficiency. What we did to fix this was to put a large washer (called fender washers in the U.S.) that spanned the entire hole on top of the flapper, with a bolt all the way through, and a washer smaller than the diameter of the valve seat underneath. This increased the efficiency of the unit quite a bit.

It seems to me that the Blake should still be able to pump to the same height, except with fewer gallons per day, when adjusting it down to your lower flow rate from your source. Are you sure nothing else is wrong? Check for:

- *Obstruction of the drive pipe or impetus valve inner area*
- *Corrosion in the drive pipe*
- *Leaks or cracks of the internal valve*
- *Water filling the bell, reducing the effective air chamber to the point that it will not work.*

Michael Welch • michael.welch@homepower.com

Hail

I would like to know if solar panels are strong enough to resist a storm of hail on them. How big does hail have to be to break the glass of a solar panel? I have twelve solar panels, and I am concerned about this issue. Regards, Bruno Soto, Guatemala, Central America • brunols@usa.net

Hello Bruno, There's no need to worry about hail that will be big enough to damage modules in your location. PV modules are designed to resist hail damage from golf-ball sized hail moving at high speeds. Hail damage to modules is very rare. Richard Perez • richard.perez@homepower.com

Summertime Hot Water Loads

Hi there, gang! Keep up the great work on the magazine. I'm working on building a house—a super-efficient house that uses solar energy as much as possible. I'm putting in a hydronic slab heating system, and plan on using a 120 gallon solar tank plus a 35 gallon propane backup water heater. The solar tank will store heated water from seven solar collectors. My problem is that this is going to be way too much summertime hot water. My summertime hot water usage will be primarily a daily shower for two people, and periodic cleaning (dishes, etc.).

I figure that I need to either provide a summertime hot water load, or reduce the amount of solar hot water produced during the summer. The only idea that I have for a load is a swimming pool, and I have no ideas for how to reduce the output. Thanks, Wayne Sheffield • wayne_sheffield@hotmail.com

Wayne, You have correctly identified the problem as seasonal imbalances with solar thermal heating systems used for space heating. When sized for wintertime space heating, they are oversized for summer. Two suggestions can help you to deal with that situation: Tilt the collectors to favor the winter months; perhaps a tilt angle equal to your latitude plus 15 or 20 degrees. That will increase winter performance and decrease summer performance.

A well-installed drainback system will have empty collectors when heat is not needed to be collected. This avoids the problem associated with stagnation temperatures damaging the glycol heat transfer fluid used with closed loop anti-freeze systems.

You might also check on your storage requirements. Depending on your climate, you will need to have on the order of 1.5 to 2 gallons of storage per square foot of collector. The radiant floor mass can offset some of that requirement, but it seems that 120 gallons storage is a bit small for seven collectors. Ken Olson • SoL@SoLenergy.org

Greetings Wayne, As Ken mentioned, you can stand the panels up higher than normal to maximize winter gain and reduce it in the summer. This may still not do the trick, and you may need to cover most of them in the summer. I don't know your system design, but I suspect seven panels will have no trouble heating a 120 gallon tank to quite high temps. Some contractors will bury a "ground loop" to dissipate the heat to the earth in the summer. Swimming pools are a good option too and are a lot more fun than a ground loop. Last one in's a rotten egg! Smitty • smitty@aaasolar.com

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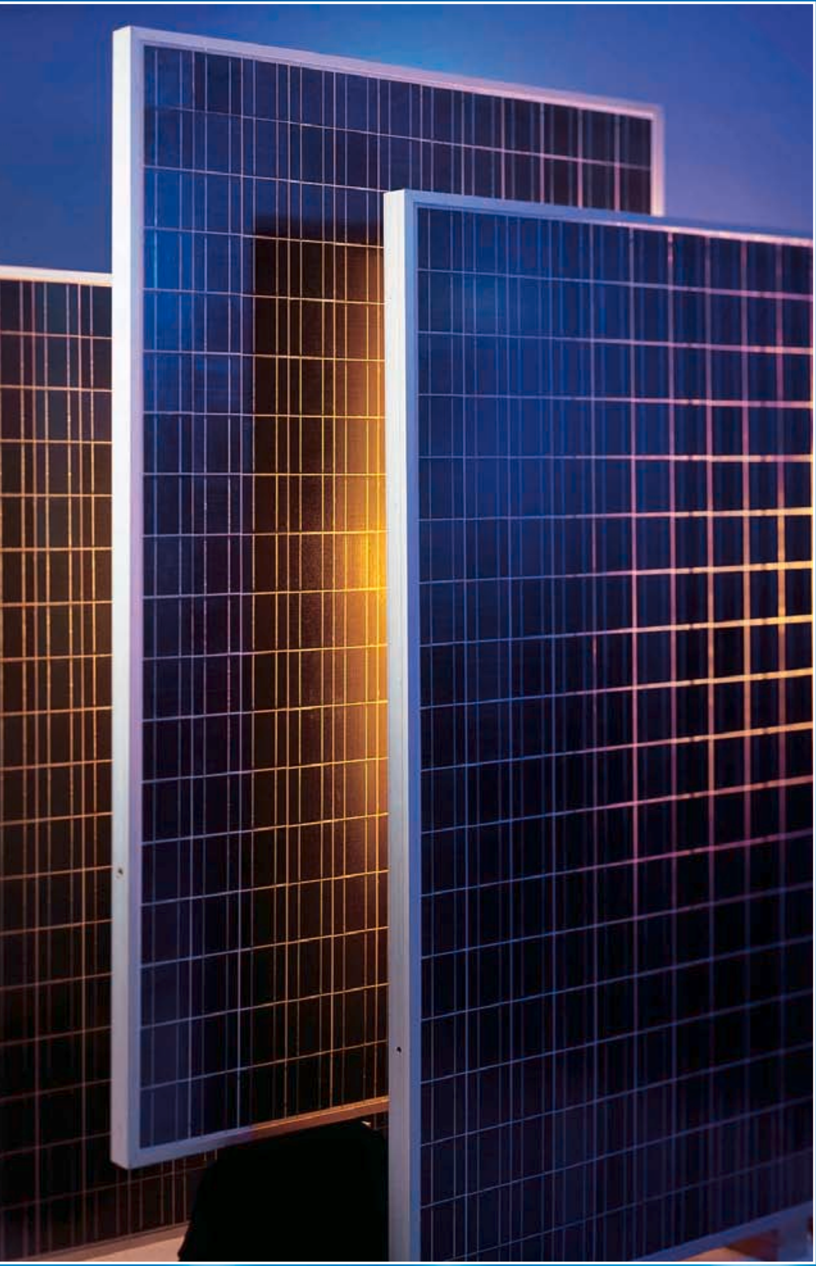

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KC167G ▶

Maximum Output: 167.0 Watt
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Maximum Power Current: 7.2 Amps
Open Circuit Voltage: 28.9Volts
Short-Circuit Current: 8.0 Amps

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The following information about your renewable energy usage helps us produce a magazine to better serve your interests. This information will be held confidential. We do not sell our mailing list. Completion of the rest of this form is not necessary to receive a subscription, but we would greatly appreciate your input.

NOW: I use renewable energy for (check ones that best describe your situation)

- ❑ All electricity
- ❑ Most electricity
- ❑ Some electricity
- ❑ Backup electricity
- ❑ Recreational electricity (RVs, boats, camping)
- ❑ Vacation or second home electricity
- ❑ Transportation power (electric vehicles)
- ❑ Water heating
- ❑ Space heating
- ❑ Business electricity

In The FUTURE: I plan to use renewable energy for (check ones that best describe your situation)

- ❑ All electricity
- ❑ Most electricity
- ❑ Some electricity
- ❑ Backup electricity
- ❑ Recreational electricity (RVs, boats, camping)
- ❑ Vacation or second home electricity
- ❑ Transportation power (electric vehicles)
- ❑ Water heating
- ❑ Space heating
- ❑ Business electricity

RESOURCES: My site(s) have the following renewable energy resources (check all that apply)

- ❑ Solar power
- ❑ Wind power
- ❑ Hydro power
- ❑ Biomass
- ❑ Geothermal power
- ❑ Tidal power
- ❑ Other renewable energy resource (explain)

The GRID: (check all that apply)

❑ I have the utility grid at my location.

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

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

❑ I sell my excess electricity to the grid.

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

(continued on reverse)

I now use, or plan to use in the future, the following renewable energy equipment (check all that apply):

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

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