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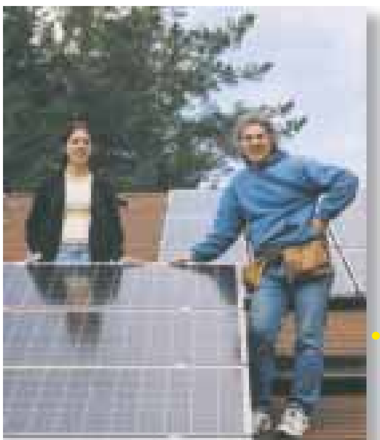
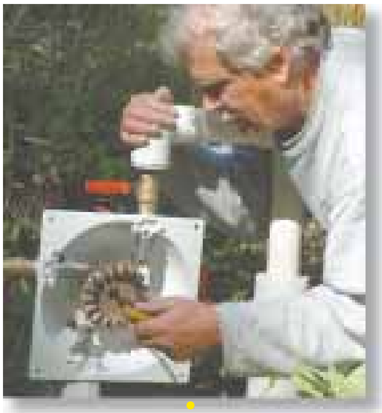


On the Cover

Carol and Steve Moore harvest veggies year-round from their award winning greenhouse.

Photo by Susan Lerner, www.SusanLernerPhoto.com.



Regulars

Build It GREEN

Most of us probably remember the story of the three little pigs. Since early childhood, we have been conditioned to believe that building a house out of straw is sheer folly. While the house built of sticks didn't fare any better in the fable, stick-framed walls nevertheless became the predominant residential building method in the United States. In modern times, the outcome of this fable would be different. A straw bale home is warm and cozy, and keeps out the huffing and puffing of cold winter winds, while reducing environmental impact.

Last fall, I participated in Solar Energy International's (SEI) Solar Home Design online course. Through that course, I learned that modern technology, innovative recycled materials, new methods, revived historic techniques, and local materials have expanded the scope of building comfortable and sustainable homes.

"Green building" encompasses a vast and loosely defined field of methodologies, principles, building materials, and creative structures. What all variations of green building have in common is efficient homes aimed at minimizing environmental impact.

With this issue, we are adding a new focus on green building in *Home Power*. We will be publishing articles covering various aspects of natural construction on a regular basis. We are excited to have this new emphasis shepherded by Rachel Ware, Laurie Stone, and Johnny Weiss from SEI. We think you will find information that will be useful to you, whether you are building a new home or retrofitting an existing structure. May you stay warm and cozy, keeping the wolves of winter away, now and forever after.

-Linda Pinkham for the *Home Power* crew

Think About It

"The scarcest resource is not oil, metals, clean air, capital, labor, or technology. It is our willingness to listen to each other and learn from each other and to seek the truth rather than seek to be right."

– Donella Meadows, (1941–2001), founder of the Sustainability Institute

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Sharp's solar power monitor blends seamlessly with the homeowner's décor. Its backlit LCD screen displays real time and cumulative electricity generation and CO_2 reduction levels.

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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
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- Easy Set-Point Adjustment
- Polarity Checker

Typical Performance: 5.2 kWh DC per day

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Solar Comfort in the Idaho Wilderness

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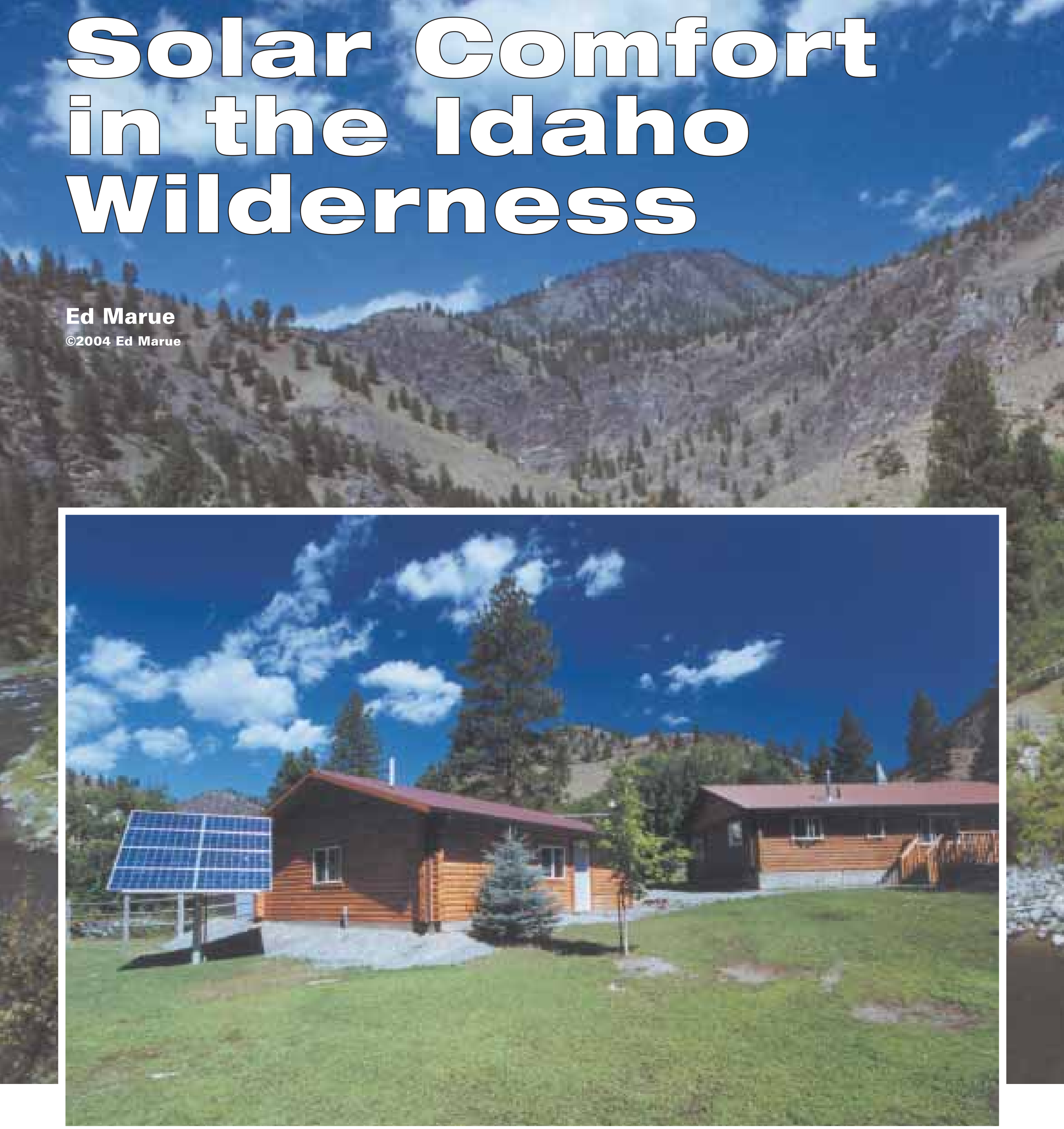
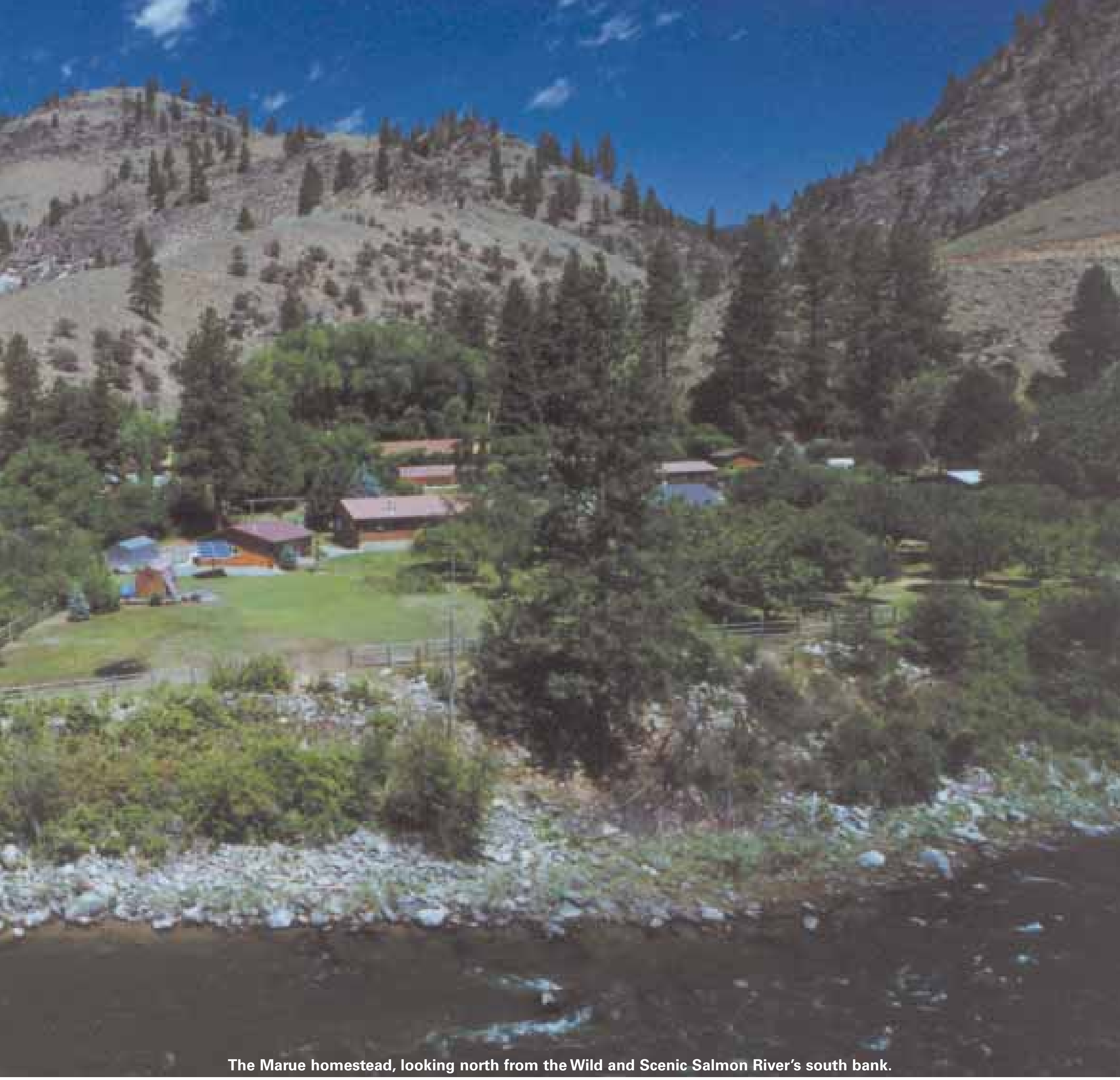


Our first exposure to the wild and scenic Salmon River in remote central Idaho was on an inflatable kayak trip in 1979. My wife Joyce and I have returned nearly every summer to paddle the rivers of Idaho, and in particular our favorite section of the main fork of the Salmon. On the river, being isolated from all forms of contact with the outside world, was the perfect escape from the rigors and pressures of the business world, and the ideal place to refresh the spirit and rejuvenate the mind.



The Marue homestead, looking north from the Wild and Scenic Salmon River's south bank.

Inset (previous page)—a closer look at the homestead's PV array, garage (left), and log home (right).

Perfect Summer Paradise

Shortly after retiring in 2000, I became aware of a small log cabin for sale at Colson Creek, 33 miles (53 km) downriver from the tiny community of North Fork, only 12 miles (19 km) from the end of the road at Corn Creek. I immediately flew from our home in Tucson, Arizona, to check out the property, and called Joyce to report what I had found.

Joyce had only two questions, "Does it have river frontage, and can we afford it?" "Yes and yes, but…" Before I could finish, Joyce interrupted me and said, "Buy it!" We did.

The "but" was that the condition of the 20-year-old cabin was such that you would characterize the place as a real fixer upper. While the log shell and roof were sound, the rest of the inside was trashed. However, that was the perfect opportunity to build our own home around a theme of simple living and less dependence on outside resources.

The electronics and vented battery box are located in the garage.

The site is 33 miles (53 km) and over US$3 million from the utility grid, and with the cabin facing the river running east-west, it had the perfect orientation for a PV system. Abundant water comes from Colson Creek, originating at a small manmade dam about a half-mile up from the river. The 15 or so residents of the area take full advantage of the water supply and produce copious amounts of fresh fruits and vegetables on riverside gardens. And while a few lucky residents are able to get some hydropower from the creek, the only available utilities are propane delivery and a telephone line.

Fixer Upper

We spent our first summer rebuilding the small 1,000 square foot (93 m^2), two bedroom, single bath cabin. The project was extensive, since it was literally from the dirt up. Many of the original floor joists were rotted from past years' water leaks, and had to be replaced. A complete new kitchen was constructed, including new cabinets, a new Servel propane refrigerator, and a basic four-burner propane range and oven. The only added extra was an energy efficient dishwasher. The bathroom was gutted, and a new shower was constructed along with a new sink, vanity, and toilet.

A laundry facility was created that included a compact, propane-fired, stacked washer and dryer unit. The old-style, bulky, tank water heater was replaced with an efficient Aquastar, propane, on-demand, tankless unit. Heating is provided by the original, centrally located, wood burning stove with the addition of a small 10,000 BTU propane wall heater for those cool mornings when the woodstove would be overkill.

Cooling the cabin after a hot summer day is simple. After the sun goes down, we open the windows at both ends of the house and allow the breeze blowing down Colson Creek to flow through and cool things off. We are considering adding a small air conditioning unit, since we have sufficient excess energy during the hottest months of July and August. But actually, we really do not spend much time indoors during the summer, since we prefer to be paddling the river, hiking, or working in the garden.

When the inside walls were being repaneled with cedar planking, I wired the entire house with electrical outlets. Lamps with compact fluorescent bulbs were installed in every room. The original gas lights were retained and upgraded, since along with lighting, they provide considerable heat, which is useful in mid-November through mid-February, a time when the canyon walls block the sun, and the PV system has to be supplemented by a propane-fired backup generator.

The Forest Service maintains the road all year, and while some residents of the area live here year-round, we do not plan to spend the entire winter in Idaho. The fall is our favorite time of year on the Salmon, since the steelhead fishing season remains world class up until the river freezes over, often beyond Thanksgiving. It's a time to relax, fish, and entertain friends and family.

Technical Specifications

System Overview

System type: Off-grid PV

System location: Colson Creek, Idaho

Solar resource: 5 average annual peak sun hours

Production: 90 AC KWH per month average

Photovoltaics

Modules: Eight Kyocera KC120-1m, 120 W STC, 12 VDC nominal

Array: 960 W STC, 24 VDC nominal

Array combiner box: Pulse Engineering PCB 10, with 15 A fuses

Array disconnect: Xantrex DC250, with 60 A breakers

Array installation: Wattsun AZ-125 dual-axis tracker

Balance of System

Charge controller: Xantrex C60, PWM

Inverter: Xantrex SW4024, 24 VDC nominal input, 120 VAC nominal output

System performance metering: Xantrex TM500 AH meter

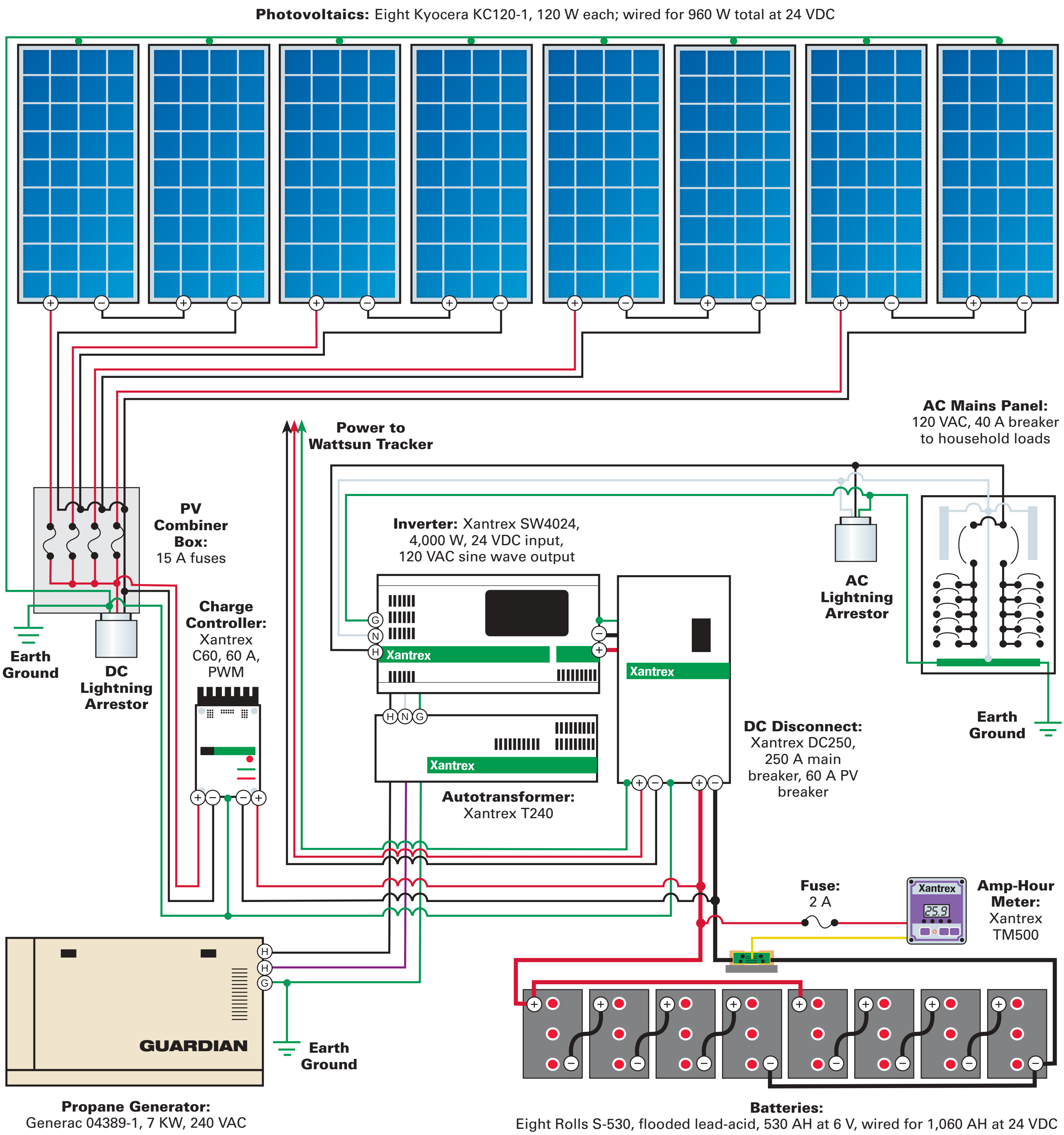
Engine generator: Generac 04389-1, 7 KW, 240 VAC nominal output, 80–100 hours average annual run time

Energy Storage

Batteries: Eight Rolls S-530, flooded lead-acid, 6 VDC nominal, 530 AH at the 20-hour rate

Battery pack: 24 VDC nominal, 1,060 AH total

Battery/inverter disconnect: Xantrex, DC250, 250 A breaker



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

PV System Design

Having a background in physics and engineering, I planned to do the entire PV system project myself, with minimal help from outside sources. All of the knowledge needed to plan, design, and construct the system was derived from reading articles in *Home Power*, and tracking reference material and sources originating from the magazine. Since discovering *HP* three years ago, I have read nearly every article from beginning to end.

Our calculated daily energy requirement came to 2,525 watt-hours. Eight Rolls S-530 batteries in a 24 volt configuration at 1,060 amp-hours would give us sufficient reserve to go four days without recharge.

The property is just above the 45th parallel, and has long summer days and a wide solar window. We calculated that 1 KW of PVs would keep the system sufficiently charged. We selected eight Kyocera KC120 panels, delivering 960 watts as the most cost effective configuration. The addition of a Wattsun AZ-125 dual-axis tracker increases output and extends our solar window somewhat.

My philosophy for electronic equipment is pretty straightforward. Reliability is very important, particularly in a remote location. Go with proven products and derate appropriately. We essentially selected Xantrex products, including an SW4024 inverter, C60 charge controller, TM500 battery status monitor, and appropriate disconnects, breakers, and lightning protection.

For a backup generator, I selected a Generac, 7 kilowatt, propane-fueled unit. While this generator was designed for emergency backup for grid-tied applications and has features we will never use, it looked like the best value considering that it comes with an outdoor environmental enclosure. Since we do not require 240 VAC for anything, the generator was wired into the system through a step-down autotransformer to balance the generator load and provide simultaneous load and battery-charging electricity when the generator is operating.

Under Idaho's blue skies, the assembled Wattsun tracker is ready for the PVs.

Marue System PV Sizing

Load	Watts	Hours / Day	Days / Wk.	Avg. WH / Day
Washer	500	0.50	4	142.9
Dryer	500	1.00	4	285.7
Microwave	1,500	0.50	7	750.0
TV	90	5.00	7	450.0
Hair dryer	400	0.05	7	20.0
Dishwasher	700	0.75	3	225.0
Answering machine	4	24.00	7	96.0
Toaster	1,200	0.05	2	17.1
Blender	350	0.05	2	5.0
Laptop computer	25	2.20	7	55.0
6 Fluorescent lamps	130	1.23	7	159.9
Vacuum cleaner	1,200	0.15	4	102.9
Fan	35	3.00	7	105.0
Hair curler	750	0.05	2	10.7
Misc.	100	1.00	7	100.0

Total Daily WH	2,525.2
2,525.2 x 1.1 inverter efficiency = **Daily DC WH**	2,777.7
2,777.7 ÷ 25 V for system = **Daily DC AH**	111.1
111.1 x 1.2 loss factor = **Adjusted Daily AH**	133.3
133.3 ÷ 5 hrs. sun / day = **Total PV Amps**	26.7
26.7 ÷ 7.1 A per module = **Parallel Strings**	3.8
3.8 x 2 in series = **Modules Needed**	8.0
133.3 AH x 4 reserve days = **Battery AH**	533.3
533.3 ÷ .5 max DOD = **Adj. Battery AH**	1,066.6
1,066.6 ÷ 530 AH = **Parallel Batteries**	2.0
2.0 x 4 in series = **Total Batteries**	8.0

Installation

Once the system was designed, I shopped the Internet over the winter for the best prices, and accumulated all the materials before heading to Idaho in April 2003. Construction of the PV system was concurrent with the building of a log garage/shop and a deck around the house. Initially, excavators and cement crews worked on all three projects simultaneously. Later, I built the deck and installed the PV system, while a local construction company finished the garage.

The Wattsun tracker was installed on top of a 10 foot (3 m) tall, 6 inch (15 cm) diameter, galvanized, Schedule 40 pipe. This pipe was set in a foundation block of reinforced concrete that is 4 by 4 by 3$^1/_2$ feet (1.2 x 1.2 x 1 m). This was a little more than 2 yards of concrete, and more than required by the calculations of a registered civil engineer.

The garage construction crew helped me hoist the Wattsun gear head onto the top of the pole. I was able to construct the frames, install the PV panels, and wire the circuits by myself. The documentation that came with the tracker kit proved adequate to complete the installation in a little more than a day. Once the garage was completed, the electrical equipment was installed on a wall about 25 feet (7.6 m) from the PV tracker pole.

On the AC side, appropriate breakers and enclosures were installed for overcurrent protection. Care was taken to bond ground rods located at the house and generator to a single point in the DC disconnect box. Lightning suppressors were placed at both the DC and AC sides. The Xantrex manuals and literature were complete enough to accomplish the installations successfully without help from outside sources. I particularly liked the technical sections of the Xantrex inverter manual, which explain the theory of operation, increasing my overall knowledge of how the system functions.

The batteries were installed in an insulated and vented box constructed close to the DC disconnect and inverter. Two inches (5 cm) of Styrofoam insulation should protect the batteries from freezing, since the winters at Colson Creek are rather mild, rarely getting to zero. The battery box was constructed out of plywood with a hinged lid like a freezer chest. I should have built the box with access through a side, to avoid hoisting each 130 pound battery over the top of the box by myself.

Connecting the Generac generator was a bit of a challenge, since this unit was designed for grid-tie applications, with no terminations provided for remote manual control. Generac was unhelpful—my e-mail request to them was returned with their concern that I might hurt myself or harm my property. It did not take much to figure out a way to interrupt a circuit on the manual start/stop switch of the Generac, and connected it to the generator control relay of the inverter, leaving the SW4024 in complete control of the generator's operation.

Performance

After completing construction of the system and double-checking all the wiring, the switch was turned and everything came to life. The only glitch was that the azimuth control of the tracker went the wrong way. I quickly figured out that the azimuth motor polarity was reversed, and it took no time to correct the problem.

In the first few weeks of operation, I fine-tuned the programming of the inverter and battery monitor. So far, through last summer and fall, the deepest the batteries have been discharged overnight is 8 percent, taking less than a third of the available summer sun hours to recharge. I wish I had a way to sell the excess electricity…

Ed & Joyce Marue in front of their newly installed PV array.

The propane-fueled Generac, 7 KW generator.

Future Considerations

Now that we have our Idaho cabin essentially complete, we'll turn our attention to some of our favorite hobbies and enjoy life in this special place. I am contemplating taking on the challenge of designing and building an energy independent home in Tucson, a particularly difficult project, considering the hot summer months in the Southwest desert region.

It took people more than two thousand years to use up 50 percent of our fossil fuel resources, and the second 50 percent will go very fast, and become increasingly expensive. Energy is the single largest problem our government is doing little about. To me, it's fun and rewarding to be doing something that will soon become an important part of everyone's energy supply.

Cost & Payback

The entire cost of the project, including all components, disconnects, wire, and conduit was US$15,081. We consider this as part of the cost of our home, and a reasonable investment, considering that the alternatives are limited.

Marue PV System Costs

Item	Cost (US$)
8 Kyocera KC120 modules	$3,512
Xantrex SW4024 inverter	2,499
Generac 04389-1 generator	2,275
Wattsun AZ-125 dual-axis tracker	1,926
8 Rolls S-530 batteries	1,592
Misc. wire, cable, & conduit	447
Concrete for tracker	425
Load centers, breakers, & disconnects	400
Xantrex T240 autotransformer	289
Xantrex DC250 DC disconnect	241
Xantrex TM500 battery monitor	191
Pulse TCB combiner box	181
PV tracker pole	179
24 Water Miser battery caps	168
Xantrex C60 charge controller	161
Battery box materials	157
8 Battery cables	136
2 Inverter cables	94
DC breaker	50
DC lightning arrestor	35
AC lightning arrestor	35
CD 60 PV array breaker	30
Stainless battery hardware	23
4 Compression lugs	20
Freight	16
Total	$15,081

When people consider an RE project, they get too hung up on payback, rather than the *benefits* of renewable energy. Why is it that people will not spend ten to twenty thousand dollars for an RE system, and think nothing about paying a premium of hundreds of thousands of dollars more than the actual construction value for homes located in major cities and suburbs? Where's the payback there?

Access

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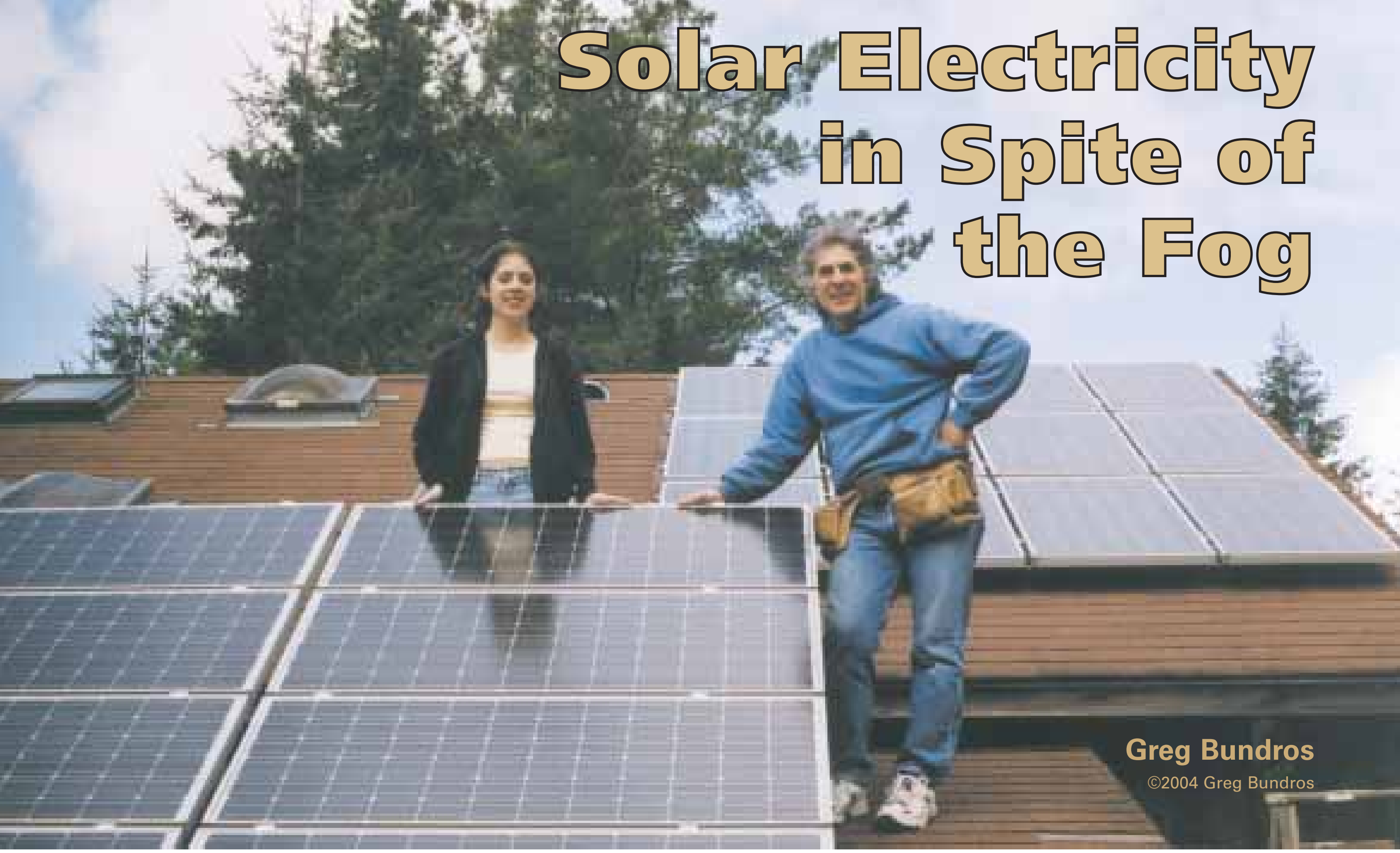
Earth Solar, Dave Regal, 6315 Canyon Dr., Amarillo, TX 79110 • 800-329-3283 or 806-359-9005 • Fax: 806-355-0585 • dave@earthsolar.com • www.earthsolar.com • System components

The Natural House: A Complete Guide to Healthy, Energy-Efficient Environmental Homes, Daniel D. Chiras, Paperback, 480 pages, ISBN 1-890132-57-8, US$35 from Chelsea Green Publishing Company, PO Box 428, White River Junction, VT 05001 • 800-639-4099 or 802-295-6300 • Fax: 802-295-6444 • info@chelseagreen.com • www.chelseagreen.com

Solar Living Source Book: The Complete Guide To Renewable Energy Technologies & Sustainable Living, John Schaeffer, Paperback, 598 pages, ISBN 0-916571-04-1, US$30 from Chelsea Green Publishing Company

Solar Electricity in Spite of the Fog

Greg Bundros



The author and his daughter Joanna installed the 24 PV panels on the garage and carport roofs.

Is installing a photovoltaic system in rainy and foggy coastal northern California a reasonable investment? I had my doubts before we made the plunge. But after the first year of operation, I truly believe our 2.6 kilowatt photovoltaic intertie system was not only a cost-effective investment, but also a patriotic one.

Using daily records from our photovoltaic system, I'll describe how well our system performed in its first year of operation. I think the numbers will speak for themselves.

Previous Solar Experience

Our family of four lives in Fieldbrook, California, located 15 miles (24 km) north of Eureka and 5 miles (8 km) from the coast. Rainfall averages about 57 inches (145 cm) per year and coastal fog can plague even the best gardens during the summer months. Nevertheless, we used a passive solar design to help heat our home when we built it more than 20 years ago.

We also installed a water heating system that uses solar thermal panels and a woodstove circulation loop. I have no numbers to show this, but I am certain the hot water system has paid for itself more than once. The only thing that had kept us from installing a photovoltaic (PV) system to meet some of our electricity needs was the high initial cost.

Rebates & Tax Incentives

The California Emerging Renewables program encourages the installation of renewable energy systems through rebates and tax incentives. Administered by the Californian Energy Commission (CEC), the program provides incentives for grid-connected PV and wind generation systems. Applying for the rebate is fairly simple. Obtain a quote for a system and submit a single-page form to the CEC. Once approved, they send you a notice confirming the amount that will be reserved for your rebate, which in our case was about 50 percent of the system cost. The system can then be purchased and installed.

After the system is inspected by your local building department and utility, and is operational, you submit the final papers to the CEC for the rebate, which is received within 4 to 6 weeks. Current state tax credits are about 10 percent of the system cost. So you recover, almost immediately, about 55 to 60 percent of the total system cost. Too good to be true? Read on.

Taking the Plunge

When I learned of the rebate program, I immediately set off to research PV system components and costs. Michael Welch, a long-time buddy from Redwood Alliance in Arcata, California, was one of my first calls. He provided a number of tips and pointed me to several good Web sites on PV technology. The Redwood Alliance Web site is a very good portal for renewable energy system links. *Home Power* magazine was an invaluable reference for system components and design. The cost table lists the PV-intertie system components that we installed for our home.

Our goal was to maximize the use of a single inverter in hopes of meeting 65 to 75 percent of our electricity needs. Because the incentive program made this purchase affordable, I decided not to skimp too much on cost. There are many good solar-electric panels on the market today, but the Siemens (now Shell Solar) seemed to fit our needs best. They are a high efficiency, monocrystalline module, and they come with a 25 year warranty. They also work well under a wide temperature range. Everyone I spoke with and all the literature I read voted strongly for the Sunny Boy inverter, an efficient, reliable, easy-to-install, batteryless, grid-intertie unit made by SMA.

While seasonal angle adjustments can increase solar output by about 5 percent at our location, I decided to mount the PV arrays at the fixed slope of our garage roof so they were unobtrusive. The roof pitch is 8:12 (34 degrees), so I felt it was close enough to our 41 degree latitude. The UniRac SolarMount racks were a perfect fit for us, because I wanted to rack panels individually on the roof instead of on the ground. The racks are made of high quality aluminum with accurately machined channels, and come with stainless steel hardware. The racks assemble easily, and the company's technical support staff is superb.

We purchased the system components through Schott Applied Power Corporation, now Alternative Energy Engineering, located about 80 miles (130 km) south of us in Redway, California. These folks have been in the renewable energy business for more than 20 years, supplying people with both off-grid and utility-intertie renewable energy systems. They are pros. Brian Teitelbaum was extremely friendly, knowledgeable, and an incredible resource.

I installed the system myself. Peter Brant, an electrical contractor, agreed to oversee the installation. Peter is a staunch supporter of renewable energy, and is enthusiastic and knowledgeable. My 16-year-old daughter Joanna and I installed all 24 panels on the garage roof in two days. Installing the inverter, running conduit, and pulling wire required another three days of work. The installation was straightforward and fun.

Bundros System Costs

Item	Cost (US$)	% of Total
24 Siemens SM110-24P 110 W, 24 V panels	$15,240	69.2%
SMA Sunny Boy SB2500U with display	2,310	10.5%
Sales tax	1,413	6.4%
6 UniRac Solar Mount SM/120 racks	1,325	6.0%
Misc. (building permit, wire, conduit, etc)	641	2.9%
Shipping	440	2.0%
AC disconnect,100 A lockable	236	1.1%
Electrician, labor	227	1.0%
DC disconnect, 600 VDC, 30 A	131	0.6%
2 Delta lightning arrestors	76	0.3%
Total Cost	$22,039	100.0%
CA Energy Commission rebate	-$10,112	-45.9%
CA state tax credit	-1,700	-7.7%
Net System Cost	$10,227	46.4%

The Bottom Line

The system is rated by the CEC at 2.2 kilowatts and cost US$22,039. We received a US$10,112 rebate from the CEC and claimed a US$1,700 state income tax credit. Thus, our net cost was US$10,227, or 46 percent of the original system cost. During our first year of operation, we produced almost 80 percent of our electricity needs, but ended up producing US$98 worth of electricity more than we consumed. I'll explain that apparent contradiction later.

Our annual electricity cost before we installed the PV system was about US$700, so our payback, based on 2001 energy costs, will be less than 15 years. I fully expect the payback to occur sooner, because energy costs will rise. Besides, the bottom line for us was the ability to produce most of our own electricity and be part of a global solution.

Net Metering Keeps the Score

A net metering agreement is signed with your local utility when you become an electricity generator. The utility installs a bi-directional meter at your home that records and displays the net cumulative electricity use. The meter subtracts (runs backwards) the amount of electricity produced by the PV system from the amount consumed in your home, and keeps a running tally from the time the PV system is operational.

The Sunny Boy inverter is mounted inside the garage.
The array's DC disconnect box is mounted to the left of the inverter.

Time-of-Use Provides a Boost

The time-of-use rate schedule (TOU) establishes the value for electricity based on the period of the year and the time of day electricity is used (or produced). Here's how it works. The year is divided into summer and winter periods, and the day into peak and off-peak hours. The summer period runs from May 1st to October 30th. The winter period is the other half of the year. Peak hours, regardless of period, are weekdays from noon until 6 PM. Off-peak hours are the remaining weekday and weekend hours.

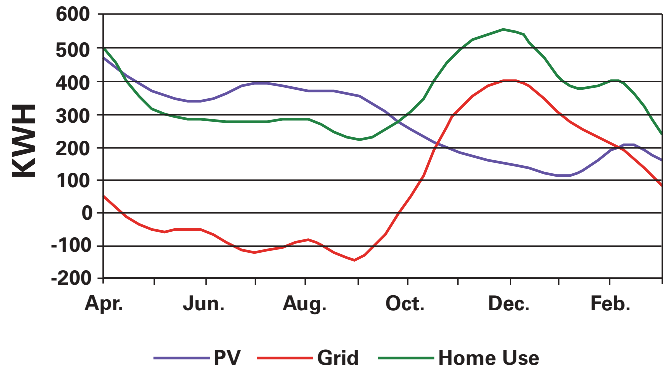
These are important points. With TOU, the price for electricity (whether you consume it or produce it) during peak hours of the summer period is three times more than for any other time. The price is also higher for peak hours during the winter period, but it is only a few cents more than off-peak hours. The price for electricity during the off-peak hours throughout the year remains the same and is less than the general rate schedule.

So the TOU rates explain the apparent contradiction mentioned earlier, because the value of the electricity you produce can make up for not producing all that you consume. In other words, for optimum financial gain, you want to limit your electricity use and maximize your electricity production during peak hours, especially during the summer period.

The Fun Stuff (for Nerds)

I am a number nerd. There—I said it. I have tracked our annual rainfall, electricity, and water use for nearly 20 years, so it was only natural to record the PV system's performance once it was operational. Each day since we commissioned the system, I have recorded our net cumulative electricity use, system production, and weather. It's actually kind of fun (I know—get a life!), and I can now predict our solar production by the weather. I will use those numbers, as they relate to net metering and TOU, to show how our system performed during its first year. We commissioned the system in March 2002.

Monthly Energy Consumption & Sources



How Much Electricity We Used & Where It Came From

The monthly energy consumption and sources graph shows our monthly energy consumption, the amount of electricity produced by the PV system, and how much electricity was pulled from the grid. In this graph, the PV production is the total amount of energy produced. It does not distinguish between peak and off-peak hours. The dates in this and other graphs that follow correspond to the end of each month.

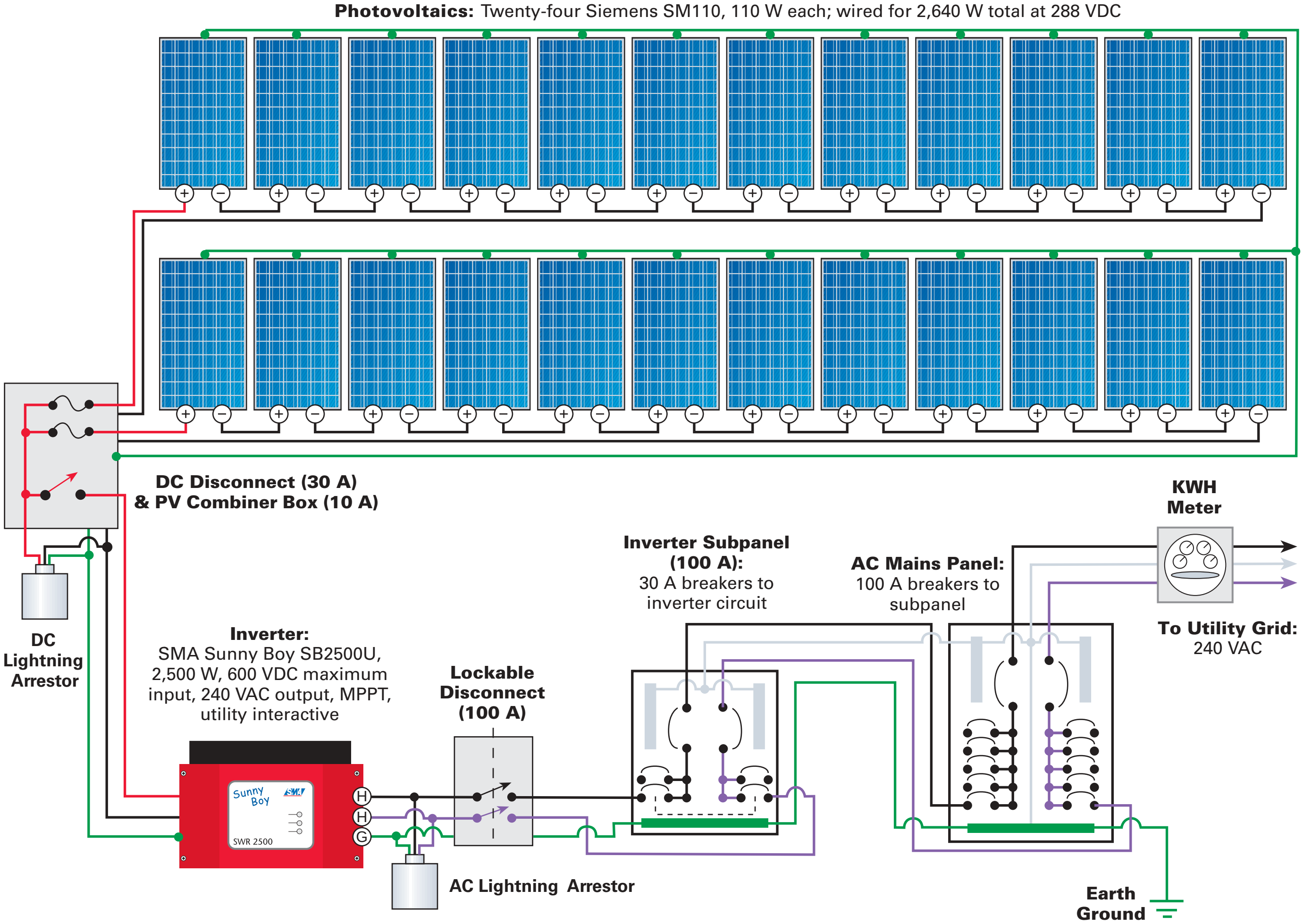
From the graph, you can see that our average monthly electricity consumption was 280 kilowatt-hours from the end of May through October. In the same period, PV production averaged about 345 kilowatt-hours per month and peaked by the end of July. Little if any energy was pulled from the grid. The PV production and home use curves cross just before the end of October, when consumption started to outpace PV production. From the end of October, more energy was pulled from the grid, especially during the dark winter months. The lowest monthly PV production occurred in January with 110 kilowatt-hours.

Net metering subtracts the amount of electricity you produce from the amount you consume, and keeps a running tally of your net electricity use. The electricity tally in the table illustrates how this works. When more electricity is produced than consumed, the net cumulative use is a negative value and vice versa. This table shows our net monthly and

Bundros Home Electricity Tally

Billing	PV Production (KWH)		Home Use (KWH)		Net Grid Use (KWH)	
Date	Month	Cumulative	Month	Cumulative	Month	Cumulative
04/30/02	469	469	500	500	31	31
05/28/02	366	835	310	810	-56	-25
06/25/02	337	1,172	285	1,095	-52	-77
07/26/02	393	1,565	273	1,368	-120	-197
08/26/02	364	1,929	281	1,649	-83	-280
09/25/02	353	2,282	218	1,867	-135	-415
10/24/02	249	2,531	301	2,168	52	-363
11/22/02	182	2,713	493	2,661	311	-52
12/24/02	142	2,855	542	3,203	400	348
01/24/03	111	2,966	383	3,586	272	620
02/25/03	203	3,169	388	3,974	185	805
03/18/03	155	3,324	236	4,210	81	886

Total Annual Use (KWH)	4,210
Total PV Production (KWH)	3,324
Difference (KWH)	886
Percent Solar Powered	79%



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

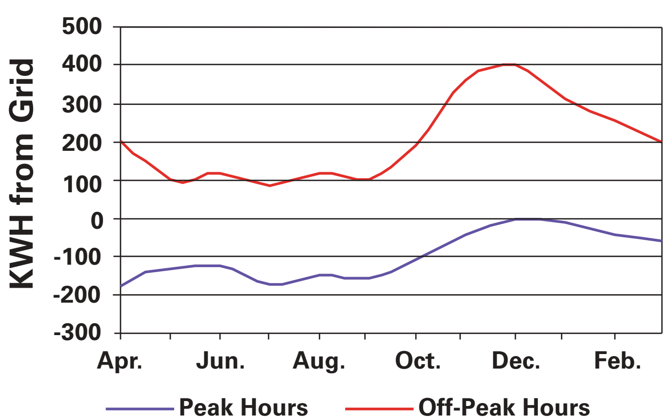
cumulative balance, and how the primary source of power changed during the year.

The table and graph show that the system consistently produced more energy than we consumed from the beginning of May through September (negative values). By the end of September, the system had banked nearly 500 kilowatt-hours of excess electricity. The system continued producing electricity, but consumption started exceeding production in October. We consumed the banked excess energy by the end of November, and relied more heavily on the grid for the winter months. By the end of the year and billing cycle, we had consumed about 890 kilowatt-hours more than we produced, about 20 percent of our annual consumption.

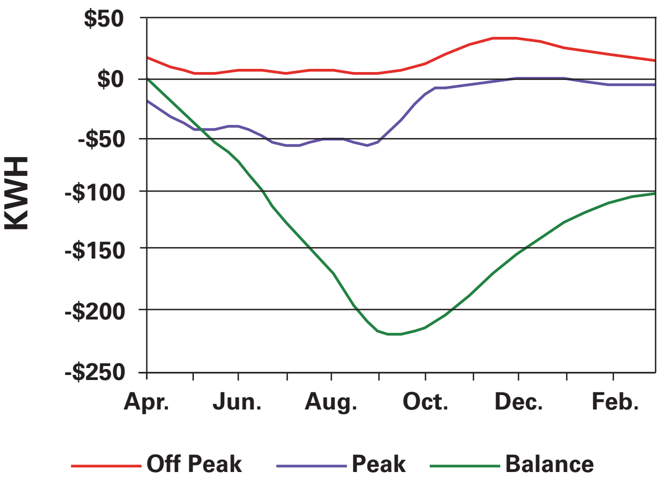
Now let's take a look at how our electricity use was spread between peak and off-peak hours. Recalling the previous discussion, net electricity use is the difference between the amount consumed and the amount produced by the PV system. Positive values represent net energy consumption. Negative values represent net energy production. The monthly peak vs. off-peak usage graph shows our monthly net use (or production) based on peak and off-peak hours.

That graph shows that the system consistently produced more than was consumed during peak hours throughout the entire year. Not surprisingly, the net peak hour production approached zero in December and January, but never went into the positive range. Net off-peak hour production was never anything to write home about. It stayed in the positive range throughout the year.

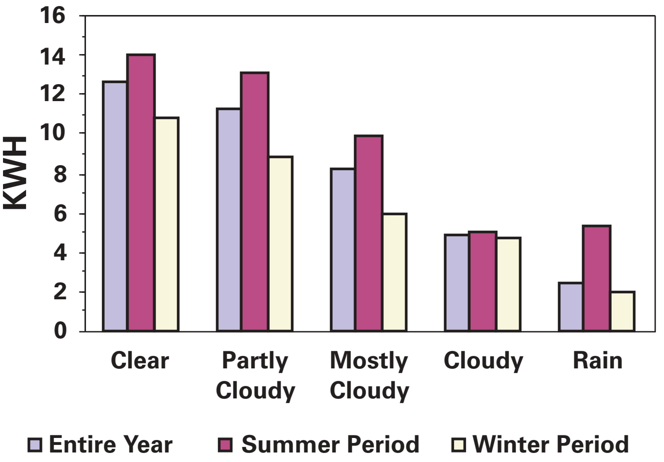
Monthly Use During Peak & Off-Peak Hours



Monthly Value of PV & Running Balance Owed to Utility



Average Daily PV Production & Weather



This is due to the location of the panels, which are bordered to the east by trees that we are not willing to remove.

So how is it that we consumed 890 kilowatt-hours more than we produced and still had a US$98 credit at the end of the first year? This is where TOU and peak hour production join forces. The monthly value graph shows how the value of electricity produced during the peak summer hours can offset consumption.

The graph shows the value of our monthly net electricity use during peak and off-peak hours. It also shows the running balance (the amount we owe, or our credit) with the utility, Pacific Gas & Electric Company. The running balance curve drops sharply at the beginning of the summer period (May 1st) when peak hour electricity is worth three times more than electricity during off-peak hours. We maintained a credit of more than US$200 through October (end of summer period), which was reduced to US$98 by the end of the annual billing cycle. This demonstrates the importance of TOU and feeding the grid as much as possible during the peak hours of the summer period.

North Coast Weather

Our climate is completely maritime because we live close to the Pacific Ocean. Eureka averages 38 inches (97 cm) of rain each year. Living north of Eureka and slightly inland from the coast, our annual rainfall averages 57 inches (145 cm), based on my twenty-year record.

The rainy season runs from October through April, when we receive about 90 percent of our annual rainfall. The dry season runs from May through September, and is commonly marked by periods of fog that usually clear by early afternoon. However, summertime fog can persist for several days to a week, or more. Annual rainfall totaled 58.3 inches (148 cm) for the first year our system was in operation.

PVs Love Sunny Days

In a final demonstration of system performance, take a look at how the system performed in different weather. The bar graph (above) shows the system's average daily output for different weather and TOU periods.

Predictably, the clear summer days (I wish we had more of them) produced the highest average daily outputs, followed closely by partly cloudy conditions. What I find interesting is that the average daily output for different periods maintains the same relative proportion during clear, partly cloudy, and mostly cloudy weather conditions. This relationship is probably related to the sun angle and solar window for the time of year. Our solar window varies from 4 to 5 hours during the winter months to more than 10 hours during the summer months.

It is also interesting to note that the average daily output remains relatively equal for cloudy (fog during summer) weather at all times throughout the year. This might reflect the panel's constant efficiency in diffuse light. The relatively high output for rainy summer days is probably due to a small sample size and low cloud density during summer storms.

For the entire year, the maximum daily output was 18 kilowatt-hours in May and June (pre-fog), and the minimum was 0 kilowatt-hours on five days in December. Daily output averaged 9.1 kilowatt-hours per day over the entire year.

No More Excuses

Was installing the PV system a cost-effective investment? I sure think so. Sure, the payback will take some time, but what good things in life don't? Our society purchases new cars and similarly high priced consumer goods on a regular basis. Think about it. For half the price of a new modestly priced car, you can produce a significant portion of your electricity for the next 20 to 30 years.

Global energy demand will increase significantly as populations and nations flourish. Nonrenewable energy resources will someday be depleted. We have the ability to

Technical Specifications

System Overview

System type: Batteryless, grid-intertie system

System location: Fieldbrook, California

Solar resource: 4.4 average annual peak sun hours

Production: 277 AC KWH per month average

Percentage KWH offset by PV system: 79 percent

Percent utility cost offset by PV system: 100 percent

Photovoltaics

Modules: 24 Siemens SM110, 110 W STC, 24 VDC nominal

Array: Two, 12 module series strings, 1,320 W STC each, 2,640 W STC total, 288 VDC nominal

Array combiner box: Xantrex TCB-10 with 10 A fuses

Array disconnect: GE heavy duty safety switch, NP 266212-E, 30 A

Array installation: UniRac Solar mounts on south-facing roof, 34 degree tilt

Balance of System

Inverter: SMA Sunny Boy SB2500U, up to 600 VDC input, 240 VAC nominal output, 250 to 600 VDC MPPT voltage window

System performance metering: Built-in inverter display

A bi-directional digital meter records net electricity use.

be part of a global solution, as long as PV system costs remain reasonable, and future costs are reduced by increased demand and advancements in component production. I applaud California for its forward-looking vision and effort to spur PV technology and use.

A nation without financial incentives that encourage renewable energy investment is a nation without a vision. Our national energy policy should provide the necessary incentives to promote renewable energy sources and energy conservation. Going to war for oil or drilling for it in places that we should hold sacred in perpetuity is dangerously shortsighted. If photovoltaic technology works in dreary coastal northern California, just think of the potential elsewhere in our nation and world.

Access

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Peter Brant, Brant Electric, PO Box 66, Arcata, CA 95518 • 707-822-3256 • Fax: 707-826-1180 • pbrant@foggy.net • Electrician

Michael Welch, Redwood Alliance, PO Box 293, Arcata, CA 95518 • 707-822-7884 • www.redwoodalliance.org • mwelch@redwoodalliance.org • Inspiration & information

Alternative Energy Engineering, PO Box 339, Redway, CA 95560 • 888-840-7191 or 707-923-2277 • Fax: 707-923-3009 • info@alt-energy.com • www.alt-energy.com • System components

California Emerging Renewables Program, California Energy Commission (CEC), 1516 9th Street, MS-45, Sacramento, CA 95814 • 800-555-7794 or 916-654-5127 • Fax: 916-653-1435 • renewable@energy.state.ca.us • www.energy.ca.gov • Buydown program

Eureka National Weather Service Office, 300 Starare Dr., Eureka, CA 95501 • 707-443-6484 • Fax: 707-443-6195 • www.wrh.noaa.gov/eureka • Weather data

Shell Solar Industries, 4650 Adohr Ln., Camarillo, CA 93011 • 805-482-6800 • Fax: 805-388-6395 • solarsalesusa@shell.com • www.shell.com/shellsolar • PVs

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

UniRac, Inc., 3201 University Blvd. SE, Suite 110, Albuquerque, NM 87106 • 505-242-6411 • 505-242-6412 • info@unirac.com • www.unirac.com • PV mounts


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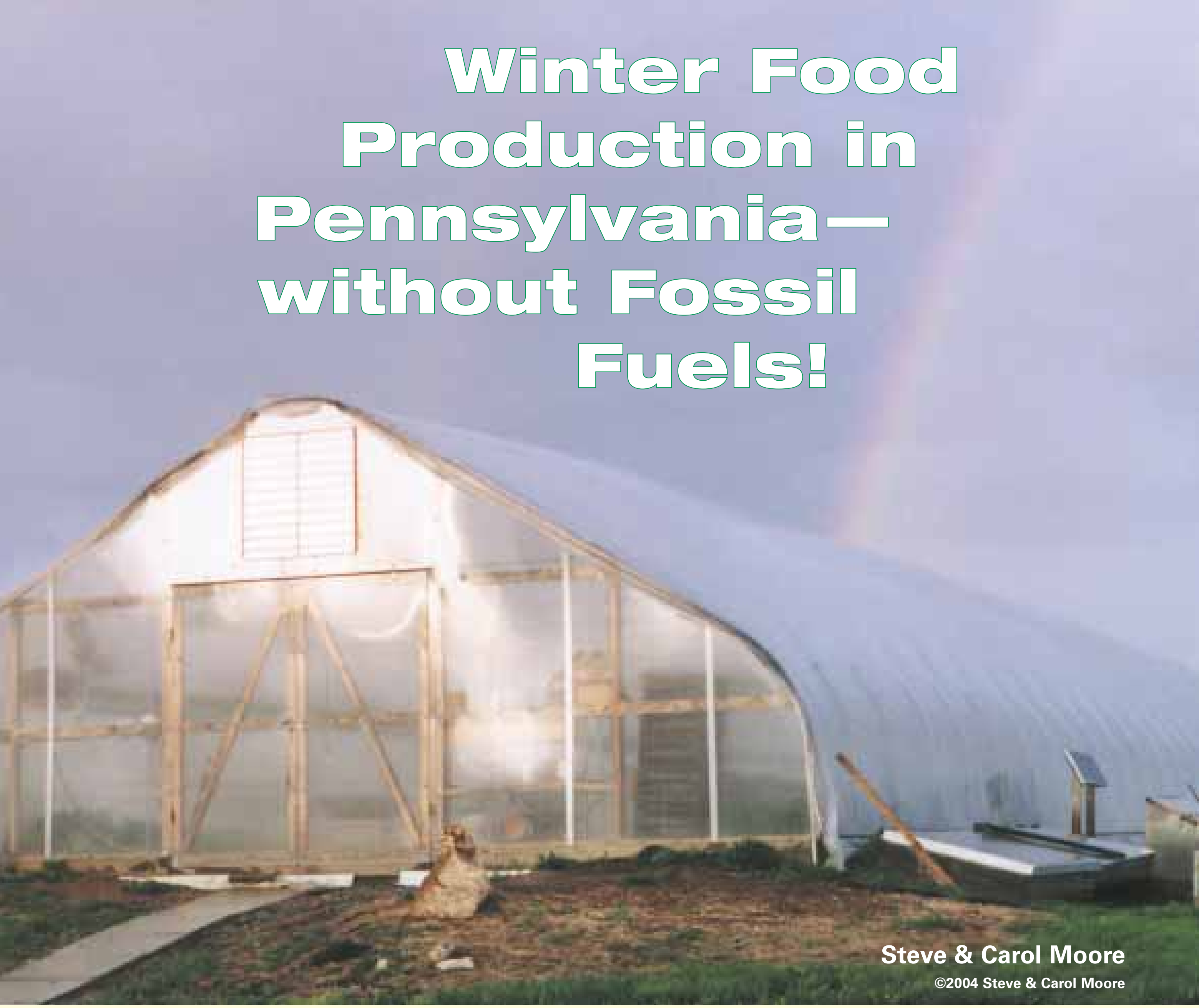


Steve & Carol Moore

A rainbow over Steve and Carol's solar powered greenhouse marks their pot of gold—sustainable food production.

Thirty years ago, we started farming as a family with the principles of organic agriculture and limited fossil fuel use. This ethic stemmed both from our concern for the environment and from our interest in self-sufficiency.

We used horse power for the first 26 years, and moved on to hand power with the incredibly efficient Grow Biointensive gardening technique. As farmers and market gardeners, we needed continual cash flow, and decided to use a seasonal extension of tomato growing for a niche market. Before we knew what had happened, we were growing tomatoes year-round and burning lots of fossil fuel to raise tomatoes in the winter. We had an epiphany as we looked at fuel consumption and asked, "How did we get so far from our mark? How can we avoid getting to this place again? Where should we go from here?"

Simple Goals

We decided to start with a few simple goals to help us stay focused as we changed our season extension plan. They were:

- Accept as much natural energy as possible
- Lose as little energy as possible
- Store an adequate amount of energy
- Keep things simple (both mechanically and managerially)
- Do it with a payback (and minimal risk)

We also wanted the freshest, most nutritious food for our family (as well as our markets). We were tired of the high labor and energy intensive preserving methods, which only led to compromised nutrition anyway.

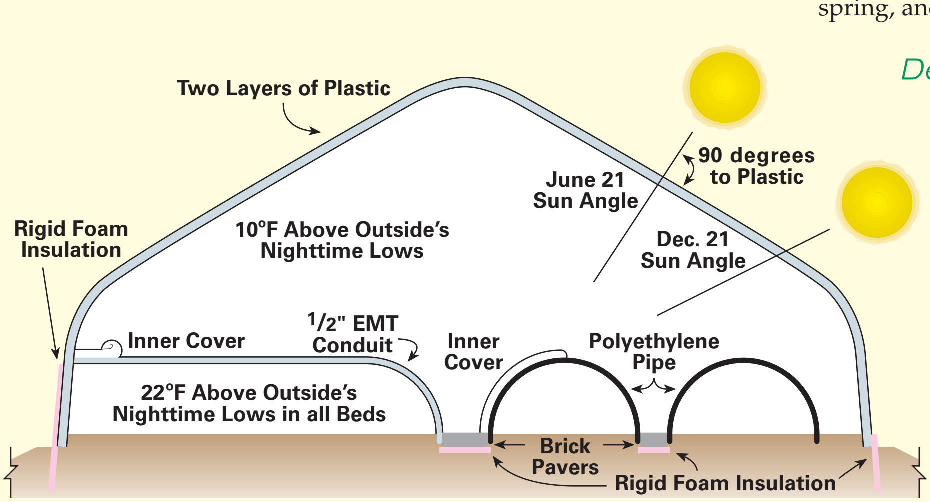
These were the beginning ideas of our passive solar greenhouse. Whether by encouragement or challenge, we moved forward with research and experimentation until we could produce food for market and our table. The main idea was embarrassingly simple—if one blanket doesn't keep you warm, add another. In our case, we added grow tunnels inside one of our big greenhouse structures.

Photo by Susan Lerner, www.SusanLernerPhoto.com.

Josh, Sarah, Carol, and Steve Moore in front of their solar powered greenhouse.

The success of these greenhouses was noticed by the Pennsylvania Environmental Resource Center, which voluntarily funded the purchasing of microclimate monitoring equipment. The data we gathered allowed us to accelerate our learning curve. As a result, we now use greenhouse perimeter and interior pathway insulation; new, more efficient interior layouts; and different films for the greenhouse and inner covers.

Here in southeast Pennsylvania, winters often bring a week of subzero (°F) temperatures, and sometimes days and weeks that never get above 32°F (0°C). We can now grow more than a dozen cold-tolerant crops right through the dead of winter. In addition to improved winter production, our new system provides "summer" production in spring, and summer crops as late as Christmas.



Design Considerations

Although the basic idea of extra blankets in the winter is simple, there are several important design and operational considerations. Singularly, each consideration is just a small improvement; but building on each other, they improve thermal performance significantly, resulting in more diverse crops over longer periods of time. Listed below are the basic design considerations.

Orientation and Location. Most greenhouses are oriented with the

Testing Greenhouse Materials

We are constantly seeking to improve the performance of our greenhouses. For the winter of 2002–2003, we received a small grant from the Pennsylvania Vegetable Growers and Mid-Atlantic Vegetable Growers Association to try various inner covers, outer covers, and combinations. The results (shown in the table) indicate that the best retention of heat is a double layer of polyethylene over the big greenhouse, and a 6 mil polyethylene inner cover (can be reused from old greenhouse film) covering the entire half width of the interior of the big greenhouse. "Thermal performance" is the ability of the greenhouse and inner covers to accept as much energy (light and heat) as possible, and retain it overnight and into subsequent days. Economic analysis shows that this inner cover is very cost effective.

Further investigation using the 7.8 mil infrared reradiating (IR) Coeva cover (a greenhouse film made in Italy) in a two-layer cover on the big greenhouse may prove to be thermally better than the two-layer, 6 mil, standard polyethylene covering. Our continuing research may also show this combination to be more economical if a useful life expectancy of eight years can be obtained (useful meaning it still transmits a high percentage of light towards the end).

Materials Comparison

	*Average Thermal Performance	Cost / sq. ft. (US$)
Tunnel Inner Cover (5 foot bed)		
Cravo Equipment XLS10 blanket thermal	0.76˚F	$0.18
Poly, 6 mil, used	0.00˚F	0.00
Poly, 6 mil, new	0.00˚F	0.10
Agribon-70 (2 oz. per yard spun polyester)	-0.76˚F	0.05
Aluminet (Green-tex)	-1.49˚F	0.33
Tufbell (PVA, poly vinyl alcohol)	-2.07˚F	0.23
Tunnel Inner Cover (1/2 of 30 foot width)		
Poly, 6 mil, new	2.89˚F	0.10
Poly, 6 mil, used	2.89˚F	0.00
Agribon-70 (2 oz. per yard spun polyester)	-2.16˚F	0.05
Greenhouse Cover		
Two layers 6 mil IR AC poly w/ 6 mil IR AC poly inner cover (new)	2.89˚F	0.24
Two layers 6 mil IR AC poly w/ 6 mil IR AC poly inner cover (used)	2.89˚F	0.19
Single layer 7.8 mil IR AC Coeva (poly) Growers Requisite Ltd., w/ Agibon-70 1/2 width of inner cover	-2.16˚F	0.15

*Compared to used 6 mil poly (5 foot bed)

long axis north-south to reduce light reflecting off the surfaces. To accept the most solar energy, solar greenhouses should be oriented east-west. Use a sun chart or Solar Pathfinder to identify the sun-restricting objects, like trees and buildings, and locate your structure accordingly. The east-west orientation also provides the smallest profile for our cold westerly winds. Always provide groundwater and surface water drainage away from the greenhouse, both to prevent heat-robbing groundwater movement and waterlogging the crops.

Longitudinal beds and environmental datalogging unit (middle).

Lateral beds. Note the cover (pulled back during the daytime) against the side of the greenhouse.

Structure Design. The Gothic arch shape minimizes interior shading, reduces snow load, and raises the height of the structure for better summer ventilation. The size and relationship of length to width affects lighting (or shading), energy gain, growing space, ventilation, cost per square foot, and much more.

For example, a 10 by 90 foot (3 x 27 m) tunnel has a 200 foot (61 m) lineal perimeter and a 900 square foot (84 m^2) growing area. A 30 by 70 foot (9 x 21 m) greenhouse has a 200 foot (61 m) lineal perimeter and a 2,100 square foot (195 m^2) growing area. Not only is this important for greenhouse growing area, but it is critical for the ratio of perimeter, or heat loss potential, to growing area (greater than 2:1 ratio in this example).

The Moores' winter greenhouse yields a healthy harvest.

Combining all the above criteria (price per square foot, etc.), a 28 or 30 foot wide by 96 foot long (8.5 or 9 x 29 m) greenhouse seems to be the best bet for success. Using this size and shape with the interior grow tunnels, we have achieved our design objectives.

Interior Design. Two interior designs can be used. One design uses longitudinal, 5 foot (1.5 m) wide beds with 8 foot (2.4 m) curved polyethylene water pipes (this can be used pipe, 3/4 to 1 1/4 inch; 19–32 mm) spaced 3 to 5 feet (0.9–1.5 m) apart and set on 12 to 18 inch (30–46 cm) pins driven three quarters of the way into the edge of the 5 foot wide beds.

Another interior design uses a center path and lateral, 5 foot beds and 1 foot (0.3 m) paths covered from the side of the greenhouse to the center path. The cover is supported by 1/2 inch EMT conduit with a PVC center support.

One 32 watt UniSolar PV provides power to the datalogging unit and inflation blower.

In either case, the covering can be as economical as old greenhouse film or as sophisticated (and expensive) as thermal curtains. The combination of the tunnels inside the greenhouse and the greenhouse covering itself results in a 20 to 22°F (11–12°C) increase over average minimum outside ambient temperature.

On sunny days, the covering on the interior tunnels can be pulled or rolled back. If the south half is rolled or flipped up to expose the bed, the incoming, short-wave solar radiation is absorbed and reradiated as long wave radiation from plants and soil. The inner covers can then reflect this long-wave radiation. If using the longitudinal beds, both sides are rolled or flipped up for harvesting, watering, or venting. When spring comes, these tunnels can be pulled up off the ground pins and removed for use on outside beds.

Ventilation. Ventilation is achieved using traditional aluminum louvers or a homemade butterfly louver that can open the upper section of the gable end. In either case, two, 4 by 8 foot (1.2 x 2.4 m) doors at each end complete the natural ventilation system.

There is no denying that these greenhouses get *hot* (105–110°F; 41–43°C) in the summer, yet we have always attained good yields. Interestingly, the leaf surface is cooler, even though ambient temperature is much higher than outside temperatures. (Hot leaf surfaces cause blossom drop and a shutdown of photosynthesis.) The plants grown in the summer—tomatoes, peppers, eggplant, cucumbers, and squash—are tropical in nature and do quite well.

Roof Coverings. Traditional greenhouses of this type use an inflation fan to keep the air pressurized between the two layers of plastic. This provides a thermal dead air space and improves the longevity of the plastic by keeping it from flapping in the wind.

Greenhouse Costs 30 x 96 Feet

Item	Deluxe Version*	Scaled Down**
Frame	$2,625.00	$2,625.00
Polygal, splices, & fasteners (end wall)	1,298.60	
IR poly, 48 x 100 feet	459.86	
Shipping	411.72	411.72
UniSolar 32 W PV module	365.00	365.00
2 Shutters, 45 x 45 inches	355.74	
Poly, 48 x 100 feet (or 2)	323.49	646.98
Wire lock (base & wires)	312.85	
12 Cross ties & frames	300.00	300.00
Framing & baseboard, sawmill	200.00	200.00
Roll-ups	174.00	
2 Golf cart batteries, 6 V	160.00	160.00
Morningstar PS30 charge controller	150.00	150.00
Gable rafter trim (wire lock)	78.40	
Inflation fan & adapter to poly	77.27	77.27
Sand & cement	75.00	75.00
Framing from lumber yard	50.00	200.00
Misc. hardware	50.00	50.00
Poly patch	21.90	21.90
2 Jumper kits	17.40	17.40
Alternative gable end poly, staples, etc.		100.00
Total	$7,506.23	$5,400.27

*Deluxe gable end with rigid polycarbonate covering

**Scaled down gable end with 6 mil polyethelene

In our system, energy for this purpose (and for powering the monitoring equipment) is provided by a 32 watt UniSolar panel, Morningstar PS30 charge controller, and two, 6 volt, U.S. Battery golf cart batteries (stored below grade). This simple system powers a surplus 12 volt, 4 watt, dual-pole blower, which is small, but sufficient to maintain adequate inflation. We are also experimenting with the use of a single greenhouse plastic film (allowing 9 percent more light to enter during the day) and more sophisticated inner covers to retain the heat closer to the plants at night.

Cultural Practice. Although energy concerns are primary to *HP* readers, a few growing points should be briefly mentioned. We use biointensive techniques and find that it gives incredible yields, great insect and disease control, zero direct fossil fuel use, and a closed loop cycling of nutrients (all issues key to a sustainable food system).

The major components of a biointensive system are deep (2 foot; 0.6 m) soil preparation, close offset spacing, enhanced composts, use of transplants, and companion planting. We have been using this system for quite a number of years in and out of the greenhouse with great results. When combined with the use of beneficial insects, good pest insect control is achieved as well.

In our greenhouses, the eggplant yield is 6.7 times the U.S. average, and the peppers have yielded 10 times the U.S. average per square foot. High CO_2 contributions (2 to 3 times outside ambient) from decaying organic matter greatly accelerate photosynthesis and corresponding growth (and profit per square foot).

Soil health cannot be overrated. We try to keep a high level of nutrient availability and biological activity. Our beds test at above 15 percent organic matter in the top 6 inches (15 cm), and above 11 percent in the 6 to 12 inch (15–30 cm) range, with corresponding low bulk densities.

Sustainable, Energy Efficient Agriculture

Crops can be grown even in the dead of winter in southeastern Pennsylvania without the direct use of fossil fuel and the need for expensive and high maintenance heating and cooling equipment. This has proven important to holding on to our market niches year-round, and spreading the work and cash flow throughout the year. It also contributes to a more sustainable food system.

Using the solar greenhouse with biointensive and other sustainable agricultural techniques reduces the high energy cost of our current food system. U.S. mechanized agriculture uses 9.8 calories of mostly fossil fuel to produce 1 calorie at the dinner table. Commercial transnational organic production may be just as energy intensive.

Techniques such as biointensive agriculture and passive solar greenhouses can reduce the conversion to 1 calorie in (mostly human energy) for 20 calories out (at the table). Extrapolating, you could generalize that this system is 200 times more energy efficient than current U.S. mechanized agriculture. Additionally, the combination of solar greenhouse and biointensive practices provides maximum freshness and improves the availability of nutrient and therapeutic components in the plants for our customers and our family year-round.

Access

Steve & Carol Moore, Harmony Essentials, 1522 Lefever Ln., Spring Grove, PA 17362 • 717-225-2489 • sandcmoore@juno.com • Two-day solar greenhouse workshops will be held March 5–6, 2004 and September 24–25, 2004. Contact Steve & Carol for details.

Grow Biointensive, Ecology Action, 5798 Ridgewood Rd., Willits CA 95490 • 707-459-0150 • Fax: 707-459-5409 • bountiful@sonic.net • www.growbiointensive.org

Growers Requisites Limited, 1915 Setterington Dr., Kingsville, ON Canada N9Y 2E5 • 800-819-8776 or 519-326-4466 • Fax: 519-326-3492 • growers@mnsi.net • www.greenhousepoly.ca • Coeva greenhouse cover material

Four Season Harvest, by Eliot Coleman, Paperback, 236 pages, ISBN 1-890132-27-6 • US$24.95 from Chelsea Green Publishing Company, PO Box 428, White River Junction, VT 05001 • 800-639-4099 or 802-295-6300 • Fax: 802-295-6444 • info@chelseagreen.com • www.chelseagreen.com

How to Grow More Vegetables, by John Jeavons, 6th edition, paperback, 240 pages, ISBN 1-58008-233-5, US$17.95 from Bountiful Gardens, 18001 Shafer Ranch Rd., Willits CA 95490-9626 • 707-459-6410 • www.bountifulgardens.org.

Winter Harvest Manual—Farming the Backside of the Calendar, by Eliot Coleman, 1998, 57 pages. US$15 postpaid from Four Season Farm, 609 Weir Cove Rd., Harborside, ME 04642 • www.fourseasonfarm.com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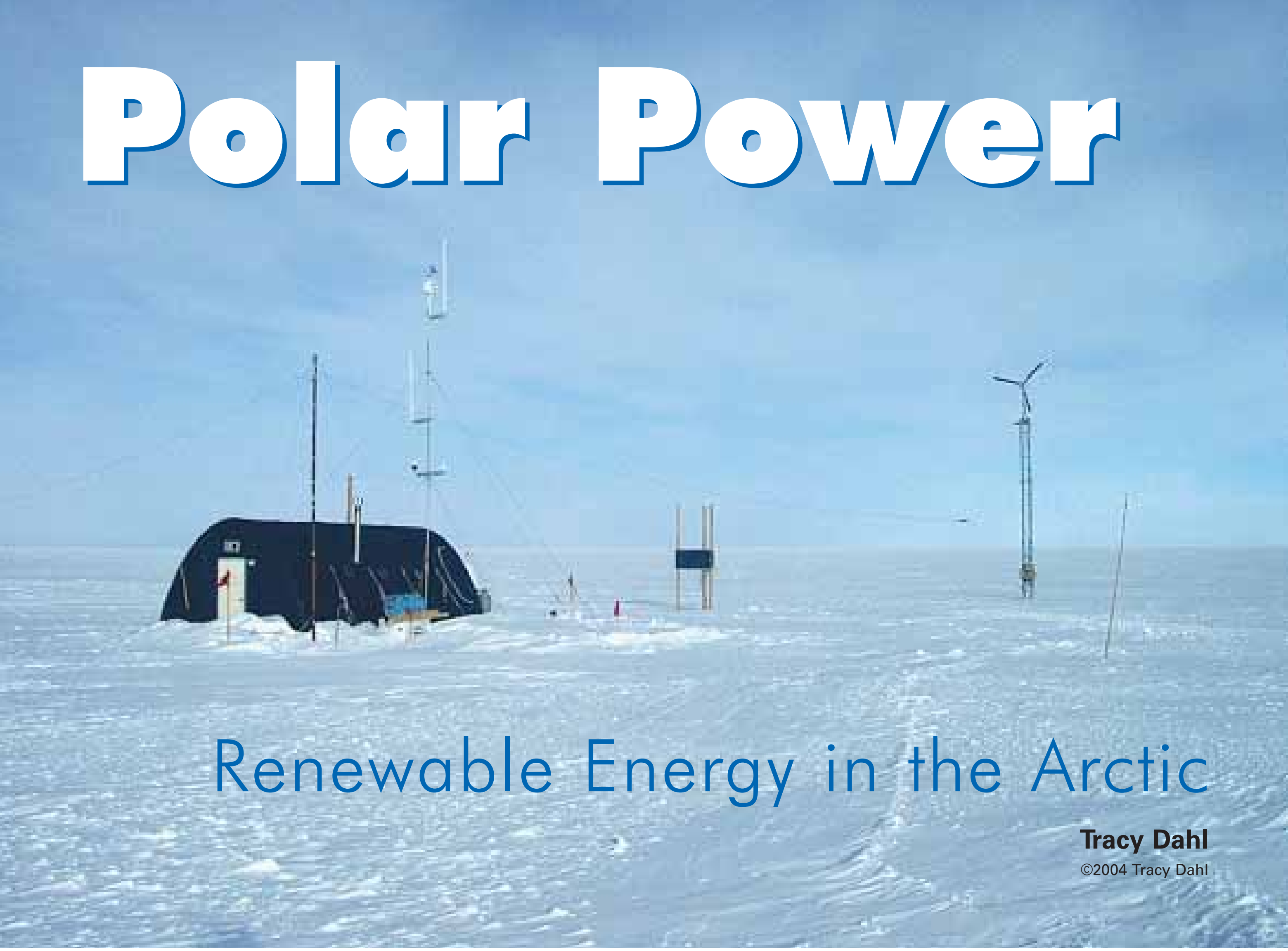
Polar Power

Renewable Energy in the Arctic

Tracy Dahl



At more than 66° N latitude, Camp Raven receives all its electricity from the almost nonstop sun and wind. The main Weather-Port tent, communications center, and renewable energy system are shown above.

The Earth's polar environments are great places for using renewable energy technologies. In the summer, 24-hour sunlight and low temperatures combine to create spectacular conditions for photovoltaics. In an ice cap environment, the reflective white surface of the snow further boosts PV panel output. Consistently high wind speeds are often the norm, making wind power equally viable.

Additionally, there are no corner gas stations. Every bit of fuel must be brought in via aircraft at great expense. Due to continuously drifting snow, fuel storage creates additional operational problems. Fuel tanks, and indeed anything placed on the snow surface here tends to become quickly buried in massive snowdrifts. But the same wind that creates so many operational problems can be made into an ally by harnessing it for the production of electrical energy.

Small renewable energy systems, such as the one described here, can often pay for themselves in a single season. Renewable energy is finding ever-wider application in these environments, in both the public and private sectors.

Camp Raven

The U.S. National Science Foundation's (NSF) Office of Polar Programs funds scientific research in the Arctic and Antarctica. One of the camps funded by the NSF in the Arctic is Camp Raven. Raven is located on the Greenland ice cap, just below the Arctic Circle (66° 29.786′ N, 46° 17.095′ W). The camp's main function is to serve as a training facility for the New York Air National Guard (NYANG), the primary logistical aircraft support provider for the United States Polar Programs. A limited amount of scientific support is also provided at this facility, with two, year-round, autonomous instrument stations.

The camp itself operates only during the boreal (far northern) summer, typically late April through mid-August. The Raven support staff consists of two people, typically a couple. My wife Amy and I have run this camp twice, first in 2001, and again in 2003. I helped develop a small but serviceable renewable energy system at the camp. Several people have contributed to the evolution of this system. I'm just the guy telling you about it.

Project manager Mark "Sparky" Begnaud put a lot of work into this system, both in the design and implementation. Joe "Solar Joe" Yarkin helped to install the system twice, and made significant contributions along the way. My wife and I alternate seasons with another couple, Mark and Louise Albershardt, who have also made several suggestions for improvement.

The Environment

Most people would find the environment on the Greenland ice cap rather inhospitable. As you might expect, it is fairly cold, with frequent storms that make working conditions challenging, to say the least. Yet Camp Raven is fairly unique among the polar ice cap facilities. Due to its relatively low latitude, it can actually get quite warm here in the summer. On a sunny day in mid-summer, temperatures can soar into the mid-40s (6–8°C). The sun is reflecting everywhere, which makes it feel much warmer. It may not sound like a scorcher by lower 48 standards, but I assure you that this is T-shirt weather.

Of course, the wholesale snow melting caused by such warm temperatures creates numerous operational problems, and may be indicative of serious implications for the entire planet. Indeed, at other Greenland ice camps, such as Summit Camp, global climate change is a major focus of scientific research. That however, is another story.

While Raven may be located in the "banana belt" of the polar ice cap camps, it is still no picnic. Typical temperatures at camp put-in can be as low as -40°F (-40°C). All outside work (and it's all outside until the structures are erected) must be performed in heavy, specialized, extreme cold weather gear. Everything must be done with gloves on, or very, very quickly with gloves off. It is an acquired skill that requires speed, dexterity, and a certain insensitivity to cold. The weak ones are quickly weeded out.

Only in extreme latitudes does this kind of PV orientation make sense. It captures solar energy throughout the day, without any complicated mechanisms. It is robust enough to stand up to the severe weather, and even works on overcast days due to the reflected light.

Having Fun at Raven—the put-in crew, from left, Dave "Tricky" Ricke, Geordan "Hollandaise" McQuiston, and the author. "Fun" is a sickeningly sweet concentrated beverage from Denmark.

Dealing with mechanical equipment here can be an extremely frustrating experience. Track dozers—10,000 to 15,000 pound, rubber-tracked machines, equipped with a blade on the front for moving snow—are critical for the operation of the runway and camp. To get a track dozer going following a storm, we must first dig out the support equipment (snowmobile, generator, and 500,000 BTU gasoline-fired Herman Nelson heater), and get it over to the piece of equipment to be brought on line. If you're lucky, the "Hermie" will start, and the generator can be warmed up. In temperatures below -13°F (-25°C), even the Hermie won't start. We often have to warm the Hermie to warm the generator to warm the track dozer. It can take several hours to get the desired piece of equipment up and running—another reason why RE is such appropriate technology.

Eventually, the support equipment is all running, and plugged in or blowing hot air on the critical places. At that point, we start digging out the track dozer and any other equipment we want to use in conjunction with it. In all, up to three hours might be spent just getting ready to do the

The Bergey 1500—a reliable turbine, in service for four years.

work we need to do. Think about that the next time the daily commute starts to get to you. Is it any wonder we love our RE system, which has been on line, doing its job the whole time, with no fuss, no muss? If we could just figure out a way to power the track dozer with RE…

The ice cap can be a hostile and often unforgiving environment. Nothing grows there. There are no permanent animal inhabitants. The birds that get blown inland from the coast rarely have the reserves to make it back. But what this area does have is abundant sun, wind, and water (albeit tied up as snow and ice).

The summer average wind speed is approximately 15 knots, or 16.5 mph (7.4 m/s). Windstorms can frequently exceed 50 knots, or 55 mph (24.5 m/s). Any time wind speeds rise above 25 knots, visibility drops rapidly, and outside work becomes nearly impossible. The winter average wind speed is very high. Several science groups have attempted to use small wind turbines from various manufacturers for their unmanned sites. To my knowledge, none have yet survived a single winter. The search continues for a small wind turbine tough enough to make it here year-round.

All that I've written so far paints a pretty bleak picture of the environment. But there is also a very special beauty to the ice cap. The light can create color hues and visual effects seen nowhere else on this planet. Indeed, at times it feels like another world. In the calm that follows a storm, ice crystals are still settling back through the lower atmosphere. Sun dogs, perihelions, and glories can light the sky like a 360 degree rainbow.

RE System

The system employed at Camp Raven is straightforward and uses good quality components. As such, the operation is fairly simple and requires very little maintenance. Since this camp is erected and disassembled every season, efforts have been made to make the electricity generating system quickly deployable.

Wind Generator

Since wind is a very consistent companion at the site, it was chosen as the primary renewable energy source. The wind generator is a Bergey 1500 model. It is capable of generating 1.5 KW of 3-phase AC electricity. This is then routed through a 3-pole, double-throw, safety/transfer switch and a 3-phase breaker disconnect. Both of these switches are mounted at the base of the tower.

The primary purpose of the transfer switch is to provide a means of shorting the windings of the generator, effectively slowing or locking the blades of the turbine. This is an essential element for the seasonal disassembly of the wind generator. While wind speeds are definitely high in the summer, they are literally off the charts in the winter gales. While the Bergey might just be tough enough to survive, there are no loads to power during that time anyway. We think it's prudent to remove the blades at camp close-out. They are reinstalled at the beginning of each season.

To increase overall system efficiency, most of the major loads at Camp Raven are run on DC.

At the base of the tower, the input from the wind turbine goes to the middle set of contacts in the transfer switch. These contacts are continuously energized when the turbine is spinning. The bottom set of contacts shorts the windings together, while the top set connects to the breaker/ disconnect. The purpose of the breaker/disconnect is to provide a simple method of disconnecting the wind generator from the rest of the system, as well as providing overcurrent protection.

Tower

The wind generator is mounted on top of a square, reinforced tower. The tower is 16 inches (41 cm) on each side, and fairly robust. It is also guyed with steel cable at two elevations on the tower, which run down to dead men anchors—4 foot (1.2 m) long sections of pressure-treated 4 x 4 inch (10 x 10 cm) lumber—placed deep in the snow.

The present height of the tower is approximately 26 feet (8 m), about 10 feet (3 m) less than when it was extended in 2001. Therefore, the accumulation of snow in the immediate camp area is about 5 feet (1.5 m) per year, or nearly 1 2/3 times the accumulation in the general area. Since wind power has been used at this site for many years, there is no telling how deeply the tower extends into the ice cap. I would guess that it goes down a minimum of 30 feet (9 m), and possibly farther.

The 3-phase AC electricity created by the wind generator is delivered to the main Weather-Port tent structure via a 6/4 (#6, 4 conductor) SO cable. The cable was buried this year in an attempt to facilitate set-up, and alleviate problems with snow removal around camp. The camp essentially gets buried with each windstorm. Everything, including the structures, must be dug out with track dozers and shovels on a regular basis. It can be a monumental effort just to keep the camp and equipment on the surface.

Extra cable is coiled on the tower, as well as on a 4 by 4 inch (10 x 10 cm) post that marks the southeast corner of the main Weather-Port structure. These extra coils of wire are there to allow further extensions as the snow continues to accumulate.

Once inside the structure, the 3-phase AC output is converted to DC by the Bergey VCS 1.5 system controller. This device is essentially a sophisticated rectifier/regulator. The nominal system voltage is 24 VDC, but the maximum voltage delivered to the battery bank has been set at 27.3 VDC, as required by the sealed gel-cell batteries.

PV System

The wind-electric system is augmented by a small photovoltaic (PV or solar-electric) system, which allows for battery charging on the relatively rare days when there is little or no wind. The location of the camp at a fairly high latitude on the ice cap creates some interesting factors for mounting a PV array. The sun changes its angle (elevation) in the sky quite rapidly over the course of the summer season. Also, by mid-May, useable solar energy is available for 340 degrees. The sun is only just dipping below the horizon before rising again. At summer solstice, there is 24-hour-a-day sun.

Tech Specs

System Overview

System type: Off-grid PV/wind hybrid

Location: Camp Raven, Greenland

Solar resource: 20 average annual peak sun hours, mid-April through mid-August

Production: 465 AC KWH per month average

Wind Turbine

Turbine: Bergey 1500

Rotor diameter: 10 feet (3 m)

Average KWH per month: 174 at 12 mph (5.35 m/s)

Peak KW rating and wind speed: 1.5 KW at 28 mph (12.5 m/s)

Wind turbine controller: Bergey VCS 1.5

Tower: 32 foot Rohn, guyed lattice

Photovoltaics

Modules: 3 Solarex SX120U, 120 W STC, 24 VDC nominal

Array: 360 W STC, 24 VDC nominal

Array combiner box: Xantrex TCB6 with 10 A fuses

Array disconnect: Xantrex DC250 enclosure with two 60 A breakers

Array installation: custom ground mount, east, south and west facing, 90 degree tilt angle

Balance of System

Inverter: Xantrex DR2424, 24 VDC nominal input, 120 VAC nominal output

PV charge controller: Xantrex C40, PWM

Wind charge controller for diversion load regulation: Xantrex C60, PWM

System performance metering: Xantrex TM500, AH meter

Engine generator: Honda EM3500, 3.5 KW, 120/240 VAC nominal, average annual run time approximately 100 hours

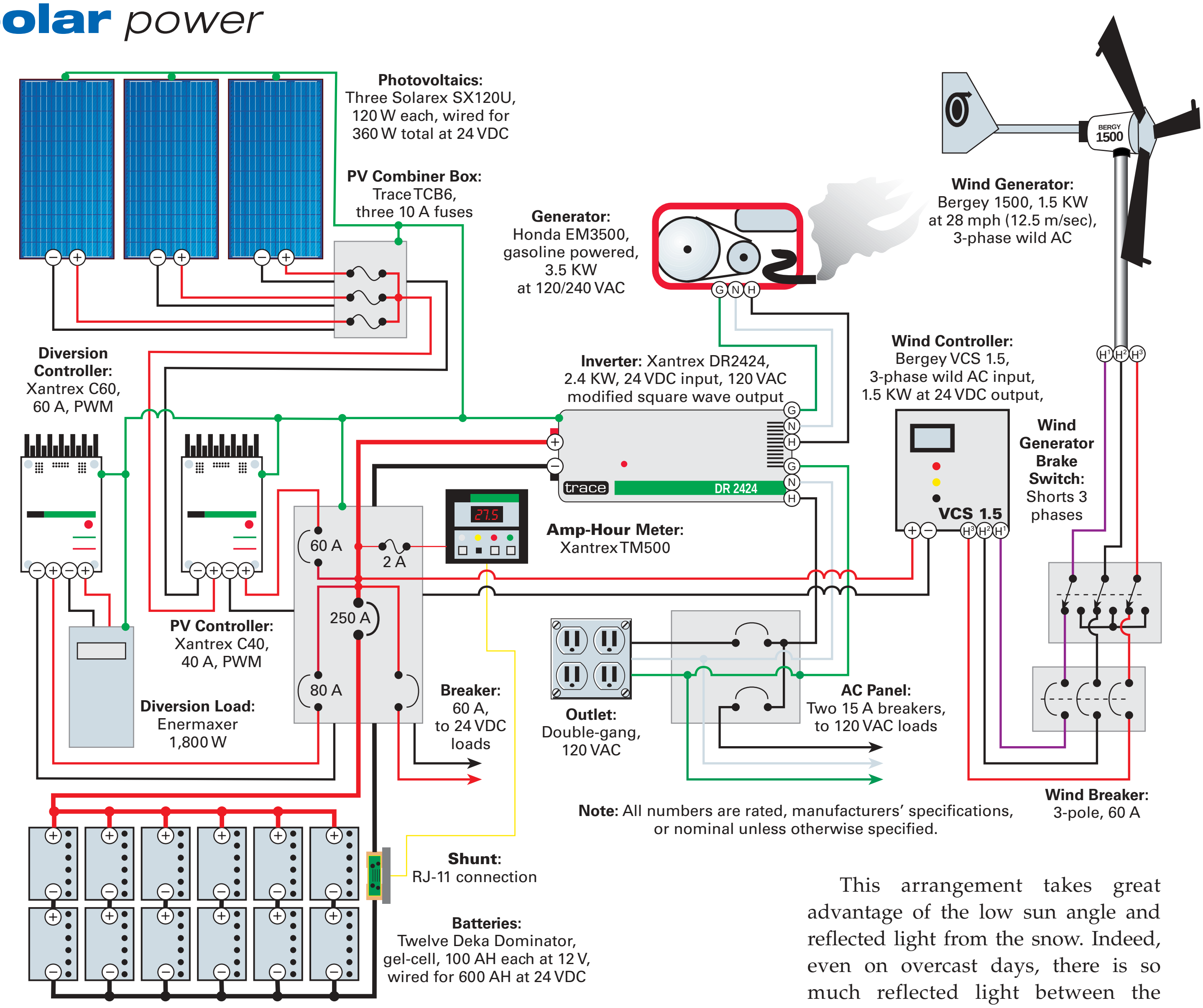
Energy Storage

Batteries: Twelve, Deka Dominator gel-cell, 12 VDC nominal, 100 AH at the 20-hour rate

Battery pack: 24 VDC nominal, 600 AH total

Battery/inverter disconnect: Xantrex DC250, 250 A breaker

A very simple arrangement is used to gain near maximum insolation over the course of the day. Three, 4 by 4 inch (10 x 10 cm) posts are set in an equilateral triangle, about midway between the wind turbine tower and the main Weather-Port (and battery bank). The three Solarex SX120U panels are mounted facing outwards from the triangle and are oriented perpendicular to the snow surface.



The RE power panel travels to the camp site almost completely assembled. It takes only six connections to make it operational.

This arrangement takes great advantage of the low sun angle and reflected light from the snow. Indeed, even on overcast days, there is so much reflected light between the surface and the clouds that the PV panels continue to produce at near maximum rated output. On a really good solar day, the reflected light, in combination with the cold temperatures, has these panels far exceeding the manufacturers' claims for sustained output.

The 24 volt panels are wired in parallel inside a Xantrex TCB6 PV combiner box. Another run of 6/4 SO cord carries the output to the Xantrex C40 charge controller mounted on the power panel inside the Weather-Port. The idea with this PV system is to provide a modest solar input over the entire course of the day, rather than the maximum output over a few hours. While it is possible to use a 360 degree tracking array, the simplicity and robust nature of this arrangement seems to make more sense for this location.

In installations I have done in Antarctica, conventional arrays, angled perpendicular to the sun, tend to act like large wings. I have actually had whole structures weighing several tons move by several meters, due to the force of the wind. It speaks to the quality of the array mount, but is a rather disconcerting experience for the occupants of the structure. Another lesson learned. If mounted on a nonpermanent structure, we typically either lay PV arrays out flat or perpendicular to the surface.

Battery & Inverter

The battery bank consists of twelve, 12 volt, 100 amp-hour batteries, wired in a series/parallel configuration. The result is a 24 volt, 600 amp-hour bank. These relatively small, gel-cell batteries were chosen to facilitate transportation by air, and because the battery bank must be assembled on site each season (carrying the batteries by hand).

The DC electricity from the batteries is converted to AC electricity by a Xantrex DR 2424 inverter. This unit is capable of producing 2.4 KW at 117 volts continuously, and can surge to nearly double that figure. This is more than enough for any loads at camp. Of course, if the inverter is used for high output purposes (such as plugging in a vehicle's block heater, running the AC space heater, electric toaster, etc.), it will very quickly deplete the relatively small battery bank, particularly if the wind generator is not producing full output. This is not to say that large loads cannot be operated, just that it requires careful monitoring of the system to ensure that the batteries are not over-discharged.

Sealed gel-cell batteries can be certified for air transportation.

Polar Code

I realize that the more code conscious readers are probably thinking, "You can't do that!" Of course *you* can't, but we can! There are many aspects of setting up a temporary RE system in this type of environment that differ from setting up a permanent system back stateside.

We used #4/0 (107 mm^2) welding cable for the DC battery interconnects and inverter cabling. The use of welding cable is pretty standard in polar environments. The cable is very tough, and remains flexible in extreme cold. It typically would not meet code back home, even though in my opinion it is a much better material to use than large gauge, UL-approved, house-type wiring. Stiff plastic insulation just explodes when you try to bend it at -40°F!

The Bergey and PV array feed into the power panel through SO type cord. The use of this type of conductor is probably not code compliant either, but it has been used fairly extensively (and successfully) in the polar regions for this type of installation. Again, it's tough and fairly flexible. It's rated UV resistant, and can even handle direct burial in snow. I don't imagine there is any UL rating for this application anyway, so we just use what works.

There is no real system grounding, because there is no real ground. Terra firma is below 7,000 feet (2,100 m) of ice. That would be a mighty long ground rod, and since it would be solid, frozen bedrock, it still wouldn't ground well. Since the electrical inspector doesn't get out this way, we basically treat the system as if it were in a boat or RV. All the normal ground points are made in boxes and fixtures. The DC load center provides the main chassis ground for the DC side of the system. The AC breaker box provides the bonding point for the ground and neutral of the AC side.

There is no use of conduit anywhere, since this system is set up and taken down annually. It has to be fast, not pretty. Many things were done to make this an expeditious setup, but they would never fly back in the "civilized" world. Readers, do not duplicate every aspect of this system for your RE system—your electrical inspector will never pass it. Still, the Camp Raven system is as safe and reliable as we could reasonably make it. It works quite well.

Camp Raven Max. Loads

DC	Watts	Hrs. /Day	Daily WH
Enermaxer DC dump load*	1,800.0	10.00	18,000.0
Engel fridge/freezer	31.2	12.00	374.4
ICOM HF radio receive	340.0	1.00	340.0
ICOM HF radio transmit	22.0	8.00	176.0
Ground band radio transmit	5.0	24.00	120.0
Telex transmit	9.5	12.00	114.0
Telex receive	80.0	1.00	80.0
Air band radio transmit	9.0	8.00	72.0
Air band radio receive	36.0	1.00	36.0
Ground band radio receive	25.0	1.00	25.0
		Total DC	19,337.4
AC			
Electric heater**	1,500.0	2.00	3,000.0
IBM Thinkpad computer	72.0	12.00	864.0
Gateway Solo computer	50.0	12.00	600.0
Microwave	1,480.0	0.10	148.0
Boom box stereo	18.0	6.00	108.0
Iridium phone transmit	5.0	12.00	60.0
3 CF lights	15.0	4.00	60.0
DeWalt charger	240.0	0.25	60.0
2 Radio charger transmit	3.0	12.00	36.0
2 Radio charger receive	28.0	1.00	28.0
Iridium phone receive	24.0	1.00	24.0
2 Radio charger transmit	2.0	12.00	24.0
Davis WX station	1.8	12.00	21.6
Makita charger	35.0	0.50	17.5
2 Radio charger receive	15.0	1.00	15.0
Coffee grinder	120.0	0.01	1.2
		Total AC	5,067.3
		Grand Total	24,404.7

* Used only when winds are high and temperatures are low.

** Rarely used; if winds are high, sun is out, temps are low.

The inverter can also operate as a three-stage battery charger. When AC electricity is applied to the inverter's AC input, via a Honda 3.5 KW generator, the inverter automatically switches to charger mode, while simultaneously energizing a 30 amp bypass relay. This allows the generator to power any loads, maximizing the running efficiency, and allowing the batteries uninterrupted charging.

The generator has its own specially built sled and vented enclosure. If the temperatures are below 5°F (–15°C), the generator must be run inside this enclosure, or the crankcase breather will freeze up. This causes the engine to become pressurized, ultimately blowing out one of the crankshaft oil seals. This was another lesson learned the hard way.

A 20 foot (6 m) long, yellow, 12/2 SO cord hangs from a pole beside the Weather-Port. It plugs into the generator with a 30 amp twist-lock plug. Two, 20 amp breakers mounted on the power panel provide overcurrent protection to the AC loads inside the structure.

DC Loads & Wiring

As many Camp Raven loads as possible run on DC, to increase efficiency. The Xantrex DC disconnect box is set up to operate as a DC load center. A 250 amp breaker provides the main disconnect from the batteries. Two 60 amp breakers are the disconnect for the solar array and a 24 VDC circuit for communications equipment.

This is a much more efficient arrangement than converting the DC to AC via the inverter, and then back to DC again via power supplies (rectifier/regulators) to feed the DC requirements of the communications gear. For example, the HF radio draws 340 watts on transmit mode when operated on DC. To operate on AC, a power supply must be added (basically a rectifier/regulator). The combined AC requirement of the radio and power supply increases the input wattage to 2,280! (It's hard to believe, but the figures were taken right out of the manual, honest.) Aside from being an incredible energy hog, it also

Dave Ricke removes the Bergey's blades at the end of the season. The generator itself will stay over the winter.

Until next year—very little other than the wind generator and the PV mount stays at Camp Raven over the arctic winter.

essentially puts an electric space heater in with the equipment we want to keep cool. We still have the ability to run all of the communications gear on AC if necessary.

An 80 amp breaker in the DC disconnect box is for a DC diversion load. When wind speeds are high, temperatures inside the Weather-Port tend to be low. By throwing that breaker, excess energy is routed to a Xantrex C60, set up in diversion mode. From there, it feeds an Enermaxer 1,800 watt diversion load. This is basically an electric space heater, controlled by the Xantrex C60. If battery voltage gets too low, the C60 will reduce output to the Enermaxer. A Xantrex system meter allows for monitoring of system voltage, amps in and out, and the state of charge of the battery bank.

The power panel is set up as a complete unit. The protective plywood box serves as the base when the panel is set up for use. It allows for easy transport when not in use. The system only requires six cable connections on site. The only downside is that it is rather heavy. It's about all two people can do to carry it across soft, uneven snow.

System Operation

While the electrical system at Camp Raven has the ability to use a backup generator, we have not had to do so for the last three years. The generator is sometimes used to operate electric block heaters on equipment, or for power tools away from the main camp. It has not been necessary to use it for basic camp infrastructure functions.

The critical camp load is the communications equipment. The equipment consists of one HF radio, two VHF radios (air and ground bands), an Iridium satellite telephone, and an Inmarsat Telex system. We also run a little Engel fridge/freezer on DC. This unit draws an incredibly small amount of energy. We could probably support a larger unit, but there is simply not enough space. Besides, there's a pretty big freezer just outside the door…

There are also numerous handheld radios that must be recharged. And two laptop computers are on fairly continuously throughout the day. One laptop has an Internet link through the Iridium phone, which allowed me to communicate with *Home Power* editors. The data transfer speed is, well—pardon the pun—glacial. The other laptop is for the Telex.

Other camp loads are fairly minimal, including a few lights (compact fluorescent), a stereo, coffee grinder, and occasional power tool use. The two heavy hitters for AC are the microwave and the electric space heater. I know what you're thinking, but the space heater is used only when wind speeds are quite high, and we have energy to burn. Hey, it's free at that point, so why not?

The load table shows all of the equipment we use. Please note that this is probably not representative of an average day. This is the absolute maximum amount of energy that we use on a busy flight day. If the winds are high enough to be using the electric heaters, the aircraft are not flying due to poor visibility (blowing snow), so the communications gear is not as active.

Basically, we have plenty of energy, as long as we recognize the limitations of the system. The system has been very reliable so far. We had a problem with fuses blowing out in the crowbar circuit of the VCS 1.5 controller for the Bergey two years ago. I called the technical support folks at Bergey from the field via the Iridium telephone. They determined what the problem was, and also advised on recalibrating the set points for our type of batteries. It was good support. We replaced the faulty unit with a new one, and had the defective unit rebuilt at the factory as a backup. There have been no problems since that time.

Global Example

The Camp Raven RE system is clean, efficient, and very reliable. It uses natural resources that are abundant here. In short, this is appropriate technology in action. The National Science Foundation's Office of Polar Programs would like to see renewable energy in more widespread use throughout its operations. It is our hope that all polar field camps will be able to go this route in the near future. It would be a worthwhile investment, for as any researcher in global climate change will tell you, as go the polar regions, so goes the world.

Access

Tracy Dahl • ts_dahl@yahoo.com • www.nsf.gov/od/opp •
See photos under "Raven 2001" at
www.summitcamp.org/photoalbum

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Arctic Sciences Section, 4201 Wilson Blvd. #755, Arlington,
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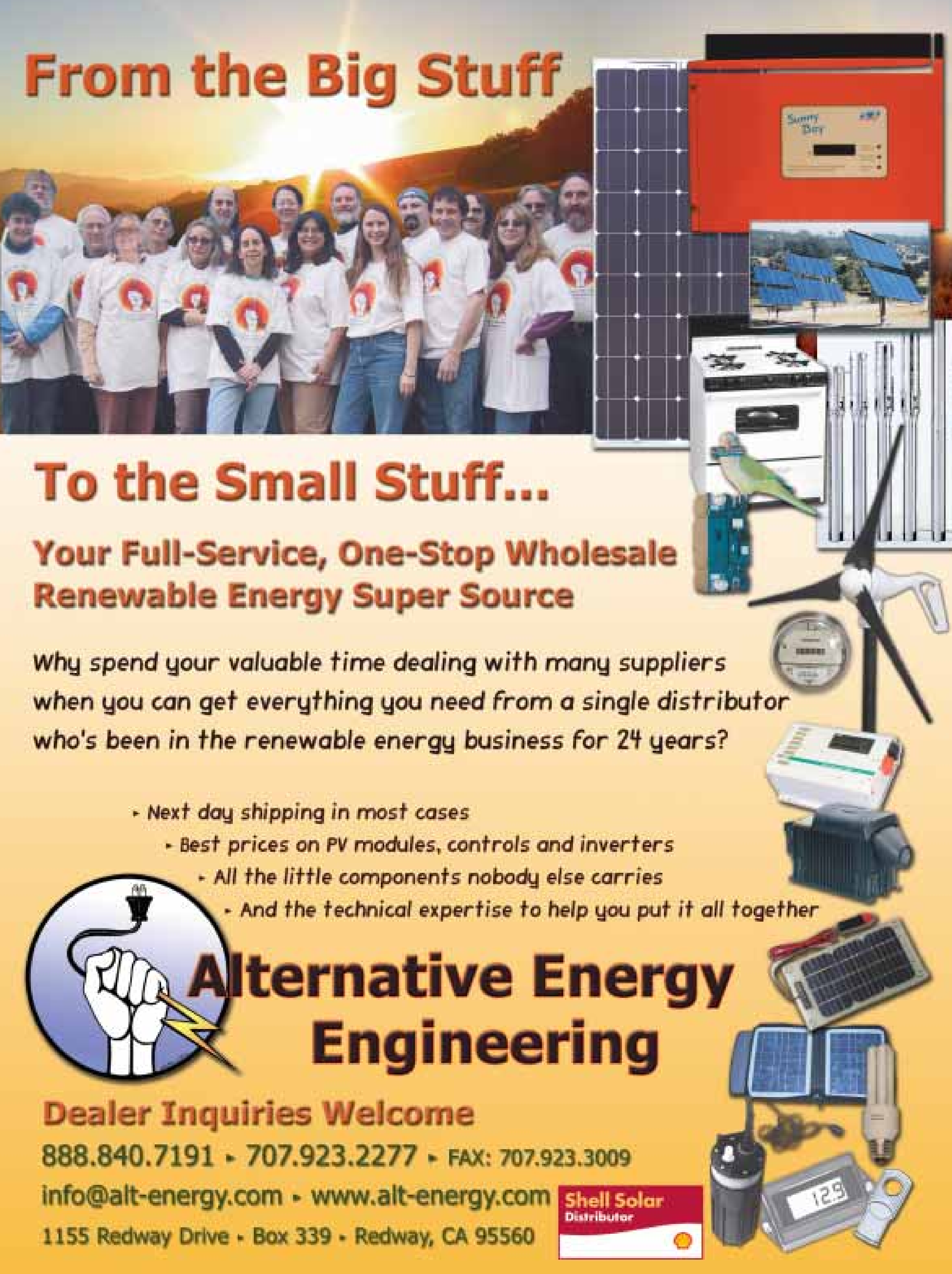

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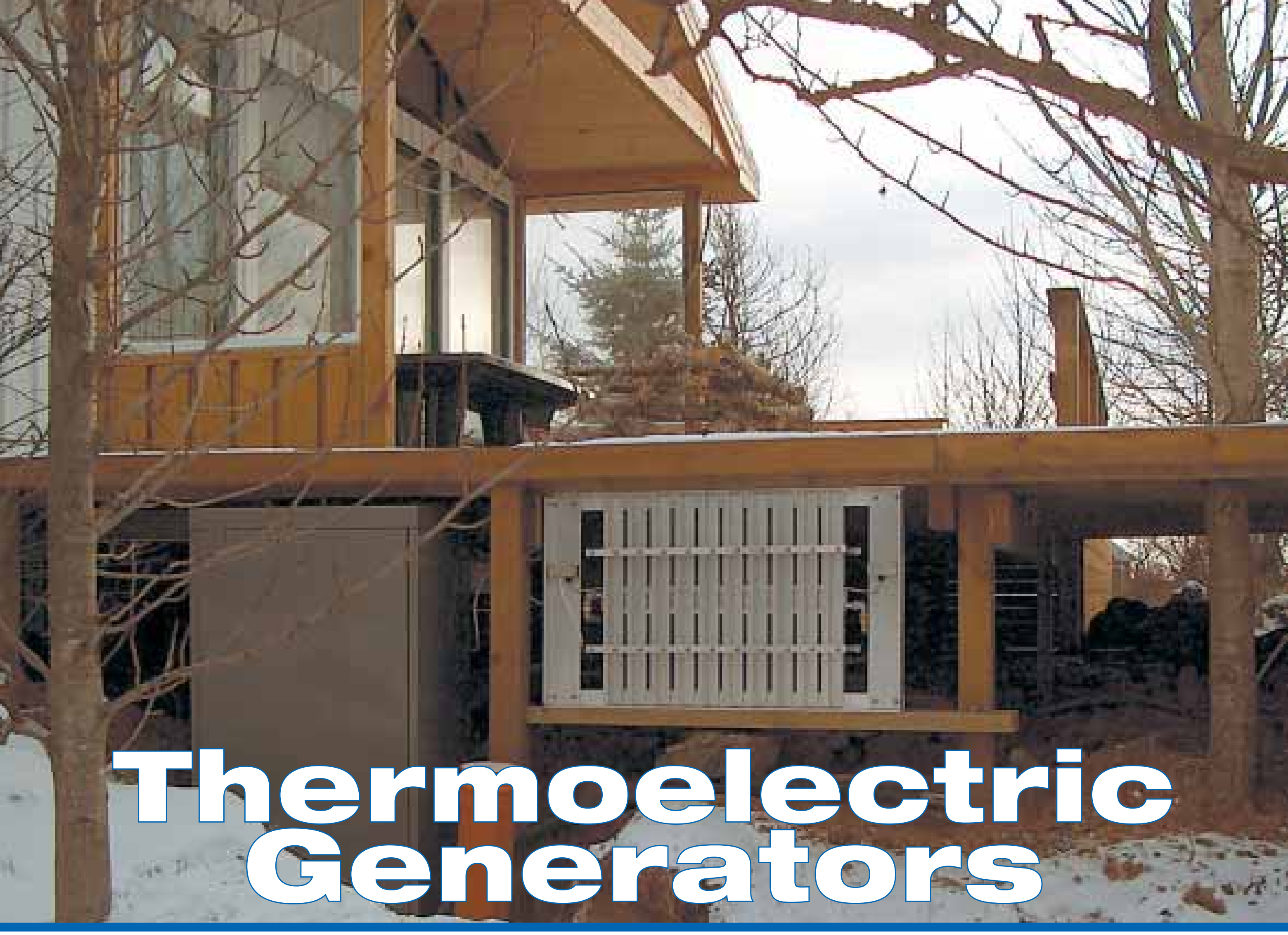


Thermoelectric Generators

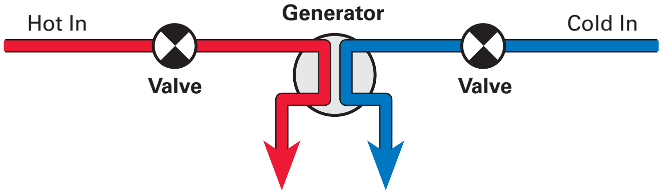
A thermoelectric generator connected to the geothermal hot water supply of a summerhouse in SW Iceland provides continuous power of 5 to 15 watts, depending on the temperature of the outside air. The most energy is supplied on the coldest days.

Bjarni Thor Hafsteinsson & Arni Geirsson

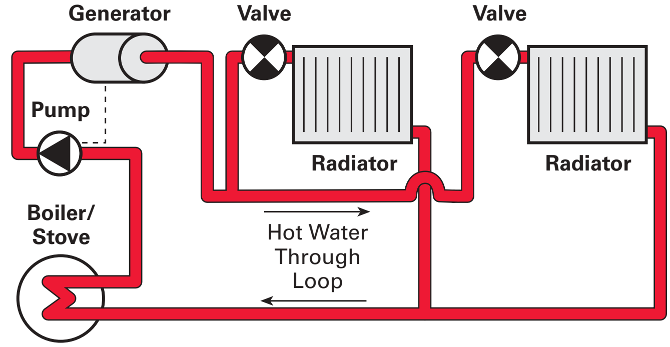
Many renewable energy enthusiasts have heard about the thermoelectric effect. It is best known for its use in cooling microprocessors in computers and food in portable refrigerators. A lesser-known reverse effect induces voltage in thermoelectric materials when one end is kept hot and the other cold.

If one side of a thermoelectric cell, often referred to as a Peltier cell, is kept hot and the other side cold, a voltmeter connected across it will show the preference of the electrons to cuddle up on the warm side. This allows electricity to be extracted from the cell as long as the temperature difference across it is maintained.

Thermoelectric Generator Applications



A thermoelectric generator makes electricity using a source of heat and a cold water flow.



A thermoelectric generator system supplies electricity to a circulation pump installed in a boiler/stove radiator system.

Possibilities & Limitations

This sounds good so far, but how much energy can we get? The honest answer is: not a lot, but it can be useful in many cases. A fundamental law of physics, known as Carnot's law, puts an upper limit on output from devices that use a temperature difference as the primary input. For example, if the difference is between boiling and freezing temperatures of water, then at most, 27 percent of the heat flowing from the hot side to the cold side can be converted into electricity.

Thermoelectric devices do even less, or about one-fifth of Carnot's maximum. Now, let's hear the good news. Thermoelectric cells are elegant in their simplicity. They are usually flat, thin, square modules, about $^1/_8$ inch (3 mm) thick and 1 to 2 inches (2.5–5 cm) on each side. With just two wires sticking out, they have no moving parts at all. Unlike turbine systems, thermoelectric cells are modular to the single-cell level, and can be used for very small systems.

Iceland: Hot & Cold

You may be thinking, "Why not have the sun heat up one side while the other side remains cold in the shade–or even with a fan?" The short answer is that for a number of reasons, you are better off converting that sunlight into electricity using photovoltaics. However, other heat sources, such as waste heat from various processes and geothermal heat, are good for thermoelectrics because they are available more consistently than sunlight, and are potentially more economical.

Iceland lies in the North Atlantic, close to the polar circle. It has abundant geothermal energy, but little sunlight in wintertime due to its high latitude. There is also plenty of cold water, and a stiff cool breeze is more common in the climate than the locals would like. The result is that Iceland makes a very interesting development site for thermoelectric generators.

Varmaraf, a small company in Iceland, has been developing such devices for almost three years. The devices turn out to be applicable much more widely than just in Iceland. The design uses geothermal water (above 60°C; 140°F) as the medium that carries heat to the device. The heat must also be carried away, and cold water is very suitable for that. Air may be more convenient in some cases, but not nearly as effective. The resulting devices have been put to good use in a number of applications.

Varmaraf's generators are unique in using water as the heat transfer medium. This makes them suitable for tapping into many heat sources. Other companies and laboratories have made experiments with water-based generators, but there have been no commercial products.

Hot condensate from a geothermal well head is siphoned through this generator to supply electricity for instrumentation.

Self-Powered Heating

The climate in Iceland, perhaps surprisingly, is cool but not cold. Houses must be heated year-round, and for that, the geothermal water offers unique luxury. In many places, there are hot water wells, and in the countryside, cottages tend to cluster in places where hot water is available. The preferred way of heating is to route hot water through wall-mounted radiators. However, such rural hot water supplies are not the most reliable, so it is usually necessary to use a closed loop with antifreeze. This loop is heated with water from the geothermal supply using a heat exchanger.

But here is the snag. Circulation requires pumping, and pumping requires electricity. In a cottage off the grid, the electrical pump could be powered by photovoltaics or wind, but in fact, a thermoelectric generator is the ideal source of electricity.

The scheme is simple. An air-cooled generator is put on the geothermal hot water supply line. This pipe is always kept hot by allowing some hot water to flow to prevent freezing. Hence, the generator charges the battery constantly.

The real beauty is that the greatest power is produced when there is the most cooling, namely in wintertime. That is also when the cottage owner needs the most heating, and the extra electricity for lighting and other things is most useful. The generator only produces 5 to 15 watts, depending on the temperature of the hot water and the efficiency of the cooling. Do not forget though, that this device is on 24 hours a day. With its round-the-clock operation, the thermoelectric generator is the equivalent of having a PV panel with an average output rating that is twenty times greater than this small generator.

Power Output

The output from a thermoelectric generator is highly dependent on the temperature difference or Delta T (ΔT) between the hot side and the cold side. First of all, the conversion efficiency is largely proportional to ΔT. This efficiency is around 3 percent at 80°C (144°F) difference, which means that 3 percent of the heat flow from the hot side to the cold side becomes electrical energy. At ΔT = 40°C (72°F), this is therefore 1.5 percent and so on.

The heat flow, of which this fraction becomes electrical energy, is also proportional to ΔT. By multiplying the two, the output from a thermoelectric cell is proportional to ΔT squared. So it is very important to receive the heat at as high a temperature as possible, and dump it at as low a temperature as possible. For the cooling, cold water is much more effective than air, but adds the extra cost of maintaining a cold flow.

This generator is water cooled for maximum temperature difference. Larger versions are available.

Not Only Geothermal

Wait a minute. Geothermal hot water is not commonly available! True. But there are useful applications where water is heated in stoves or boilers. Take a cottage with multiple rooms and a good oil stove with a boiler. Spreading the heat into the rooms with a system of radiators is a good way to ensure comfort. Creating a thermosyphon, where hot water rises from the stove and sinks in the radiators, is the classic way to maintain circulation in such systems. This requires rather bulky piping. Laying it out in a manner that ensures good function is something of a black art. Even when successful, a thermosyphon feed is slow to start and can be difficult to control.

Here, the solution is to install an air-cooled thermoelectric generator just

The Seebeck & Peltier Effects

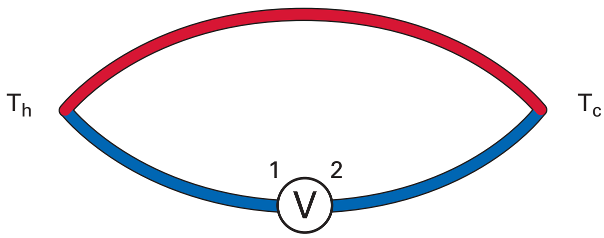
The Seebeck effect occurs when junctions of two dissimilar materials are formed, and a temperature gradient is established within the loop. This is shown in the diagram below. If the two junctions are maintained at a different temperature ($T_h > T_c$), then there is a voltage (V) created between points 1 and 2 according to the equation: $V = A\ (T_h - T_c)$.

If the loop is connected to an external electrical resistance, then electrons flow in the loop and the device functions as a generator, converting thermal energy to electrical energy. A is called the Seebeck coefficient of the junction, which is dependent upon the two materials in the loop. In order to have A as large as possible, specialized semiconductor materials have been developed and are used in thermoelectric devices.

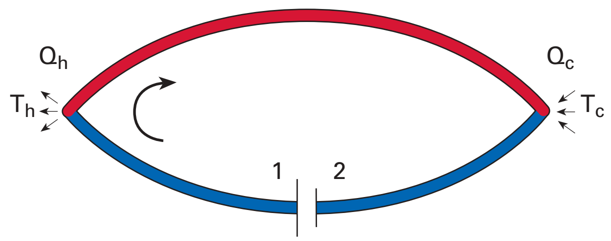
The direction of voltage and current in a Seebeck device is fixed, and there is no tendency for any reverse current operation, thus no need for diodes. The module behaves more or less like a battery with the same voltage/current characteristics.

The Peltier effect is the reverse of the Seebeck effect. In the diagram below, the same loop has been connected to a DC voltage source. When there is a current (I) through the loop, heat is absorbed at one end of the junction and liberated at the other. Thus, the device can now function as a refrigerator, pumping heat (Q) from the colder junction to the hotter junction.

Seebeck Effect



Peltier Effect



above the boiler. After the boiler is fired up, the water rises naturally into the generator, which is directly connected to a small centrifugal pump, such as an El-Sid from Ivan Labs.

In 2 to 5 minutes, enough water has risen to the thermoelectric generator to exceed the starting voltage of the pump. As it starts pumping, more hot water reaches the generator and the voltage rises. Suddenly, there is vigorous pumping in the system and the heat spreads quickly to the radiators. A small, 3.5 watt centrifugal pump, slightly modified to lower the startup voltage, does the trick. (The modification is a slight realignment of the magnetic Hall sensors within the pump.) The beauty in this arrangement is that the system is self-sufficient. No interaction is required by the user, and there is no battery to worry about.

Heat drawn from a volcano is used with cold air from a glacier to provide electricity for instrumentation and telemetry for scientists.

Electrical Interfacing

Thermoelectric cells exhibit a linear characteristic between the open circuit voltage and the short circuit current. In contrast, photovoltaic arrays have a characteristic with a "knee" at which the maximum power point is located. The linear characteristic of the thermoelectric cell results in maximum power output when the voltage under load is half the open circuit voltage, and consequently, the current is half the short circuit current. This is achieved when the external and internal resistances are the same.

The easiest electrical interfacing is achieved by wiring the cells to induce 24 volts in open circuit at the nominal hot/cold temperatures. When connected to a charge controller, the current drawn is that which drops the voltage to about 12 volts. This places the operating point at the maximum power point.

In this nongeothermal application, an oil stove heats water that rises into the thermoelectric generator to power the pump, which sends the heated water to the home's radiators, distributing the heat.

Food for the Imagination

Given a heat source, the possibilities are limited by the imagination only. Remember that it is important to get the temperature as high as possible as long as the temperature range of the thermoelectric cell is not exceeded. Putting the cell in direct contact with a hot metal surface can be difficult, and subtle thermal effects can get in the way. We have had interesting results by boiling water in a closed circuit to get 120°C (248°F) steam condensing in the generator. The condensate flows back to the boiling section.

In this application, the Thermator L generator from Varmaraf, the size of a can of beans, can produce over 30 watts continuously as long as the heat source is on. This can be an important contribution to the energy supply of a house relying on photovoltaics during the darker months.

Scientific Applications

The ultimate in these kinds of applications is to be found in the middle of Iceland's largest glacier, on a very active volcano. There, scientists have used a thermoelectric generator for about twenty years to generate electricity for instruments and telemetry. Heat is drawn from the volcano below using a thermosyphon, and is dumped into the glacier.

A new generator from Varmaraf was installed there recently. A similar generator has been used as a power supply for well-top instrumentation using the boiling hot condensate effluent from the well silencer. These can hardly be referred to as "home power," but the message lies in the versatility thus demonstrated.

Another RE Tool?

When considering thermoelectric generators:

- Check the efficiency in the context of the entire system. If the heat is supplied to the generator only, the efficiency is usually quite low. If the heat is useful after going through the generator, the efficiency is potentially much better. The best opportunities exist when the generator is applied in connection with a heating system of some sort.
- Work out the economics based on KWH per year rather than peak power.
- Check how the thermoelectric generator complements other generators you may have in matching your demand.
- Note that a successful application requires basic understanding of thermal engineering, which can be subtle and slippery.

Thermoelectric generators are an interesting addition to the options available to the renewable energy toolbox. The limited conversion efficiency puts certain constraints on feasible applications, but on the other hand, they may complement nicely other means of generating small-scale energy, especially where sunlight is scarce during wintertime. The user must be especially mindful of phantom loads that quickly eat up a large fraction of the energy generated.

The user should expect to pay at least US$20 per watt of maximum generating capacity. Varmaraf thermoelectric generators range in cost from about US$300 to US$900, depending on type and size. The energy generated is also very dependent on temperature difference, flow rate, and other factors that are different in every system. An endless variety of different system configurations are possible, since thermoelectric generators can be built into other systems, like any other plumbing component.

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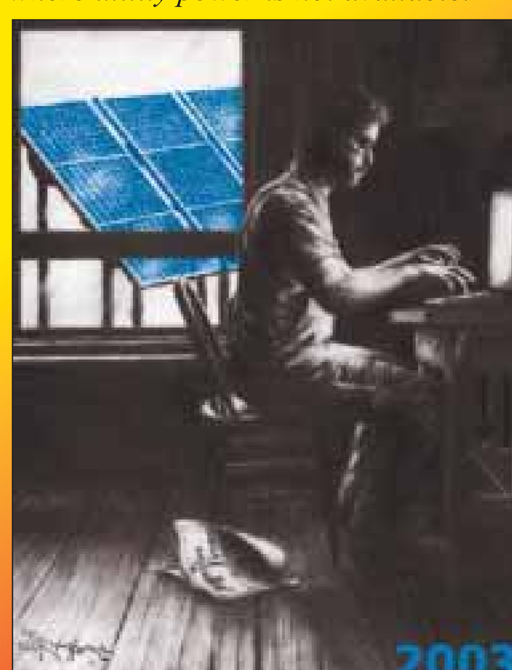
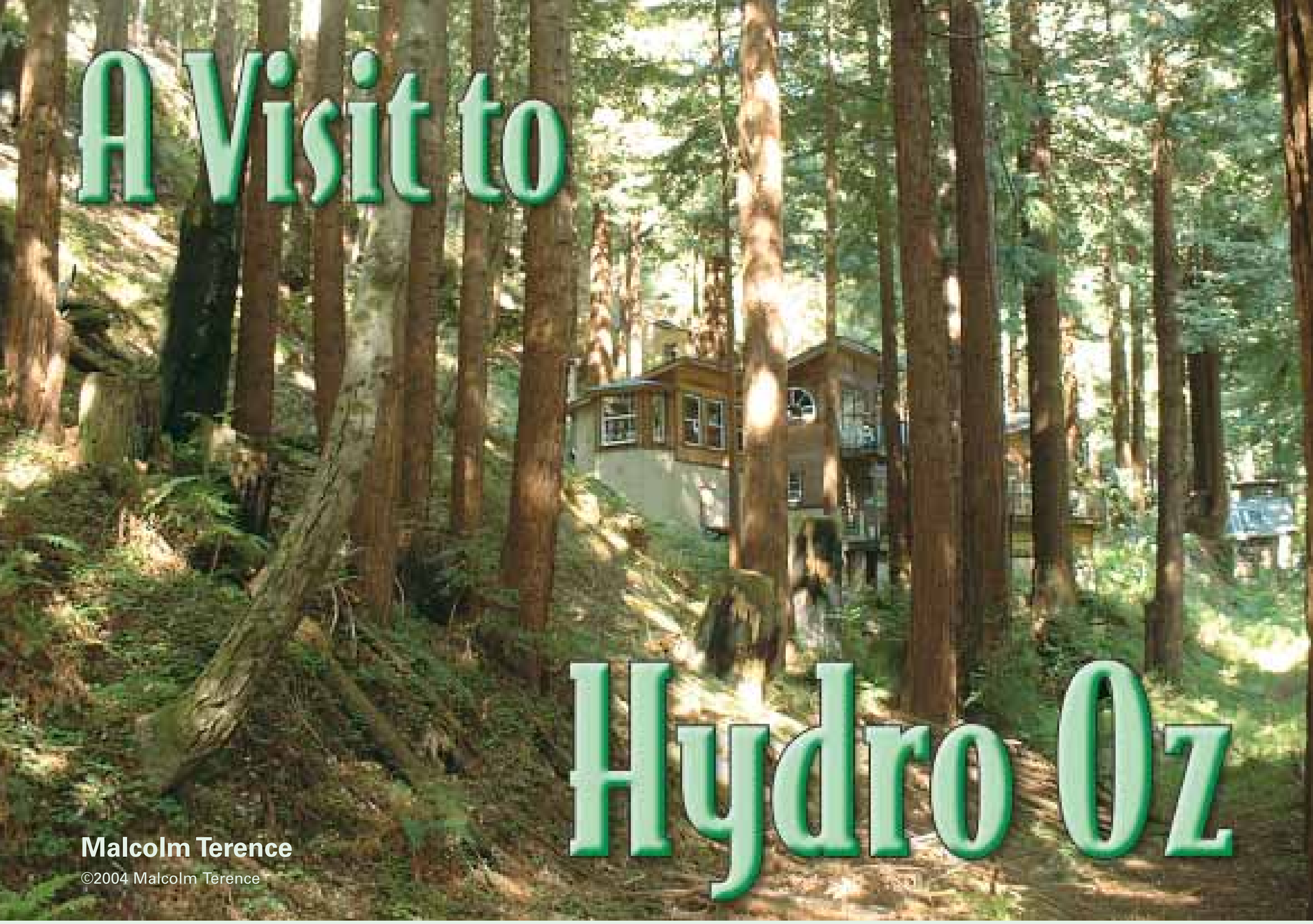
See "The Need for Winter Energy Supplement," Steve Willey, *HP36*, page 47.

FuelCellStore.com, PO Box 4038, Boulder, CO 80306 • 866-327-3835 or 303 237 3834 • Fax: 303 237 7810 • info@fuelcellstore.com • www.fuelcellstore.com • Varmaraf thermoelectric generators





A Visit to Hydro Oz

Malcolm Terence

Nestled in the tall redwood trees of a steep coastal rainforest—the perfect place to find a wizard of microhydro-electricity.

We drove down the winding, rutted, mountain road, like Dorothy and her companions approaching Oz. We had left behind sunny Santa Cruz, California, with its beach traffic and tourists, and were creeping over the ridges into a shady, steep canyon, thick with tall redwoods.

We were approaching the home and workshop of inventor Don Harris, builder of the tireless little hydroelectric plant I'd bought more than fifteen years earlier. The turbine had worked—with only a little tinkering—ever since, churning out more than 300 watts continuously at my home in Northern California.

It had delivered—let me do the math—40 megawatt-hours, and outlasted every appliance or power tool I'd ever owned. But now it was broken. We'd neglected a worn bearing too long, and the same water power we'd harnessed for years had started an oscillation that chewed up several parts in a few noisy days while we were away.

Hydro Breeder

Harris was standing in one of the few flat spots outside his home when we arrived. "Up there's where most of the work gets done," he said with a nod, "and down there is the power plant for all our electricity. This is really a breeder facility—using hydro to build hydro."

He explained that nuclear promoters in the 1950s said America could use reactors to make their own fuel and solve all our energy and pollution problems at once. Somehow Harris's claim to "breeder" sustainability seems less sinister than the nuclear industry's.

Harris' workshop, perched on a steep hillside in the Santa Cruz Mountains, is powered entirely by one of his turbines. He has produced more than 3,000 turbines here.

Harris's turbine looks like a streamlined bread machine at the end of a 2 inch PVC pipeline that snakes down out of the forest. An alternator like one in a car was bolted snugly onto its top. Hidden underneath was a small bronze waterwheel with a fringe of double cups, each the size of a tablespoon. It sat near the edge of a tiny stream channel and looked much like mine, but without the covering box I'd built to protect mine from the elements. "I leave it out in the weather and abuse it to see how it does," Harris said with a grin. "So far, so good."

The Hydro Doctor Is In

We pulled out a sack of parts from my turbine and he pored over them like a pathologist. He carefully counted and inspected the cups on the small brass waterwheel, which is the real center of the turbine. "Fifteen cups," he said. "You've had this for some time. I switched to seventeen cups to get a few percent better efficiency." He led the way up to his shop, past shelves stacked with shiny new housings and other components, and into a small room crowded with machine tools.

"I started back in 1981. Back then, I riveted the cups on the wheels. I milled the cups one at a time for the first 50 wheels. I remember I got the idea from a book called *Hydro Power for Home Use*. Nobody was building anything for small creeks. Then we switched to castings, where we build the wheels in wax and take them to a foundry where they're poured. First we used aluminum. Your wheel is the first kind we cast from bronze. Bronze was a little more resistant to erosion, and there's less electrolysis between the metals of the wheel and the alternator shaft."

The wheels with their distinctive double cups, Harris explained, were invented by Lester Pelton to win a federal design contest in 1881. Another designer, Abner Doble, refined the shape of the notch and the double elliptical catches. One of Harris' gifts is to say phrases like "double elliptical catches" to people as though they understand what that means.

Don Harris holds a turbine on its side to show the four-nozzle layout designed for sites with high flow.

This generation of Harris turbines used Motorcraft alternators. He has since switched to permanent magnet alternators for increased efficiency, durability, and reduced maintenance.

Harris said that impulse turbines such as Pelton wheels, as they are still called, and Turgo wheels are much more tolerant of wear from silt in the water. The silt has a more destructive effect on reaction-style turbines that use propellers machined to very sensitive tolerances. Then he looked grimly at the advanced wear on my wheel. "It might still have a few more years on it," he said. Deftly he ran a shaft through the center of my wheel as an arbor and tested it for balance. With the drill press he removed a little dimple of brass near the center, tested again, drilled another place, tested again, and declared it fine for use.

Since he started, Harris has built more than 3,000 of his turbines for small hydro operations all over the west and as far away as Appalachia. He started with automotive Delco alternators, switching to Motorcraft alternators for big wattage gains. Recently, he began using permanent magnet (PM) alternators for even greater efficiency.

Head & Flow

He sells a range of hydroplants that go from a 12 volt, single-nozzle model at around US$1,000 to a four-nozzle, PM model that sells for US$2,020. The variables are the amount of water and the amount of water pressure.

Don Harris demonstrates the final truing of a new bronze wheel on the machinist's lathe in his workshop.

head both at the level of wear and at the age of my unit. "We don't make them like that any more. Let me build you one and convert you to a hose fitting. It'll hold up better if you get vibration again."

Harris pulled a part out of a box on the floor and mounted it on an ancient machinist's lathe. He tugged the belt to overcome the motor's inductive load and start it in motion, and 60 seconds later he'd shaped the piece of a PVC thread/slip adapter, designed for a whole different purpose, into a near-perfect hose nipple.

"Where'd I put the hacksaw?" he asked no one in particular and said, "It's a little bit of anarchy in here," with a gesture across the cluttered shop. To Harris, anarchy is probably high praise, if not a great organizing principle for a shop.

Pressure is a function of how far vertically above the turbine the water enters the pipe—what hydro people call "head." The diameter, type, and length of the pipeline also affect the pressure that can be delivered to the wheel.

One of Harris' turbines was operated at 1,000 feet (305 m) of head at the Grand Canyon. It doesn't take very much water to generate some electricity at that much pressure. The nozzle was almost a pinhole (approximately 0.070 inches; 1.7 mm) to get 300 watts. When inquirers have less than 25 feet (7.6 m) of head, Harris often refers them to Paul Cunningham of Energy Systems & Design or Ron McLeod of Nautilus Turbines because their machines are designed for the higher flows needed to compensate for low head.

Harris reels off what he calls his basic law: potential output in watts equals head in feet, multiplied by flow in gallons per minute (GPM), divided by eight for a permanent magnet model or by ten for an alternator.

Watts = Head x GPM ÷ 8 or 10

Inefficiencies creep into the equation, he says, but because hydro works 24 hours a day, its output needs are lower than solar or wind power to still achieve the same daily energy generated. This is especially true at my home, where the sun peeks over the ridge to the south for barely two hours a day around winter solstice.

Quite a few of Don's systems operate with relatively low flow, in the 3 to 4 gpm range. But with 300 feet (91 m) of head, a Harris wheel can still generate more than 100 watts (more than 2.4 KWH per day) at these low flow rates.

Positive Anarchy

Harris interrupted his explanation to examine the next broken part in my bag, a tube that held the nozzle. A gaping hole was worn in its side from the vibration. He shook his

Don Harris' Hydro System

Don's penstock (water delivery pipe) is 1,300 feet (400 m) long, with 3 inch PVC reducing to a pair of 2 inch lines. The head (vertical drop) is 161 feet (49 m), and he uses a 5/16 inch (8 mm) nozzle delivering 21 to 22 gpm at peak flow. Don is using a single-nozzle for his permanent magnet alternator, the first one of the current series, which he built and installed two years ago. At peak flow, the hydro plant produces 430 watts of 24 volt electricity. In the dry season, he has seen his output fall to 80 watts.

He uses a 200 foot (61 m) run of #4 (21 mm^2) copper wire to carry the output to a series of 20, single-cell, nickel-iron batteries. Each is 1.2 volts and 270 amp-hours. He says they are inefficient and guzzle replacement water, but last forever and are environmentally benign. Besides, he says, they are easier to pack than an L-16 battery.

For the workshop machinery, a six-year-old Trace SW4024 inverter gives Don AC. Battery voltage is controlled with a 20-year-old Enermaxer regulator. His house nearby still uses 12 volt DC electricity, although he also uses a DR series Trace 2512 to provide some AC. On the roof of his workshop, he has installed a 900 watt photovoltaic array, but he hasn't needed them enough yet to hook them up to his batteries.

Bliss Kok, Harris' co-worker, carefully assembles the wax plug of a turbine wheel. The wax is cast in plaster, then melted out, after which the plaster mold is filled with bronze. A new wax pattern is used for each wheel.

Don told a story about installing a system in Nicaragua during the Contra War in an old Somoza regime hacienda that had been taken over by peasants. When the American-backed Contras blew up the main utility lines nearby in 1987, the Harris system generated the only electricity in the region. Soon after, Ben Linder, one of Harris's American co-workers, was assassinated by Contras. "The Contras were terrorists backed by Reagan, and the consequences of terrorism, are borne by the common people," he concluded.

Vision

Harris said the switch to PM alternators delivered higher wattage output with the same flow and pressure input. On the other hand, it has more awkward controls than the Delco-type system used on my machine, which adjusts with the twist of a knob. The PMs require stopping the turbine for each increment of adjustment. While he put the finishing touches on the hose fitting, Harris announced that he was working on a better PM system, one that came to him in a vision.

Speaking over the hum of the lathe, Harris told a long story that began, "Once I gave five rupees to a beggar in Nepal…" and ended several minutes later with "…on the way back across Utah, I saw the Tibetan priest again sprinkling out the dust." It's hard not to trust a vision for an invention that begins in Nepal and ends in the Utah desert, so Harris has dedicated months to constructing the next generation of permanent magnet turbines, machines that can be adjusted without being shut off. He pulled a prototype out of another box of anarchy in the corner and started explaining to me about magnetic lines of flux, a topic that made me long for the simplicity of double elliptical catches.

Although his father was a physicist working in optics, Harris says he is mostly self-taught, with a few harmless forays into Southern California colleges 40 years ago. "Most of what I know about mechanics and fabrication I learned from building drag racers," he said as he buffed the hose fitting, removed it from the lathe, and threaded in a $1/2$ inch (13 mm) nozzle. He handed it to me with a length of special hose and a replacement field adjustment rheostat.

Finally we had all the histories, repaired parts, and visions that we could manage, and we bid Don a goodbye with an invitation to visit our canyon further north in California someday. I remembered in the end that Dorothy's companions also got all they needed when they visited the Wizard of Oz. I felt like a modern day scarecrow. "Let's see, I needed a brain, a $1/2$ inch nozzle, and a new rheostat. Now I'm set."

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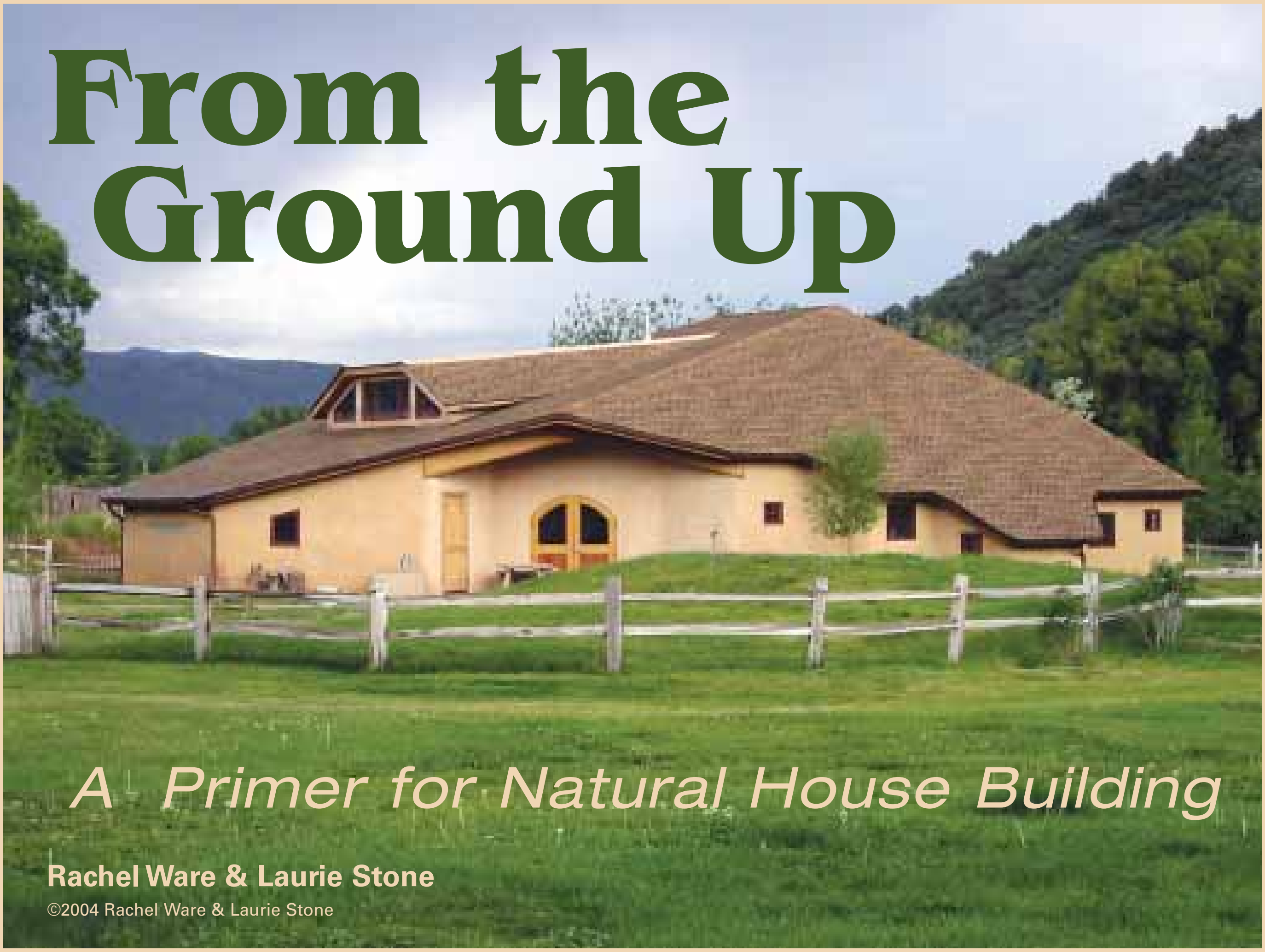
From the Ground Up

A Primer for Natural House Building

Rachel Ware & Laurie Stone



This straw bale building creates a warm, quiet, nurturing environment for kindergarten students at the Waldorf School in Colorado's Roaring Fork Valley.

Many people, especially *Home Power* readers, think about the energy they use in their home. But how many people think about the energy that goes into the materials of the home itself? Embodied energy, the energy consumed by harvesting, transporting, manufacturing, and disposal of materials, can be very high in most conventional building materials.

Fortunately, our homes don't need to be built out of just concrete, wood, and fiberglass. Building with natural materials, such as earth and straw, can reduce embodied energy and create healthy, beautiful homes. If you plan to use renewable energy and be energy efficient in your home, consider starting from the ground up. Make your house as sustainable and energy efficient as you can by building or retrofitting with natural, low-energy materials.

Many natural materials can be used in construction. Depending on your climate, you may want a highly insulating material, a material with high thermal mass, or a combination of both. Building codes and the materials available locally are also considerations. This article provides an overview of natural building materials and methods. It is the first in a series of green building articles to get you started on your way to a more natural, energy efficient, and earth-friendly home.

A Good Pair of Boots

Foundations provide a solid base to support and distribute the weight of a heavy structure. Concrete is the most common material used to build modern-day foundations. However, concrete is expensive, requires significant manual labor, and is not very friendly to the do-it-yourselfer. Portland cement (the key ingredient in concrete) has an enormous amount of embodied energy (see the table). Reducing the use of concrete in a foundation is one of the first steps an owner-builder can take when designing a natural structure. Using less concrete can reduce cost, labor, and embodied energy.

For structural foundations that are also retaining walls, using earth may not be feasible. However, many options are available to reduce the use of, or avoid using concrete altogether.

Foundations can be built with stone, over which concrete can be poured or bags of earth can be set. Generally, stone foundations are used for small houses or sheds. Dry-stacked stone is a time-tested method. Stone is strong, usually locally available, and resistant to weathering.

"Give your house a good pair of boots and a good hat."

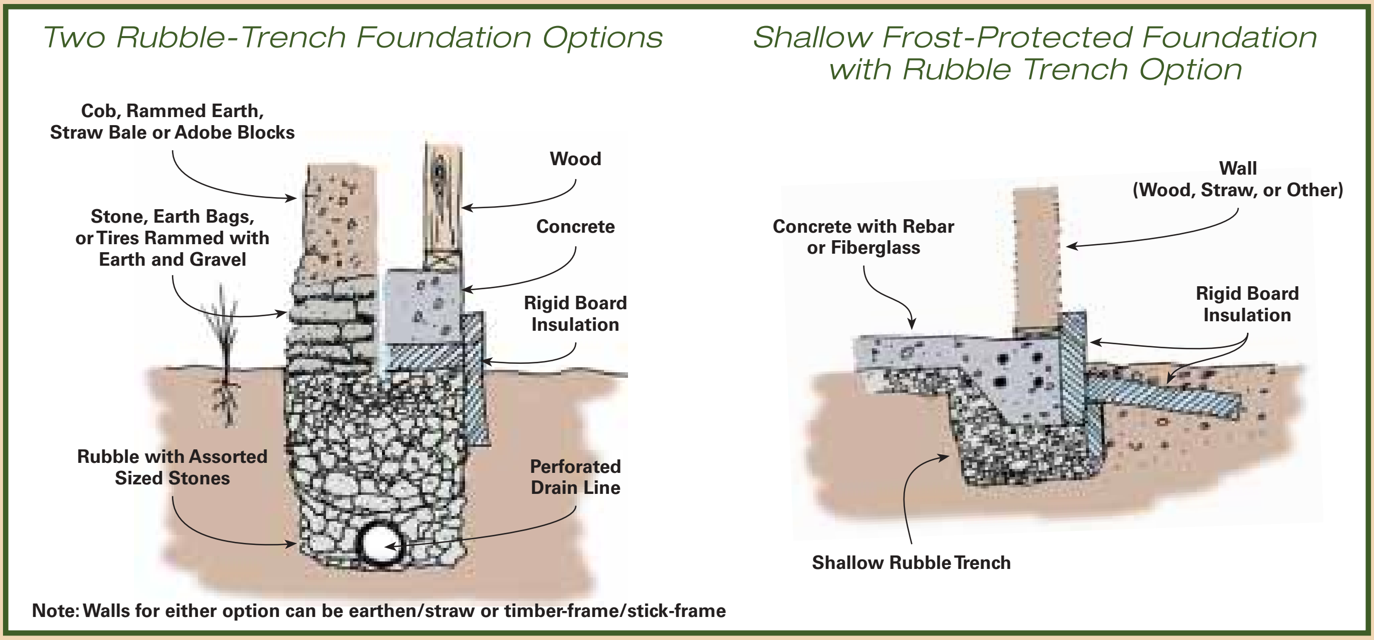
~ Old English saying

Rubble-trench foundations, popularized by Frank Lloyd Wright, are trenches that extend below the frost line and are filled with gravel and a sloped drainage pipe. A landscape fabric (polypropylene lumber tarps, burlap, asphalt-impregnated felt) should be used to line the trench and act as a filter to prevent loose soil from clogging up the drainage pipe. The "rubble" is typically washed and compacted gravel, but can also be washed stone or recycled, crushed concrete.

Rigid board insulation can separate the rubble or gravel from the concrete slab or earth bag footer that completes the foundation. You can create a "drainage path" to replace the drainage pipe by placing large stones to create an air cavity at the base of the trench. Rubble-trench foundations are not specifically addressed in U.S. building codes, but they do meet the intention of the U.S. building code. You may need to provide additional documentation for inspectors.

Shallow, frost-protected foundations are typically made of concrete, but use significantly less than conventional foundations. By insulating the perimeter of the foundation with both vertically and horizontally placed rigid board insulation, the depth of the foundation, and therefore the

This rammed earth, pressed block, home has a very cozy and inviting interior.



This still-to-be-stuccoed straw bale home will keep the Struempler family warm during the cold Colorado winters.

amount of concrete, may be reduced. This type of foundation must be designed to accommodate the soils and climates where it is used. It may be more acceptable than rubble-trench foundations to urban building inspectors.

Polypropylene bags also known as sand bags may be used as a footer to get straw bales or other natural building materials up above ground moisture. This type of foundation technique is gaining in popularity due to the ease of construction and low cost.

First, a rubble trench is created to aid in draining moisture away from below the frost line. The first two or three courses of bags are then filled with gravel or rubble. As each bag is filled, it is tamped, compacting the materials into the bag, which acts as a simple form. The upper bags are then filled and tamped with a clay and sand mixture. After placement, the bags then need to be plastered to protect them from sunlight, which can deteriorate the polypropylene in a matter of months.

A Natural Enclosure

While the foundation of a building is like a good pair of boots, crucial to the home's health, wall systems are the flesh and bones of the building, and make up the bulk of the material in a house. More and more people are turning to the natural materials of earth and straw to build their walls.

Straw Bale

Straw has been used as a building material for centuries. In Europe, you can find houses built out of straw and reeds that are over 200 years old. In the United States, the idea of building straw houses started in the late 1800s in the Nebraska "Sandhills" area in response to a shortage of lumber. These "Nebraska-style" structures used bales like bricks, and have the roof load bearing directly on their straw bale walls.

Straw is generally a waste product—it's what's left after grain is harvested. It's also a renewable resource that is grown annually. The U.S. Department of Agriculture says that straw from the harvest of major grains in the U.S. could be used to construct four million, 2,000 square foot (186 m^3) homes each year.

Embodied Energy in Building Materials

Material	Watt-Hr. / Kg
Straw bale	67
Adobe block	117
Rammed earth	117
Local stone	219
Concrete	361
Plasterboard	1,694
Portland cement*	2,167
Plywood	2,889
Fiberglass insulation	8,416

*Worldwide production of cement is estimated to be responsible for 7 – 10% of the world's CO_2 emissions, second only to electricity generation.

Source: Centre for Building Performance Research

Straw bale homes can be extremely energy efficient. Straw has very high insulating properties. Testing indicates that a 2 foot (0.6 m) thick bale has an R-value of 2.4 per inch, or over R-50 total. While R-values are often debatable, this beats a wood frame wall with R-19 batts by a factor of three. Overall, plastered straw bale construction creates an excellent building envelope. It creates high R-values, a nonconvective wall section, a low air leakage rate, and high levels of thermal mass.

There are two basic ways to build with straw bales. One is the Nebraska style, which uses the straw bales as the load bearing structural walls. The more common method is stick-framed or post and beam construction, using the straw bales as an in-fill system, where the bales are not load bearing. The post and beam construction supports the roof. The straw bales merely act as an insulated wall between or around the structural posts. The posts and beams can consist of rough-cut timber, peeled logs, square or round posts, or metal elements.

Adobes drying in the sun.

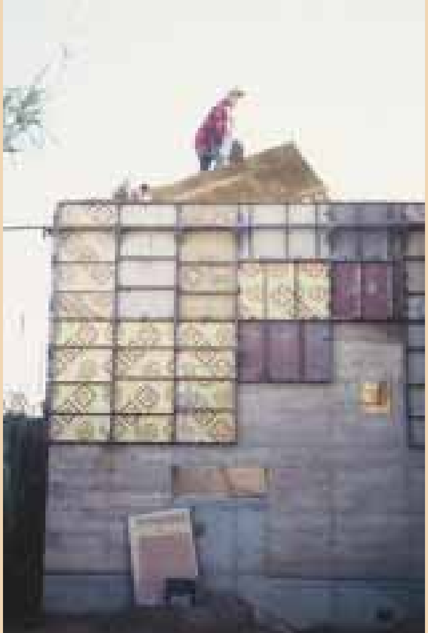
Left: Putting up an adobe wall.

Right: Making adobe blocks in a wooden frame.

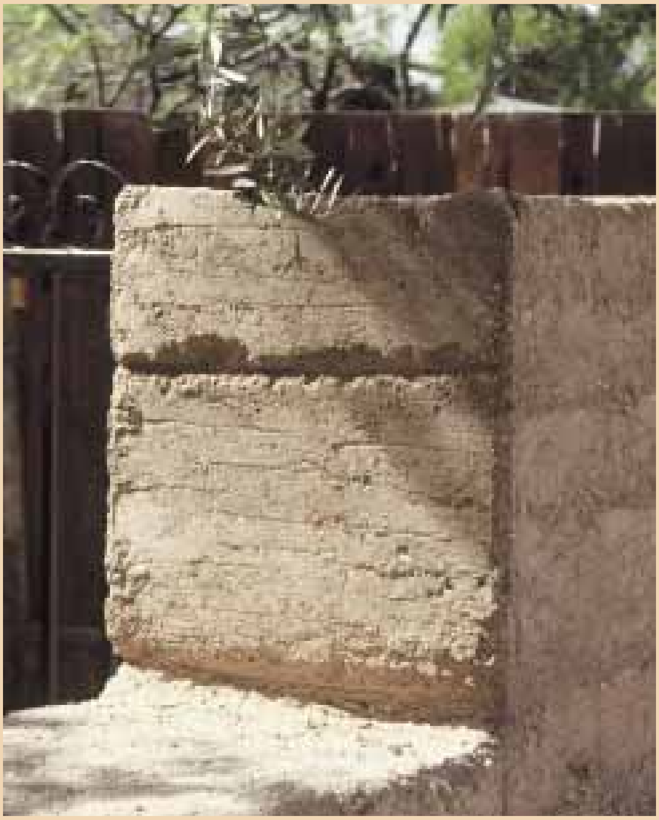
Adobe & Rammed Earth

Adobe blocks are clay, sand, straw, and water mixed together into a pourable condition, shaped in a mold (or by hand), and dried by the sun. The resulting blocks can be almost any shape or size, but are normally 14 by 10 by 4 inches (36 x 25 x 10 cm). They can be laid up with cement or mortar made of clay, sand, and water. Adobe, because of its thermal mass properties, has the ability to absorb, store, and release heat. Adobe bricks absorb the sun's heat during sunny winter days. When the temperature drops at night, the bricks radiate their heat into the home. Likewise, adobe construction helps keep homes cool in the summer, acting as a heat sink.

Rammed earth walls also have very high thermal mass. They are created by tamping earth, stabilized with a small amount of Portland cement (about 5 percent), and lubricated with a small amount of water, into forms defining the walls. Rammed earth walls are typically 24 inches (61 cm) thick, labor intensive, and require extensive forming and tools. Modern techniques for rammed earth use heavy machinery (loaders), pneumatic tampers, and commercial steel or wood forms.



Left: Rammed earth construction typically requires industrial forms.



Right: A 24 inch thick rammed earth garden wall ready for stucco.

Building Codes

David Eisenberg ©2004 David Eisenberg

The common perception is that building codes are inconvenient and restrictive. To some degree they are, especially when you are proposing natural building materials or systems, or things outside what is specifically covered by the codes. However, you may find that building officials are curious and eager to learn more about natural building and the durability, health, and safety of alternatively built homes.

Remember, building codes are designed to protect the health, safety, and welfare of the public. Alternative systems pose a challenge to building officials for the following reasons.

The perception of risk. What is unfamiliar represents the unknown, which always appears riskier than the known, even when it isn't.

The burden of the process. Gaining formal code acceptance for an alternative building material or system requires a long, extensive, and costly process. Few "natural" materials or building systems have access to the kind of financial or organizational resources that more mainstream, industrial products have, so they usually lack any official sanction or approval.

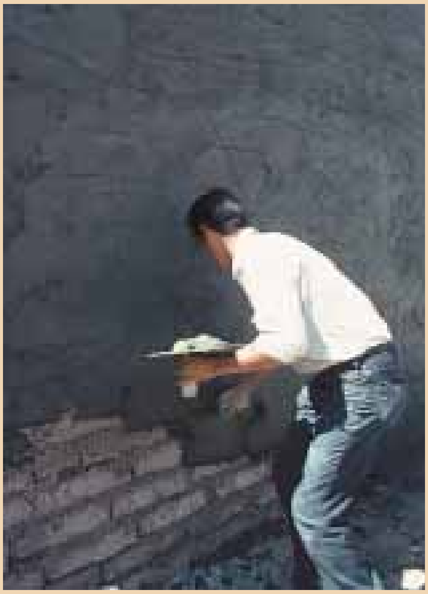
Information limitations. Alternatives typically have less technical information available on which building officials can rely to judge the adequacy of the proposed new material or method.

Time limitations. Building departments ordinarily have limited time to deal with conventional plans, much less the unusual ones requiring more time, attention, and documentation.

The status quo. It's human nature to take comfort in what is familiar. There will always be some level of resistance to anything new or different.

David Eisenberg is the executive director of the Development Center for Appropriate Technology (DCAT).

Rammed earth can also be used to make pressed blocks, using hand-operated or motorized hydraulic machines. Often the blocks can be made from soil taken directly from the building site. Earth is fed into a block machine, which compresses it and reduces the volume by 30 percent. After they are pressed, the blocks are set aside to cure. The building process is the same as with adobe blocks.



Stucco can be lime, gypsum, or natural earth.

Straw-Clay & Cob

Straw-clay and cob combine the thermal mass qualities of earth and clay with the insulative quality of straw to make an exceptional building material. Modern straw-clay construction is considered a European building system. It is a nonstructural insulation/mass system that compresses a mixture of clay and loose straw into a wall cavity. Compressed straw is coated with a clay slip and compacted into temporary wooden forms. The mixture typically consists of approximately 80 percent straw and 20 percent clay.

The word cob comes from an Old English root meaning "a lump or rounded mass." It's a simple, traditional, building technique using hand-formed lumps or loaves of earth mixed with sand and straw. Traditionally mixed with your feet, cob differs from straw-clay in that the mixture typically consists of approximately 80 percent clay and 20 percent straw. It dries to a hardness similar to "lean" concrete, and is used like adobe to create self-supporting,

A straw-clay wall with one side of the form removed.

Having fun mixing cob the traditional way.

load-bearing walls. Cob has been used for centuries throughout Western Europe, even in rainy and windy climates, as far north as the latitude of Alaska. It is also a great option for interior partition walls.

When you build walls of cob, it is recommended that you construct your wall in lifts, applying a few feet of material at a time to prevent slumping, and letting each lift, or course, solidify overnight. Depressions need to be jabbed into the top of the damp course, and then the next course will have something to "key" into. With cob, the wall is typically wide at the base and becomes narrower with each course.

Making cob "loaves" that can be thrown to a person on a ladder.

Bamboo

As Darrel DeBoer describes in *The Art of Natural Building*, bamboo is an extremely strong fiber, having twice the compressive strength of concrete and roughly the same strength-to-weight ratio of steel in tension. Among its numerous benefits, bamboo is:

- Renewable: it will grow 10 to 12 inches (25–30 cm) a day once a grove is established. The living stalks can be harvested within three to four years.
- Versatile: It may be manufactured into boards to be used in floors, walls, and roofs.
- Available worldwide.

In traditional Japanese farmhouses, bamboo was used for structural components, roof trusses, and rafters. In the U.S., bamboo has mainly been used as flooring or as an alternative to rebar in straw bale and earthen walls.

Used as trim, bamboo can add exotic beauty to a home.

Photo courtesy of David Eisenberg of the Development Center for Appropriate Technology (DCAT).

Natural Plasters

Cedar Rose Guelberth & Dan Chiras

Natural plasters, those made from natural materials that generally require very little processing, include three basic types—earthen, lime, and gypsum. The oldest type of wall finish is earthen. It was often used by early builders to protect and beautify walls because its components—sand, clay, and fiber—were readily available throughout the world.

Over time, builders began to experiment with various materials to create effective, durable plasters. One locally available substance was gypsum, used for interior plaster and to make decorations on walls and ceilings. Another was limestone. Lime, when mixed with water and sand, makes an excellent durable interior and exterior plaster and mortar.

Most earthen plasters consist of clay-rich dirt, sand, and fiber mixed with water. Clay is the binding agent and waterproofing, sand adds the structural strength, and fiber provides tensile strength and reinforcement. Fiber can consist of materials such as dry straw, hemp fiber, cattails, coconut fibers, or animal hair.

Other additives are often used to improve the quality of plaster. Cooked flour paste, milk powder, cactus juice, manure, and oils can all increase the workability, durability, and water resistance of an earthen plaster. The proportions of these ingredients in your plaster will vary depending on the ingredients themselves.

The advantages to using an earthen plaster over a synthetic or cement based stucco, are numerous. Earthen plaster is:

- Protective
- Durable
- Recyclable
- Easily repairable
- Easy to clean up after
- Safe to work with
- Fun to work with
- Inexpensive
- Breathable
- Easy to sculpt and carve
- Environmentally beneficial

Cedar Rose Guelberth & Dan Chiras are the authors of The Natural Plaster Book.

Wall R-Values

Construction	R-Value
Straw bale	42.7–70.3
Wood frame, 2 x 6 in. studs w/ R-19 batts	15.4
Adobe, 10 in. thick walls, insulated	11.9
Wood frame, 2 x 4 in. studs w/ R-11 batts	10.2
Adobe, 10 in. thick walls, uninsulated	3.5

Source: U.S. Department of Energy

Recycled Materials

It is important to remember that some materials that may not be considered "natural" are also used to build sustainable, energy efficient, and quality buildings. Using recycled or second-hand materials will cut costs, reduce waste, and greatly lower the amount of embodied energy in a building.

Not only are you reducing the amount of energy it takes to manufacture a new product, you are negating the amount of energy it would have taken in disposal of the reused material. Used tires and aluminum cans (used in Earthships) are only some of the recycled products that can be used to build energy efficient sustainable homes.

A Healthy Coat & A Good Hat

Once the walls are up and the roof is on, it's time to put a healthy coat on your home. Covering a natural home with cement-based stucco is one option. However, there are many ways to cover a home with natural plasters. The three basic types of plasters—earthen, lime, and gypsum—can be used on interior and exterior walls. They are durable and weather-resistant (see sidebar).

Most homes built out of natural materials have roofs that use conventional architecture and materials. It is important to have larger than usual overhangs. Large overhangs prevent bulk moisture damage to walls and foundation systems. Another important detail is where the natural wall meets the roof. There are many design considerations to this detail, and this will be covered in a future article.

Natural Solutions

The most important thing to remember is that you don't have to pick only one of these building materials. Hybrid solutions, such as a straw bale home with cob to round out the corners, or an adobe home, with a straw bale northern wall for insulation, might work best for your location and climate. Whichever natural building materials you choose, you're sure to have a comfortable, beautiful, energy efficient home just waiting for a renewable energy system to power it.

Access

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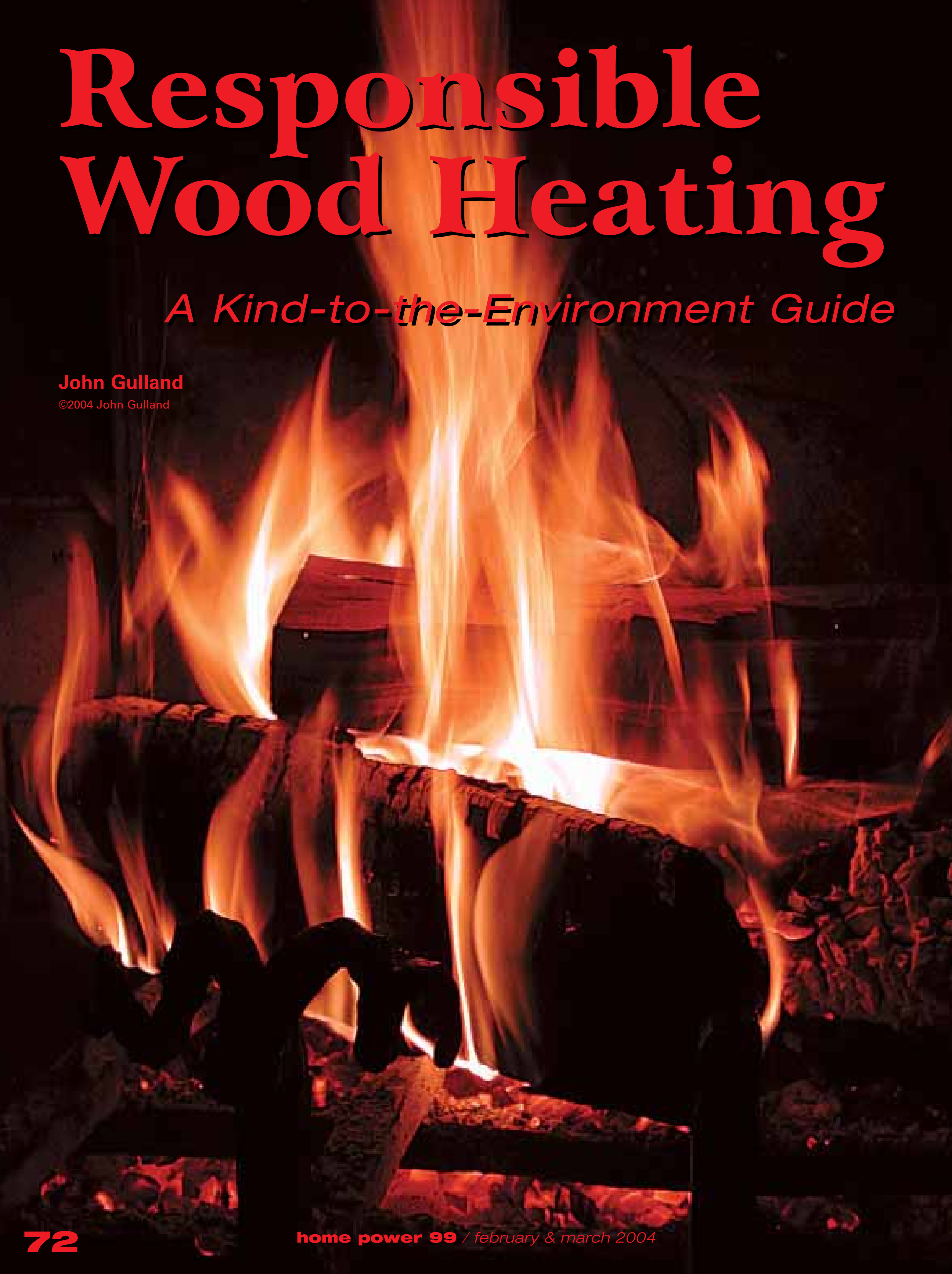
Responsible Wood Heating

A Kind-to-the-Environment Guide



John Gulland

Wood energy is the black sheep of the renewable energy family. Of all the renewable options, it causes environmentalists the most discomfort. Mostly they worry that burning wood means making a lot of smoke pollution and cutting down precious trees for fuel. Besides, woodstoves are not as technologically sexy as glittering solar panels and whirling wind turbines. As one anti-wood burning activist said at a public meeting, "We need to look to new sources of energy, not old ones."

But wood can be a renewable fuel, and as all renewable energy aficionados know, there aren't too many options available, especially ones good at providing bulk heat. In practical terms, households hoping to run on renewable energy in moderate and cold climate regions will likely rely on wood fuel to some extent.

Copco Dave uses only a couple of cords a year to heat his mountain cabin in southern Oregon. An efficient Jotul woodstove provides lots of heat from not much fuel.

Can Wood Be Good?

The main gripe about wood heating is the smoke, which can cause problems in your community and among neighbors. At the community level, topography and climate can conspire to trap smoke close to the ground. The pollution is visible, unpleasant, and downright unhealthy, especially for children, the elderly, and those with respiratory sensitivities.

A different kind of problem arises when one household's wood smoke is so dense that the neighbors are driven indoors, and even there the smell permeates clothes, rugs, and drapes. Both problems are serious, and together they give wood burning its bad name.

An EPA certified insert can convert an inefficient fireplace into a clean burning, energy efficient source of heat.

Clearly, the unreserved promotion of wood heating in all locations and circumstances is not environmentally acceptable. Even venturing to say something mildly positive about home heating with wood opens the door for criticism in some circles.

Acknowledging that heating with wood is not a good option for everyone, everywhere, how do you go about judging suitability in your particular case? A concise set of criteria to guide decision-making, or even to guide a discussion of the issue is a good place to start.

Three Myths & Four Questions

It might be useful to clear up three common myths:

- Wood heating involves simple equipment at the level of folk technology.
- Installation of wood heating systems entails only the application of common sense.
- The skills needed for successful heating with wood are intuitive.

In truth, effective wood heating is neither simple, "just" common sense, nor intuitive. Effective wood heating technologies are not simple. In fact, it is *simple* wood burning equipment that makes too much smoke and is

In Medford, Oregon, an inversion layer frequently traps auto, industry, and wood burning emissions, creating air quality problems. This can be mitigated somewhat by practicing environmentally responsible wood burning.

terribly inefficient. Common sense in the absence of proven technical guidelines for woodstove installation can cause house fires. And if anything, bad wood burning habits seem to come naturally. I've been building and maintaining wood fires every winter for almost thirty years, and I'm still learning. Maybe it's intuitive for some people, but not for anyone I know.

To make a sound decision about whether to burn wood or not, you'll need to answer these four questions:

- Should you even consider burning wood where you live?
- What kind of device should you burn the wood in, and how should the installation be arranged?
- What is an appropriate source of firewood, and how can you get some?
- How should you operate the wood heating system?

Each of these is a big topic, justifying its own article, so in the interest of brevity, this article will just skim the high points.

Should You Consider Wood Heating?

If you live downtown in a multi-story building, forget about wood heating. Even if it were physically possible, it wouldn't be responsible. Even in detached houses, urban wood heating can be problematic, unless you opt for a pellet stove, which is capable of very low emissions. Wood pellets are produced from sawmill waste, which is dried, ground, and compressed. Packaged in 50 pound (23 kg) bags, they are easier to transport, manage, and store than firewood in urban environments.

In general, wood heating works best at the urban fringe and beyond, but even using that criteria, there are limits. For example, if your nearby urban area has frequent air quality problems in winter, you might want to consider other options that have less local impact. If you're unsure about whether wood heating would be suitable where you live, consider this: if all your neighbors also decided that wood heating was a good idea, would it make your area a less pleasant or healthy place to live? If so, look for other options.

Also worth considering is the fuel supply. Wood heating is best done in a local context, so the fuel supply, in the form of standing trees, should be reasonably close to where you live. If your area is not well forested, other heating options would be better.

So, if you don't live in town, and your region doesn't have winter air quality problems, but is forested, then hey—wood heating might be for you.

Selecting & Installing the Right Equipment

Selecting wood heating equipment is when many costly mistakes get made, and is the source of one of the most common pitfalls. Strictly decorative or recreational wood burning is not environmentally appropriate. Conventional fireplaces without heat recovery are inherently wasteful and polluting. The goal is efficient, low pollution wood heating, and you can't do that with a conventional fireplace.

A word about houses—we shouldn't allow our houses to waste energy, because virtually all energy use produces environmental impacts. It is relatively easy these days, using standard building materials, to create a snug, efficient house, the very kind that is best suited to wood heating.

The most efficient form of wood heating is space heating with a woodstove, as distinct from central heating with a furnace. Ideally, the heater is located in the most lived-in part of the house, typically the central area consisting of the

A selection of freestanding, EPA certified woodstoves at Orley's Stoves & Spas in Medford, Oregon.

kitchen, living, and dining rooms. This arrangement makes the space where you eat, relax, and entertain the warmest in the house, while utility areas and bedrooms stay cooler. A moderately sized, energy efficient house can be heated comfortably with a single, well-located woodstove.

A chimney is an important part of heater operation—it is not simply an exhaust pipe. Think of it as the engine that drives the wood heating system. Straight chimney systems provide the most reliable, maintenance-free performance. So locate the chimney directly above the stove location so the flue pipe and chimney run straight up from the stove flue collar. This arrangement produces a quickly building, strong draft, with no back drafts and much less chance of smoke rollout when the door is opened for loading. Plus, maintenance is reduced—in thirteen years of use, my chimney has never had a brush through it, although I check for creosote build-up often. Straight-up chimney systems give the kind of performance we all want.

Getting the right heater is important, and fortunately, the general criteria are fairly simple. Look for anything that is certified for low emissions by the U.S. Environmental Protection Agency (EPA). A good selection of EPA certified woodstoves, fireplace inserts, and factory-built fireplaces is available. Not only will an EPA certified heater emit about ninety percent less smoke, it will deliver up to one-third higher efficiency than the old parlor or airtight stove. You'll get more heat from less wood and make less pollution in the bargain.

If you are a fan of masonry construction, you could consider a masonry heater, which cannot be EPA certified because of their design features, but which have been shown to burn clean and provide efficient heating. A masonry heater is a specialized design in which a fire is burned rapidly and the heat is absorbed by tons of masonry mass for gentle release over the next 12 to 24 hours.

You'll need help selecting the right heater. For stoves, inserts, and fireplaces, visit as many specialty hearth retailers as you can, and hear what the sales people have to say. If you are able to visit at least three, their relative competence will probably be revealed. I suggest you pick the dealer you trust first, before making the final product decision. A good dealer can offer you workable options. Then it is up to you to select what you think works best for you. Because the stove, insert, or fireplace will become an ever-present member of the family, you'd better like the look of it.

Minor differences in smoke emission ratings or in published efficiency figures don't really mean much, considering that your fuel and operating practices will have such a large effect on performance. Find a good dealer, listen to his or her advice, and pick what you like, as long as it is EPA certified. Chances are good that you'll be satisfied.

If a masonry heater is more to your liking and within your budget, contact a member of the Masonry Heater Association of North America. In my experience, heater builders are talented, committed individuals who could make a lot more money in some other line of work if they didn't insist on doing what they love.

A U.S. Environmental Protection Agency tag like this one identifies a clean burning heater. The efficiency rating is an average and is not meaningful.

Identifying Appropriate Firewood

Wood is considered to be a renewable fuel and almost carbon dioxide neutral because trees absorb CO_2 when they grow. When trees mature and fall in the forest and decompose there, the same amount of CO_2 is emitted as would be released if they were burned for heat. In heating our houses with wood, we are simply tapping into the natural carbon cycle in which CO_2 flows from the atmosphere to the forest and back.

When wood fuel is used to displace the use of a fossil fuel, the reduction in net CO_2 emissions occurs quickly because of the increase in the rate of growth (and therefore the rate of CO_2 absorption) where trees are removed from the forest. Advanced wood heating technology enhances the effect since it allows you to burn less wood and at the same time conserve energy produced from fossil fuels.

Appropriate firewood is produced using sustainable forest management practices. The integrity of the forest, including the trees, the soil, and the site, is maintained and species diversity, both plant and animal, is maintained or enhanced. While this may seem like a tall order or a utopian vision, the fact is that sustainable forestry management has been practiced for decades in thousands of private woodlots across North America. Farmers' woodlots that look the same today as they did fifty years ago are really the proof of good forest management practices.

A healthy forest yields tons of biomass each year, some of which can be beneficially diverted for home heating. This forest in Oregon's Cascade mountains has been sustainably logged by the same ranching family for more than 100 years.

The other major source of firewood is logging operations that produce lumber, pulp, or veneer logs. In these operations, there is always waste produced, such as trees that are rotten in the center or are damaged by road and trail building, and the tops and branches for which there may be no commercial market other than firewood. While these logging operations do not necessarily use sustainable methods, many do, and the damage would be done whether or not some of the waste wood is diverted as firewood.

The key to understanding sustainable forestry is to view the forest not as a museum containing exhibits, but as a living community, which like all communities, is constantly evolving. Climate, soil quality, and site characteristics vary widely, but many of the forested areas of North America are highly productive, meaning that a lot of firewood can be removed each year from each acre, while the quality of the stand and wildlife habitat are enhanced.

In practical terms, sustainable forest management can be described as uneven age selective harvesting. It means removing damaged or diseased trees and thinning concentrated stands of single species, while leaving seed trees of all present species and some standing dead trees to provide wildlife habitat. Woodlots in farm country generally conform to this prescription. If you can get your firewood from a farmer, there is a good chance that it comes from a sustainable source.

One man's slash.... Gathering firewood from a logging slash pile, which usually gets burned anyway, will put that wood to use while helping to clean up an unsightly mess.

Those of us who heat homes with wood can do our part for sustainability by pressuring our firewood suppliers to prove that the wood they sell comes from a sustainable source. If many of their customers asked questions about sustainable forestry, firewood dealers would soon pressure their suppliers, and the public will would be expressed within the firewood market.

Firewood should be cut, split, and stacked in an open area in early spring to be ready to burn in the fall. Very hard woods like oak may take longer, and drying in damp climates can also take longer than just the summer months.

Here is one final suggestion about sustainable firewood. Ugly woodpiles that include wood from less desirable species tend to be more sustainable than perfect piles of maple or oak with regular pieces in the classic wedge shape. This is because straight lengths of these high-value, slow growing species should be used for furniture, not wood heating.

Ugly woodpiles are created by using everything, right down to 2 inch (5 cm) diameter sticks, and including all the bent and twisted sections of the tops. Although I live in sugar maple country, my firewood is mostly white birch and poplar because I have a lot of them on my property, and because they mature in about 35 years and then fall over. I just catch them for firewood before they fall.

Regarding fuel other than firewood, don't burn it. Burning waste paper, or even worse, general household trash, produces elevated emissions of dioxin and other nasty toxic gases. Burning saltwater driftwood has the same result. Burn clean, dry, uncoated, untreated wood and just enough newspaper to light the fires.

Operating a Wood Heating System

What day-to-day practices produce less smoke and higher efficiency? There is no simple formula for building and maintaining fires that deliver maximum heating efficiency and minimize smoke, except to say that wood should be actively flaming until it is reduced to charcoal. (See www.woodheat.org to learn about the top-down fire starting technique and more wood burning tips for maximum efficiency and minimal smoke.)

The design differences among woodstove models and chimney configurations, and differences in firewood and heat demand all have their effects on wood burning practice. That is to say, we users must adapt to conditions and learn by experience the best way to operate our wood heat systems to achieve the twin goals of high efficiency and low emissions. Given that limitation, however, here are some general guidelines that might be useful.

EPA certified woodstoves differ greatly from those built up until the late 1980s. These advanced stoves achieve higher combustion efficiency and fewer emissions by burning the smoke before it leaves the firebox. Catalytic models have a ceramic honeycomb coated with a catalyst inside the stove that lowers the ignition temperature of combustible gases.

Noncatalytic stoves use firebox insulation, large baffles, and super-heated combustion air distributed in the firebox to burn the smoke effectively. The operating instructions supplied with the heater should be followed, especially the procedures for operating catalytic stoves, which usually give precise instructions for ensuring that the catalyst lights off properly.

Beauty is in the eye of the beholder—a sustainable woodpile does not contain uniform pieces of only the "best" wood.

Tips for Clean Wood Burning

Understanding the key phases in the combustion process will assist you in achieving a cleaner and more efficient fire. There are three stages of burning.

Evaporation

The first stage of combustion is evaporation, when energy is expended to remove moisture from the wood. Using energy to drive off excess water in firewood robs the stove of energy needed for an efficient and clean burn. Also, much of the energy wasted in evaporating water is energy that could have heated your home.

Emissions

As heat inside the stove intensifies, waste gases are released from the wood. Unburned gases in smoke are emitted into the air as pollution or condensed in the chimney, causing creosote build-up. Waste gases from wood need oxygen in order to burn. This is why starving a fire for air, or "banking down a fire" is the worst way to burn. Always give a fire a generous supply of combustion air.

Charcoal

When most of the tar and gasses have burned, the remaining substance is charcoal, which burns with a steady red glow and little or no flame. A good-sized coal bed can give hours of efficient, smoke-free heating, so don't rush to add wood unless the space has started to cool off. Then rake the remaining charcoal to the front of the firebox where it can quickly ignite the new load.

Only Burn Seasoned Wood

Unseasoned wood is hard to ignite and very inefficient. When logs are cut, 50 percent of their weight is water. If wet when burned, a high amount of energy is wasted to drive off excess moisture, resulting in very poor combustion, increased pollution, and creosote build-up.

The best fuel is dry, "seasoned" wood. Seasoned wood has moisture content of about 20 percent or less. It tends to be dark in color, cracked on the ends, lighter in weight, and has bark that is more easily broken or peeled.

Source: Oregon Department of Environmental Quality

Gathered fallen deadwood ready to be bucked. Small diameter wood burns fast and clean.

Wood burns best in cycles. A cycle begins with the placement of several pieces of wood on a coal bed and ends when that wood has burned to a similar-sized coal bed. Adding one or two pieces per hour in the attempt to maintain constant heat output is *not* a good strategy. In fact, adding only one or two pieces is not a good idea at any time. When loading, always add at least three pieces to create a triangular formation where the glowing surfaces of one burning piece radiate on the other pieces, creating the site where a fire ignites and is sustained.

To burn in cycles, wait to reload until you notice that the room or space is beginning to cool off, then add a load of at least three pieces. Match the size of the load to heat demand. That is, in the relatively mild weather of spring and fall, use several smaller pieces of wood, rather than fewer of the large pieces you would use in colder weather.

A cycle should last between four and eight hours, depending on a variety of circumstances. For example, in spring and fall, I like to use the "flash fire" technique, which consists of three to six small pieces of firewood placed in a crisscross arrangement and burned fairly fast. The result is about four hours of heating, with no smoldering and no overheating of the space. In colder weather, use larger pieces placed compactly in the firebox to slow down the rate at which they ignite and burn.

Never let a fire smolder. In advanced, EPA certified stoves, the wood should be flaming brightly when you go to bed at night, and you should still have plenty of coals in the morning with which to rekindle the next fire. Gone are the days of "banking" fires with huge unsplit "blocks" and choking off the air supply before bed, a procedure that wasted much of the wood's potential energy and coated the chimney with flammable creosote. The new stoves call for new operating procedures.

Remove ashes frequently. Don't let them build up in the firebox or ash pan. In the firebox, they interfere with proper loading and make dealing with the coal bed more difficult. In stoves with ash pans, the forgetful owner who doesn't empty ashes frequently enough ends up with a dusty mess to clean up as ashes end up everywhere under and inside the stove body. In cold weather, I remove a small amount of ash from my firebox every morning before loading.

Much more could be said about the finer points of modern woodstove operation. But with these basic ideas and a good attitude as a starting point, you can develop your own special practices that suit your system, firewood, and heat demand. And that's part of the pleasure of heating with wood.

A Place for Wood in the Future

Some environmentalists take a dim view of wood energy, seeing it as crude and backward and just plain polluting. But in a post-fossil-fuel future, in which renewables dominate as they must, any serious analysis cannot overlook the limitations of sun and wind as producers of the bulk heat needed to warm houses in moderate to cold climates.

Instead of ignoring wood and hoping it will go away along with coal-burning power plants and toxic pesticides, we should confront the issue head-on by forcing wood energy into the twenty-first century. We should promote advanced combustion technologies and the social responsibility of using them appropriately. Those of us who choose to heat with wood need to pledge our commitment never to make visible smoke—an outcome, which with care, is achievable now.

Access

John Gulland, Killaloe, Ontario, Canada • Wood heat consultant and executive director of the Wood Heat Organization, Inc.

Wood Heat Organization, Inc. • www.woodheat.org

HearthNet • www.hearth.com

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The Masonry Heater Association of North America, Beverly J. Marois, Administrator, 1252 Stock Farm Rd., Randolph, Vermont 05060 • 802-728-5896 • Fax: 802-728-6004 • bmarois@sovernet.com • www.mha-net.org

Oregon Department of Environmental Quality (DEQ) • www.deq.state.or.us/aq/woodstoves/woodstoves101.htm


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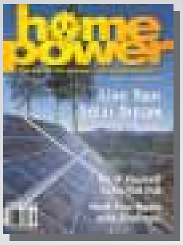

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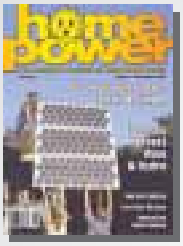

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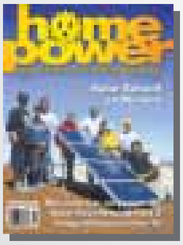

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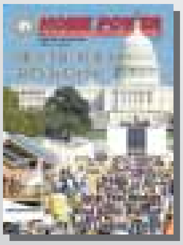

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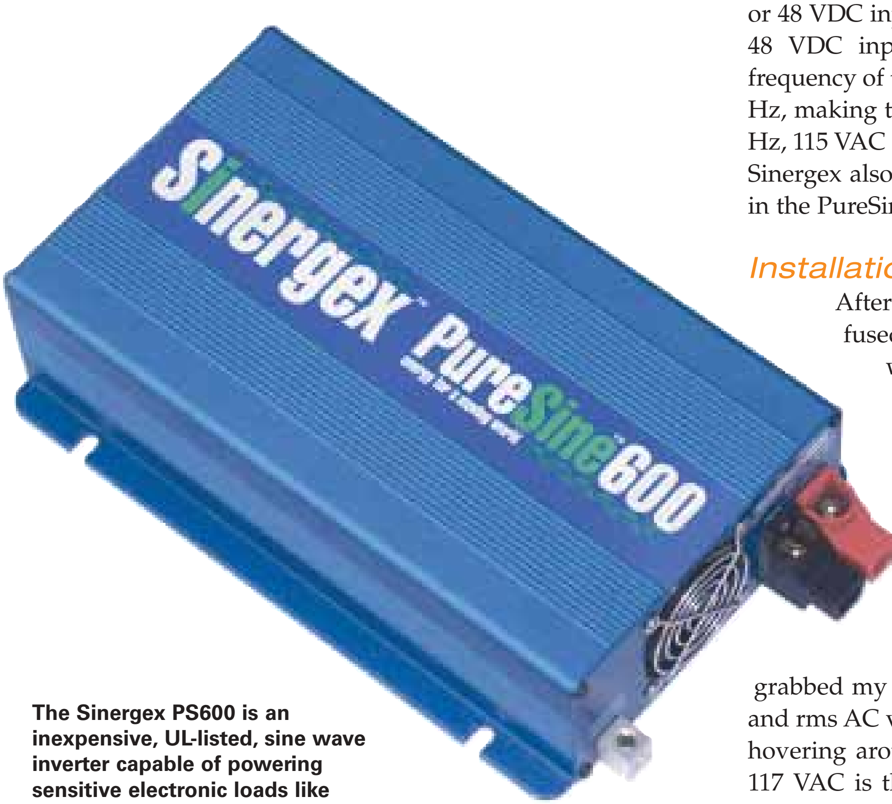
Sinergex PureSine 600 Inverter

Joe Schwartz

Application: For nine months, I ran my home office and entertainment gear with a Sinergex PureSine 600, 12 VDC nominal input inverter. Loads included two laptops, a satellite Internet system, compact fluorescent (CF) lighting, computer speakers, and a subwoofer for that big bass sound.

System: The PS600 is part of the cabin system that powers a camp trailer up on my property, located at 4,600 feet (1,400 m) in the mountains east of Ashland, Oregon. Major system components include 700 AH of Trojan L-16 batteries configured for 12 VDC; an Outback MX60, 60 amp PV controller; 700 W of Sharp NT-R5E1U, 175 W PVs; and a Cruising Equipment E-Meter amp-hour meter.



The Sinergex PS600 is an inexpensive, UL-listed, sine wave inverter capable of powering sensitive electronic loads like computers and audio gear.

I'm about a year and a half into homesteading a new piece of land. In the fall of 2002, I moved to the property full time and needed to get a bigger PV system together to power my home office. I had an old, 1,500 watt, modified square wave inverter to run the occasional power tool. My circular saw didn't like it much, and groaned to life every time I used it. I groaned too, but hey, the situation was only temporary.

I sure wasn't going to subject the sensitive (and expensive) electronics I use to work at home to the chunky waveform of the modified square wave inverter. So I went looking for a small sine wave inverter. Since the Taiwanese-made Sinergex PureSine series was new to the U.S. market, I decided to run one and collect some performance data.

The PS600 is available in six different versions—12, 24, or 48 VDC input with 100 to 120 VAC output, and 12, 24, or 48 VDC input with 220 to 240 VAC output. The AC frequency of the inverter is user selectable for either 50 or 60 Hz, making the inverter a candidate for countries where 50 Hz, 115 VAC or 50 Hz, 230 VAC appliances are the standard. Sinergex also makes 150, 300, 1,000, and 1,500 watt models in the PureSine series.

Installation & Operation

After the inverter was mounted on the wall, and the fused battery leads were connected, the installation was pretty much done. The AC output of the inverter is provided via a single-gang receptacle with two outlets. I fitted a male cord cap on a 4 foot (1.2 m) length of #12 (3 mm^2) SO cable that ran to the 15 amp breaker panel in the camp trailer. From there, the electricity is distributed throughout the trailer to various light fixtures and receptacles.

Once the inverter was up and running, I grabbed my Fluke 87 digital multimeter to check the peak and rms AC voltages. I was surprised to see the rms voltage hovering around 110 VAC. I'm a power quality nerd, and 117 VAC is the magic number when it comes to 120 VAC nominal inverter output. I took a look at the inverter specs again and noticed that the inverter's AC output can be set for 100, 110, or 120 VAC. But there was no mention in the user manual of how to configure the inverter for different output voltages.

I disconnected the DC input to the inverter, opened up the case, and found a pair of unmarked dip switches. I went out on a limb a bit and reconfigured the dip switches until I found the 120 VAC output setting. Obviously, this info needs to be added to the manual. Next I connected a Fluke 43B AC Power Quality Analyzer to the inverter's output, and the THD was at 0.8 percent with a couple hundred watts of AC loads running. That indicates a high quality AC output waveform, so I was in business.

Inverter status is monitored by three LEDs that display input voltage level, load level, and faults. The inverter fault conditions displayed include overvoltage, undervoltage, overtemperature and overload. An on/off switch is also included.

Overvoltage

The Outback MX60 PV charge controller I'm running is equipped with battery temperature compensation. As the battery temperature decreases, the controller increases the regulation voltage to ensure a full state of charge. The inverter had been on line for a couple of weeks and the weather began to get colder with the onset of winter. I came home one night, turned on a light switch, and was still standing in the dark. The LED status indicators on the inverter were displaying an overvoltage condition. The high voltage cutout for the inverter is factory set at 15.3 VDC. I regulate flooded lead-acid batteries at 14.8 VDC. With the temperature compensation kicking in, the inverter was shutting down due to overvoltage.

The only solution was to disable the MX60's temperature compensation, which was less than ideal, since the batteries would no longer be attaining a full state of charge in cold weather. Based on this experience, I wouldn't recommend using the PS600 inverter in systems with flooded lead-acid batteries in cold climates. Since sealed batteries have lower voltage regulation requirements (typically 13.8 to 14.4 VDC), overvoltage shutdown shouldn't be an issue. Upping the high voltage cutout to 16 VDC would be a great improvement to this inverter.

Power Quality

I occasionally check the power quality of the utility grid and often see total harmonic distortion values between 2 and 3 percent. With that in mind, the AC power quality of the PS600 beats the grid even on its good days. This means the electricity produced by the inverter is of high enough quality to run any electronics that you have, providing the combined load falls within the inverter's output rating. The cost of the PS600 inverter is on the low end when compared to other small, sine wave inverters.

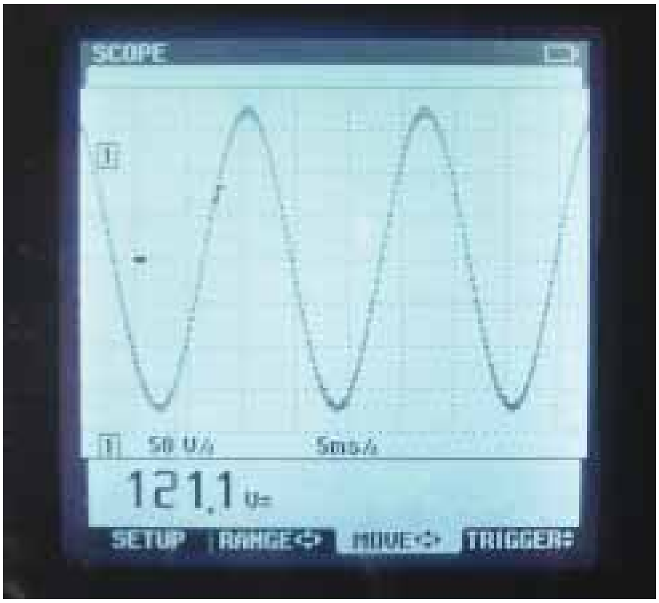
Test Equipment & Setup

Inverter test data was collected while adding incremental AC resistive loads to the inverter. Battery voltage, battery current (via a 100 mV/100 A shunt), and peak and RMS AC voltage were measured using three Fluke 87 digital multimeters. AC amperage was measured with a Brand Electronics model 20-1850 power meter and a Fluke 43B AC Power Quality Analyzer with a 20 amp current clamp. The Fluke 43B was also used to measure total harmonic distortion and power factor. The battery temperature during testing was 72.4°F (22.4°C.)

Sinergex PS600 Inverter Test

AC Out					DC In			
Load Watts	Volts (Peak)	Volts (rms)	Amps	THD*	Watts	Volts	Amps	Efficiency
Idle	170.0	121.3	NA	1.0%	11.5	12.74	0.9	NA
15.7	170.0	121.1	0.13	1.0%	28.0	12.71	2.2	56.3%
21.8	169.6	120.9	0.18	1.0%	34.3	12.70	2.7	63.5%
43.4	168.8	120.5	0.36	1.0%	57.0	12.67	4.5	76.1%
67.3	168.0	120.2	0.56	0.9%	80.9	12.64	6.4	83.2%
90.0	167.6	120.0	0.75	0.8%	103.4	12.61	8.2	87.0%
174.0	166.8	119.2	1.46	0.8%	194.2	12.53	15.5	89.6%
258.7	166.8	119.2	2.17	0.8%	294.6	12.43	23.7	87.8%
343.9	166.8	119.0	2.89	0.8%	396.7	12.32	32.2	86.7%
496.9	164.4	118.3	4.20	0.9%	594.9	12.14	49.0	83.5%
585.6	168.4	118.3	4.95	1.4%	718.8	12.02	59.8	81.5%
664.5	162.8	117.4	5.66	2.7%	848.7	11.92	71.2	78.3%

*Total harmonic distortion



The PureSine 600's waveform displayed on a Fluke 43B.

Tech Specs

Power: 600 W continuous at 40°C (104°F)

Surge Power: 800 W

Sine Wave Quality: Less than 3 percent THD typical

Efficiency: 87 percent at full load

Idle Draw: Less than 15 W

Input Voltage: 10 to 15.3 VDC

Dimensions: 11.6 by 7.1 by 2.8 inches (29 x 18 x 7 cm)

Weight: 5.4 pounds (2.4 kg)

Note: All specifications supplied by manufacturer.

Because I'm at the start of my homesteading project, and have limited space that's protected from the elements (we're talking 80 square feet; 7.4 m^2), I mounted the PS600 inverter inside my camp trailer. One thing I really appreciated about the inverter was its near silent operation. Even with the fan running, the noise level was tolerable.

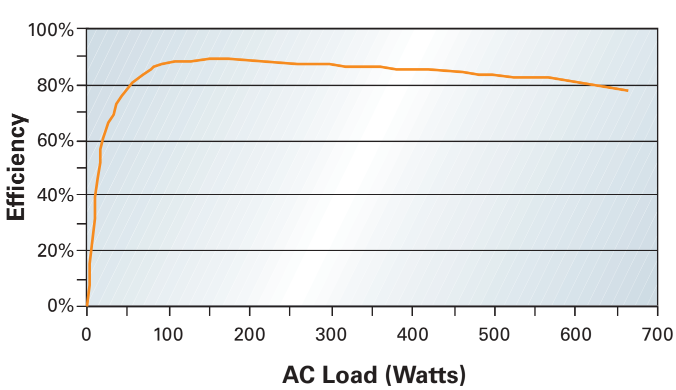
Shortcomings

While the AC power quality of the PS600 inverter is great, some of its design characteristics fall short of my dream inverter. The battery input terminals on the inverter are well isolated from each other, but they are not conduit ready. This makes a code compliant installation difficult, since you'd have to add a custom junction box to the DC end of the inverter.

The inverter's DC terminal blocks use Allen-type, compression set screws that require a small ring lug. The inverter package included two of the appropriate sized lugs, but wire size was limited to #6 (13 mm^2) CU wire. This was fine in my case, since the battery to inverter wire length was only 6 feet (1.8 m). But longer and larger inverter/battery wiring will require a combiner block or lugs to transition down to #6 wire at the inverter. A lug is provided for the equipment ground conductor and accepts up to #8 (8 mm^2) wire.

In the features section of the inverter's manual, "high surge in motor start capacity" is listed. This is definitely stretching things a bit. The maximum output rating for the inverter is 680 watts for three minutes. The surge rating for the inverter is only 800 watts. This inverter isn't a good candidate for systems that will power small power tools or motors that surge above 800 watts. However, many small RE systems have loads similar to mine—computers, lighting, and entertainment gear. The high power quality of the PS600 makes it an appropriate choice for systems with similar loads.

PS600 Efficiency



Features

High Points:

- Sine wave output
- Inexpensive
- Super quiet

Low Points:

- Not conduit ready
- Low surge capacity
- 15.3 VDC overvoltage shutdown

List Price: US$600

Warranty: 12 months from date of purchase

Inverter Swap

A few months ago, I transitioned into serious construction mode, and needed a larger sine wave inverter to run power tools, and power my computers and other electronic gear. I swapped the two, 12 VDC inverters in my cabin system for a single, 2,000 watt sine wave inverter that will run my office gear and my circular saw. I'll be reinstalling the Sinergex PS600 at *HP's* production office, so I can run my laptop off-grid when I work downtown.

Access

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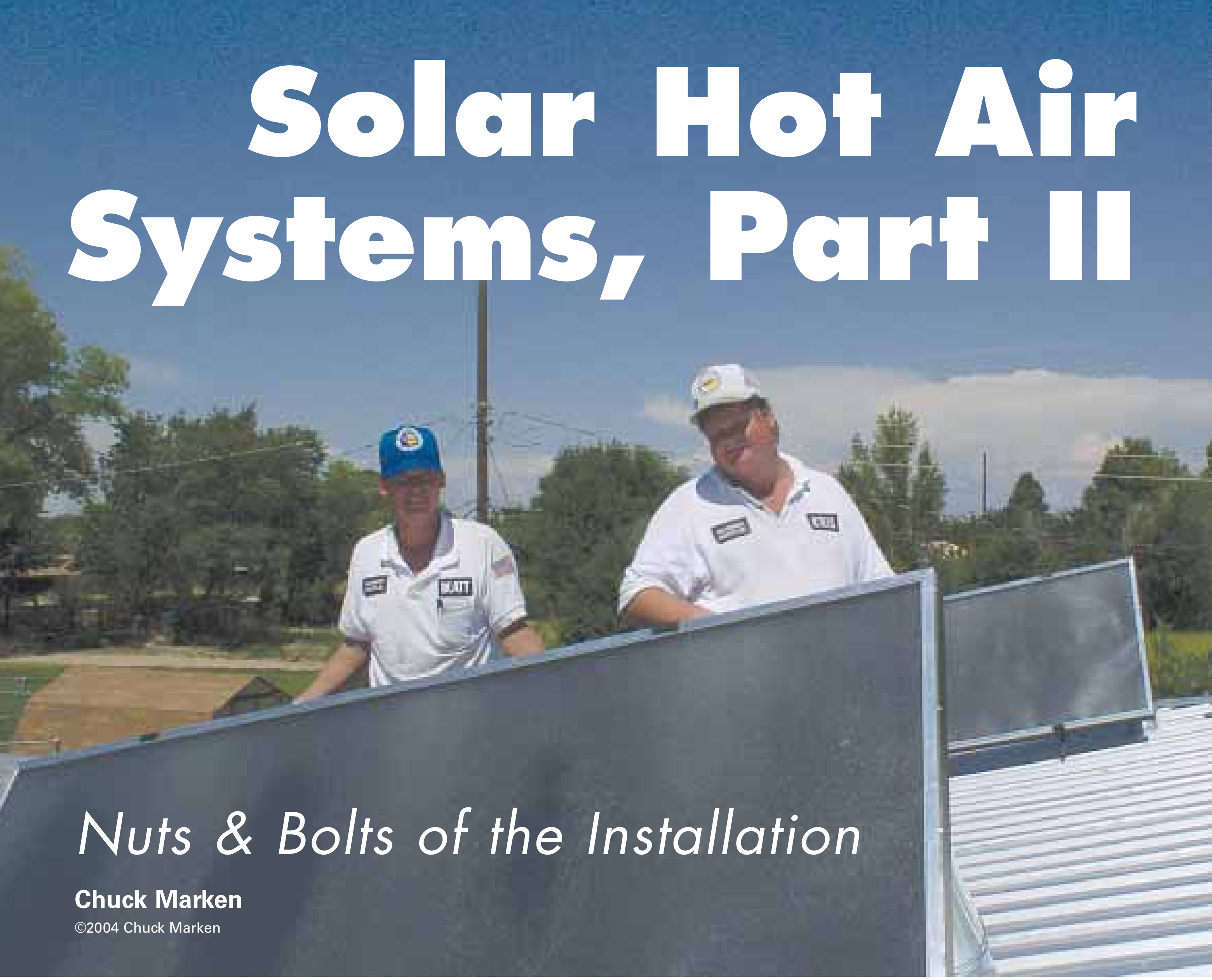
Solar Hot Air Systems, Part II

Nuts & Bolts of the Installation

Chuck Marken



Matt McKivigan and Kris Kadera of Sun Friendly Concepts, Inc. with a simple solar hot air system that you can install.

Solar air heating systems are easy to install compared to other solar heating systems. Part 1 in *HP98* looked at air collector types, construction, and overall system design. That article also defined the function and operation of each major component, including blowers, controls, and backdraft dampers. By reviewing that article, you will have a better understanding of where we start in this article. Here we'll get out the tools and go through the nuts and bolts of an installation.

Follow a few simple rules to the letter, add some quality workmanship, and you'll have a system that provides free heat for the coming decades. A seasoned crew of two can install a solar hot air system in a few hours, though sometimes it takes a long day. If this is your first time, plan on a weekend, even with help.

The reputation of solar air heating has suffered a great deal from poor installations. I know of two large manufacturers in the 1980s that printed unworkable system designs right on the front page of their product literature. It's no wonder so many of these systems failed to perform up to expectations. Follow along and we'll go through the right way to install a solar air collector system on your home, office, garage, or shop.

The basics of placement and mounting of solar liquid collectors was the subject of an article in *HP94*. That article's detailed instructions on roof or ground mounting collectors and sealing roof penetrations applies to air collectors as well. The only thing different is that air collectors have larger roof penetrations to accommodate the ducts. Unless you are comfortable with sealing roof penetrations or plan to place the collectors elsewhere, I strongly suggest you review that article.

The Roof

The most popular place to put solar hot air collectors is on the roof. Less shade will affect them, and the roof allows you to easily do a clean, efficient installation. Let's start on the roof and work our way down.

Kris cuts a 9 inch hole, for the 8 inch duct, in exactly the right spot.

The collector is usually mounted first. The holes in the roof are normally cut within about 2 feet (0.6 m) of the back of the collector. On composition shingle roofs, a roof jack will make the transition between the roof and the duct.

Roof penetrations for the air handling ducts in an air collector system will be 7 or 9 inches (23 cm) in diameter, to accommodate 6 and 8 inch (15 and 20 cm) insulated flex duct. An inch (2.5 cm) of insulation makes the ducts 8 or 10 inches (20 or 25 cm) in diameter respectively, and the roof jack holes will be 1 inch smaller. This makes the duct fit tightly through the roof. We use 7 or 9 inch (18 or 23 cm) roof jacks and plastic roof cement as the sealant.

Insulated flex duct is constructed of a high temperature (240°F; 116°C) flexible duct, encased in a spiral of wire for structural integrity and 1 inch of insulation that is covered with a vinyl or foil exterior. Flex duct can be found at plumbing and HVAC specialty stores and some home centers.

Roof penetrations on this composite shingle roof get plenty of plastic roof cement, both at the mounting rack's feet and the galvanized roof jack.

Galvanized duct is used as weatherproofing outside the outer covering of the insulated flex duct, and overlaps the roof jack. Any adjustable elbows for the weatherproofing need to be placed over the insulated flex *before* it is attached to the collector. Straight pieces of duct snap together to connect the elbows to the roof jack, and all of the joints should be sealed with silicone sealant.

The snap disc sensor (a simple, thermostatic fan switch, described in the previous article) also needs to be fastened to the collector absorber plate via the duct port, before the ducting is installed. This wire will not be hot (energized) yet, so there will not be any danger of electrical shock until it is connected to a live circuit. The temperature rating of the wires into the collector should be above 300°F (149°C). You can use toaster wire (at AAA Solar, we use 200°C rated #14) or other suitable high temperature insulated wire inside the collector.

Matt attaches the snap disk in the hot air outlet before connecting the duct. The wires will run between the flexible duct and the rigid duct.

The wire is then run through EMT conduit or just inside the galvanized steel weatherproofing. The wire (2-conductor Romex with ground) will run into the attic and be connected later—make sure to leave plenty of wire that can be cut to length when the time comes. If you are not familiar with home electrical wiring, this job is best left to a qualified electrician. All roof penetrations and mounts should be sealed with plastic roof cement.

The Attic

The attic is a hot place—get in and out as quickly as possible! A two or three person crew will normally coordinate things and get the attic work completed in the morning, avoiding the heat of the day.

The attic is where everything ties together. Work to be accomplished here includes hanging the blower and

Tools

Required:

- 3/8 inch drill/driver and bits (at least one 1 inch spade bit)
- 1/4 inch hex socket driver bit
- Reciprocating or keyhole saw
- Measuring tape
- Pliers
- Sheet metal shears
- Screwdrivers
- Socket set for lag bolts and mounts
- Electrician's tools (or hire an electrician)
- Drop cloth
- Ladder for roof and 6 foot step ladder for inside
- Flashlight
- Hammer

Nice to have:

- Stud finder
- Angle gauge
- Compass
- 1/2 inch driver drill
- Circular saw
- Torpedo level
- Trowel for plastic roof cement

backdraft damper, passing the duct up to the roof, cutting the cold air return, installing the hot air supply boot, hooking up the duct, and connecting the wiring. Plumber's tape (flexible metal strapping with pre-punched holes) is used to mount the blower assembly and any ducting that needs to be secured.

Cold Air Return

Of all these jobs, finding and cutting a good cold air return is most critical. Cold air will not travel upwards. If a cold air grille is placed 4 feet (1.2 m) above the floor, all the cold air below the grille will tend to stay where it is. The result will be an uncomfortably cold area right where people sit and recline.

This is where so many solar air collector systems were short-changed; many cold air grilles were installed in the ceiling. Some unknowing manufacturers even recommended it and went so far as to depict it in their drawings and literature. The solar air heating system will only heat to a level of the cold air return grille. This means that if you want the heat down at floor level, that is where you must draw the cold air going to the collector. Many cold air returns were incorrectly installed in the ceiling because it was easy and convenient. It is not just inefficient—it won't work, ever.

Building codes allow cold air returns in wall cavities behind the wallboard. In most homes, this makes an ideal location for a cold air return duct. You don't even need to install duct in the hollow wall space as long as the air temperature is less than 120°F (49°C). You can use the wallboard and framing studs in an interior wall (without insulation) as the duct.

By careful observation and measurement, you can locate a suitable entry point into the attic. Once you are sure of the location, the double top plate above the wall needs to be cut with a reciprocating or keyhole saw. Always take special care to avoid cutting through electrical wires or structural members. It's best to drill a couple of 1 inch (2.5 cm) holes in the plates to make the sawing easier. Care must be taken—it is easy to damage a finished wall that is typically only a 1/2 inch (13 mm) piece of gypsum wallboard away. A cold air return duct for a single collector should be at least 30 square inches (194 cm^2), or a space of at least 10 inches (25 cm) wide. The standard interior wall cavity (14.5 inches or 50 square inches; 37 cm or 323 cm^2) is plenty of space.

Once a cold air return opening is cut in the attic and a 6 by 10 inch (15 x 25 cm) grille opening is cut in the wallboard at floor level below, a duct transition needs to be made. Boots are what the HVAC industry calls these transitions—they are rectangular on one side and round on the other. A 4 by 12 rectangular to 6 inch round (10 x 30 to 15 cm) boot will screw down nicely over the top plate opening. Use silicone sealant to ensure that no air is lost in the attic. Replace any insulation that was pushed out of the way to accomplish the work. The cold air return duct is ready to be run to the collector.

Don't have a suitable hollow wall space? Other options include using closets, with or without duct, or ducting down a garage or outside wall. You can also duct down an inside wall and build what is called a "chase" space to conceal the ducting. You don't have to use round duct for

Cold air return grilles should be mounted close to the floor, and strategically away from the hot air register.

this—the HVAC industry also has a ready-made 3¹/4 by 10 inch (8.3 x 25 cm) duct that will serve in many instances. No matter what, get the cold air from the floor level of the rooms you wish to heat if you want the system to work.

The Blower & Hot Air Supply

The hot air supply is normally a much easier task than the cold air. A 6 by 10 inch (15 x 25 cm) hole is cut in the ceiling sheetrock with a keyhole saw at a convenient location—hallways, living rooms, dens, and dining rooms are good places. A 6 by 10 to 6 inch round (15 x 25 to 15 cm) boot is placed over the drywall in the attic, and the hot air register is screwed into the boot, through the wallboard from below. Again, it is good to apply a small bead of silicone caulk on the flange of the boot to help secure it to the wallboard. That's it for the hot air except to connect the duct.

The blower/backdraft damper assembly is easier to deal with if it is put together first and carried into the attic as a unit. The backdraft damper should be in a square to round transition. Blower outlets are usually square or rectangular and you will attach the unit to 6 inch (15 cm) round duct. The square part of the damper housing is bent over the blower outlet and screwed and duct taped to ensure no air or heat loss.

The blower (left) and backdraft damper (right) should be assembled before you crawl into the attic.

A 6 inch starting collar is screwed to the blower inlet on the side to allow flex duct to be easily connected. The hinge of the spring-loaded backdraft damper should be vertical when the blower is positioned so the inlet is on the side of the blower. The backdraft damper should open like two doors hinged in the middle when in this position—this is the way the blower will be mounted.

The blower assembly is hung in the attic with plumber's tape. Attaching a blower to rafters or trusses with fixed mounts can cause very unpleasant noises—do so at your own peril. Plumber's tape installation will dampen any harmonics from the blower to the wood. The blower assembly should be mounted at three points, at a minimum.

Working in tight quarters—Matt hangs the blower, runs the duct, and then finally wires the system.

Attaching all the components, like boots to wood, duct to metal, and other jobs is easiest if you use self-tapping screws with a ¹/4 inch (6 mm) hex driver in a cordless electric drill. These #8 screws come in lengths from ¹/2 to 2 inches (13–50 mm). An air collector installation can be accomplished with ¹/2 and 1 inch (13 and 25 mm) screws. Use 1 inch (2.5 cm) screws for the truss attachment of the blower and ¹/2 inch (13 mm) screws to attach the plumber's tape to the blower. Be careful not to run any screws into the blower where they might interfere with the operation of the squirrel cage fan. Once the collector, roof jacks, boots, and blower are mounted, it's time to connect the dots.

The Ducting

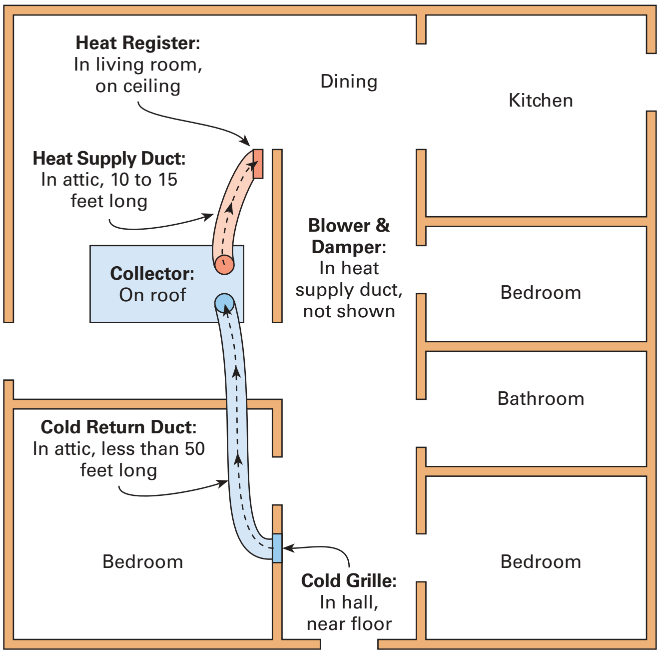
The cold air return of the system is connected to the collector inlet (usually the bottom of the collector, but in some designs it could be on the side). It runs in one piece from the cold air boot to the collector. Only one more piece of duct is needed to connect the collector output (normally the top opening) to the blower inlet (the inlet should be on the side of the blower if mounted correctly).

In general, the hot air duct should be as short as possible; the cold can be longer without harming efficiency as much. The cold air duct may be up to 50 feet (15 m) long if necessary, but shorter is better. If possible, make the duct from the blower to the hot air register the shortest run.

The nature of air makes pulling it (vacuum) easier than pushing it. The cold air duct and the hot air up to the blower are under negative pressure caused by the blower. Negative pressure tames the air into moving much more in the direction you want it to go. The only positive pressure part of the system is after the blower, hence the shortest run of duct for the best efficiency. Too little duct in this run will give excessive blower noise in the home—3 to 5 feet (0.9–1.5 m) is ideal, with a maximum of about 10 feet (3 m).

Insulated flex duct can be cut with a razor knife and wire cutters. It typically comes in 25 foot (7.6 m) lengths. After

System Layout Example



Note: Ideal systems have one hot air supply and one cold air return. Multiple ducts can create unpredictable air flow reducing efficiency.

cutting it to a size that will make a tight duct run, three screws securing the spring wire will attach it to the component. Duct taping the connection ensures that the wire will not come loose, and seals the duct.

Once the attic is done, there should be two ducts and one piece of Romex wire going to the roof. The blower will be mounted and ducts going to the hot and cold air boots installed.

Inside Layout

The inside work for the ducting isn't much. Cut the wallboard for the cold air grille and hot air register, mount them plumb and level, and that's about it. A register is just a fancy grille that has moveable vanes and can close all the way if you wish. Most of the inside work has to do with laying out the system and tying into an electrical circuit.

The system layout is different with every installation. One cold air return and one hot air supply per collector can effectively heat up to 1,000 square feet (93 m^2) or more. The largest space AAA Solar has done with a single blower and single hot and cold air ducts is 2,800 square feet (260 m^2), but that was unusual and had four collectors manifolded together.

The more normal situation is one 4 by 8 foot (1.2 x 2.4 m) collector for every 500 to 1,000 square feet (46–93 m^2). Larger areas requiring more collectors are usually zoned—in other words, a separate duct and blower for each collector. Some very large homes may require five or six systems. They will usually work better and be more efficient as zones rather than being manifolded together.

If possible, the hot and cold air should be separated by a wall, although this isn't absolutely necessary. If you can find a flow path of air that naturally fits your home and the hot air will end up where the family spends most of the time, that's where you want to locate the cold air grille and hot air register.

The grilles are often placed in a hallway, closet or bedroom if the door is left open. Don't put the cold air return in a bathroom—unpleasant odors may be circulated throughout the home. Even if the hot and cold air are in the same room, the system will work fine if the hot air doesn't blow directly into the cold air inlet. Separation by just a few feet is all that's needed, but around a corner will give better results.

Electricity

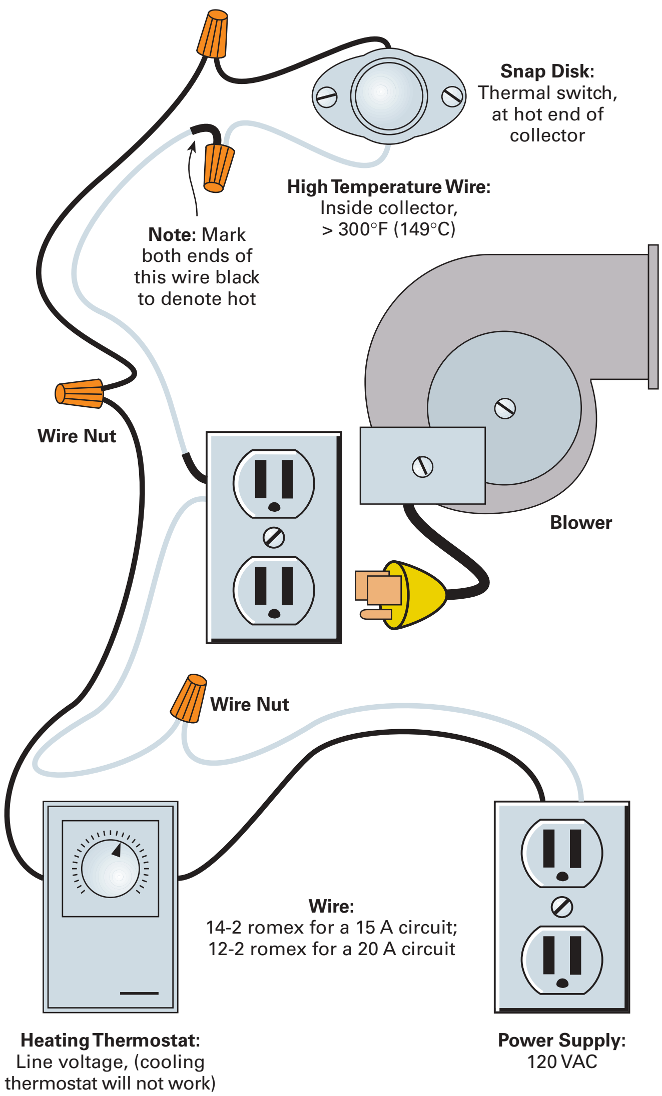
The blowers used in a normal solar air collector system are fractional horsepower AC motors. What this means as far as the electrical code is concerned is that they can be cord and plug connected, and the electricity to run the blower can be taken off any branch circuit in the home. Usually a convenient receptacle near the cold air return makes a good choice. An electrical remodel box can be set in the wall space above the receptacle and wires snaked up from the receptacle to the remodel box and down from the attic. The line voltage thermostat controlling the system will be mounted on the remodel box.

Caution—if you choose to do the wiring yourself, make sure the breaker to the receptacle is off. Also make sure the

Left: Kris locates and cuts a 6 by 10 inch hole for the hot air register in the ceiling of the living space.

Right:The register face plate is screwed through the ceiling and into the 6 x 10 to 6 inch round (15 x 25 to 15 cm) boot in the attic above.

System Wiring



receptacle is not controlled by a wall switch; many in living rooms and dens are switched. Beyond that, a picture is worth more than a thousand words—check out the electrical drawing.

Wall-Mounted Collectors

Mounting an air collector on a wall is even simpler than the roof mount. If the collectors have the cold air inlet and hot air outlet on opposite ends of the collector, it can even be mounted flush with the wall. The cold air will be on the bottom and the hot air on the top.

As long as the duct is limited to through the wall, a small propeller fan can be used to circulate the heated air through the collector and into the building. Since the fan is in the airflow path, it is best to mount it in the cold air return, pushing air through the collector. This is different than roof mounted units, but placing a fan motor in the hot air path may damage the motor.

When wall-mounted hot air collectors are feasible, the installation can be very simple.

A snap disc control at the hot air outlet is incorporated to turn the collectors on at 110°F (43°C) and off at 90°F (32°C). The wiring is similar to that given in the wiring drawing with the exception that many wall mount collectors have a provision for cord and plug connection of the fan and snap disc control.

Backdraft dampers used with small propeller fans are not the spring type used with blowers. These fans aren't strong enough to open spring-loaded dampers, so their dampers are usually counterweighted. This allows them to open with a minimum of force and still close when the fan turns off.

The only things to watch out for with wall-mounted collectors is ensuring that you are in a suitable stud space for the through-the-wall ducts, and that you secure the collectors to structural members. But this is usually not much of a problem in most homes.

Maintenance & Repair

Air collector systems have two moving parts—the blower and the backdraft damper. The thermostat and snap disc are very durable and reliable, and should last decades. Assuming the collector is well made and the installation done with care, all the nonmoving parts should last for fifty years or more. The blower will eventually wear out (lifespans of 15 to 20 years or more are common).

The backdraft damper spring may weaken with age and fail to close all the way. An air collector system that reverse thermosyphons at night (cold air comes into the house through the cold air return) is a symptom of a failed backdraft damper. In high humidity climates, failed backdraft dampers can allow water to get into the collector. The moisture-laden warmer air rises to the collector, and some moisture condenses on the absorber plate and stays in the collector.

Water in any collector can be remedied with small (1/8 inch; 3 mm) weep holes drilled in the lower corners of the collector. Small weep holes like this will not affect performance noticeably, but will allow any accumulated moisture to weep out on the roof or the ground.

Hot Air System Costs

Item	Cost (US$)
Air collector, 4 x 8 ft., back-pass design	$760
Blower, 382 CFM, & damper	235
Duct, roof jacks, grilles, & boots	135
Mounting kit for collector, incl. lag bolts	45
Thermostat, line voltage	30
Wire, remodel box, screws, duct tape, caulk, & plastic roof cement	25
Snap disc control	20
Total	$1,250

Solar Comfort

Solar air collector systems are simple, relatively easy to install, and have quick paybacks in climates requiring building heat in the winter. How quick the payback is depends on the fuel displaced. It can be as little as two or three years if displacing high priced electricity and propane. It can be as long as fifteen years if you have cheap natural gas and limited sunshine.

Air collector systems are a good option for saving energy and money—if the building is already energy tight. Good insulation, weatherstripping, double pane windows, and caulking all air leaks should be taken care of before considering a solar heating system. So if you have a good energy-tight home heated by a forced air furnace or woodstove, check out solar air collector systems and enjoy a warm comfortable home, courtesy of the sun.

Access

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Five previous articles with additional background on solar air collectors were published in *HP25, HP40, HP64, HP72*, and *HP98*.

Photovoltaic Module

AKA: PV module, solar-electric panel, solar-electric module

Used In: Solar-electric systems both on and off the utility grid

What It Is: A group of silicon cells or other materials that are specifically manufactured to generate electricity when exposed to sunlight.

What It Ain't: Electrical photography

Photovoltaic modules power homes, businesses, satellites—you name it—by using sunlight to generate electricity.

In 1839, a French physicist named Edmond Becquerel discovered that certain dissimilar materials, bonded together, would generate electricity when exposed to sunlight—the photovoltaic (fōtō-völ-tāy'-ik) effect. More than 100 years passed before U.S.-based Bell Laboratories developed a silicon solar cell that produced enough energy for use in practical applications—mainly charging batteries used in remote communications systems. Today, companies large and small, both public and private, are manufacturers of PVs that go into grid-connected and stand-alone power systems.

PV modules shouldn't be confused with solar thermal modules. Thermal panels use the sun's *heat* to warm water or air. PV modules use *light* from the sun to generate electricity, and actually perform better when the ambient temperature is colder.

The photovoltaic effect is based on the physics of using sunlight to force the flow of electrons through a material (typically silicon). The silicon is doped (treated) with elements that have one more or one less electron in the material's outer (valence) electron orbit compared to the base cell material. The majority of PV cells use phosphorus, which has five valence electrons, to create the negative side of the solar cell. Boron, which has three electrons in its outer valence orbit, is often used to create the positive side of the PV cell. When exposed to sunlight, an electrical current is created that forces electrons to the positive side of the cell, creating electricity that can be put to work.

PV modules are a revolutionary energy source. They have no moving parts. In addition, PV is a modular energy source, meaning more panels can be added to the system as energy demand grows. In most locations, PV modules will generate all the energy it took to manufacture them in two to four years.

Most PVs have 25 year warranties, and are expected to produce electricity for 50 years or more. Not many products have an operational lifespan that comes anywhere close to this. The result is emissions-free electricity, and no finite resource use for 50 years or more. No fossil fuel based electricity source can even begin to compete with PV when clean electricity, resource use, and durability are considered.

—Joe Schwartz • joe.schwartz@homepower.com

The Nuts & Bolts of Fasteners

—Part 1

Mike Brown

Using the correct fasteners has a direct effect on the safety and reliability of a vehicle, mechanism, or structure. Choosing hardware for your electric vehicle (EV) conversion should not mean grabbing whatever is in the coffee can on your workbench.

What is a 5/16 inch-18 x 1 1/2 inch, Grade 5, hex head cap screw?

Let's break that question down and look at the separate parts. First, we have to examine the dimension 5/16 inch and the last four words, "hex head cap screw," to define the terms that will be used in the rest of this article.

The word "screw" is used to define a fastener with screw threads as opposed to a smooth sided fastener like a rivet or pin. In this article, we will use the common practice of calling any threaded fastener from #4 (0.116 inch diameter) up to 1/4 inch diameter a machine screw, and any fastener from 1/4 inch diameter and up a bolt. In common usage, the object in question would be called a 5/16 inch bolt, as all threaded fasteners are first defined by their outside diameter (OD).

Head Trips

"Hex head cap screw" describes a threaded fastener that has a six sided (hex) cap or head on one end that gives you a place to grip the fastener with a wrench and thread it into a threaded hole or nut.

Two other cap screw types are also used on automobiles and machinery. The first type is called a socket head cap screw. This fastener has a round head with a hex socket formed into the center of the cap for the hex or "Allen" wrench that is used to thread it into place. This cap screw is used in places where there isn't room for the head of a hex head cap screw, or when the top of the fastener's head can't project above the surface of the part it's installed in.

I use these on the motor-to-transmission adaptor of an EV. In this application, it is recessed in a counterbored hole. A counterbore is a flat-bottomed hole whose diameter is slightly larger than the diameter of the head of the cap screw, and has a depth greater than the head height. This hole is made with a tool called a counterbore after the hole for the body of the bolt is drilled.

The second type is called a flat head cap screw. It has the same hex socket as the socket head cap screw, and has a flat head with an outside diameter a little more than twice the OD of the body of the bolt. The underside of the head tapers from the OD of the head to the OD of the body at an 82 degree angle.

The flat head cap screw is used when the head of the fastener has to be flush with the surface of a part that isn't thick enough to be counterbored to accept a socket head cap screw. To accomplish this, a tool called a countersink is used to form a recess around the bolt hole that matches the shape of the bottom of the flat head cap screw. Another function of the large diameter head with the tapered bottom is that it spreads the load from the bolt head over a larger area.

If you are looking at the small (up to 1/4 inch diameter) machine screws, there are more head styles to choose from. While hex heads are not used on these screws, the Allen

L to R: Grade 5 and Grade 8 hex head cap screws, a socket head cap screw, and a flat head cap screw. Rear and far right: two types of Allen wrenches for socket and flat head screws.

L to R: Coarse and fine threaded bolts; Phillips head and straight slot machine screws.

socket head and the Allen socket flat head are. There are also two different head shapes and two other drive styles. The round head's shape is described by its name and is the more common style. The pan head, which looks like a frying pan turned upside down, is used where head clearance is an issue.

The other drive styles are the straight slot and Phillips head. The main difference between them is their resistance to damage by the screwdriver during installation and removal. The straight slot screw head is the easiest to damage. The Phillips head style is stronger but can still be "stripped out." The Allen socket style is the strongest, but the drive tool required is not as available as the common screwdriver.

Coarse & Fine

If the fraction 5/16 inch defines the size of our bolt, what does the "-18" mean? This part of the bolt's description tells us that there are 18 whole threads per inch of bolt length. The 5/16 inch -18 thread is considered a coarse threaded bolt, and is identified by the initials UNC. A 5/16 inch bolt with 20 threads per inch is considered a fine threaded bolt and identified by the initials UNF.

The UNC and UNF initials mean that the threads on these bolts comply with the Unified Thread Form Series. Some hardware stores and fastener suppliers use the initials USS for UNC and SAE for UNF, but they mean the same thing.

A thread form series is defined by the thread angle, the distance between the teeth of the thread (pitch), the major and minor diameters of the thread, and the clearances between the male and female threads of fasteners being threaded together. The value of a standard thread form system is a guarantee of interchangeability between all fasteners made to the specifications of that form.

Fine thread bolts are about 10 percent stronger than coarse thread bolts because they provide more contact area per inch of bolt length. This is the basis for a long running argument amongst people involved with fasteners. The welder who builds the battery racks and motor mounts for my kits thinks that all the fasteners on a chassis should be fine threaded because they are stronger. However, the fastener salesman I buy from thinks that the fine thread form is obsolete and should not be used or even produced at all. He feels that the 10 percent difference in strength is not an issue.

I agree, and when given the choice, I use coarse threaded fasteners. They are easier to use, and have less chance of cross threading when you are starting the nut on the bolt or installing a bolt into a tapped hole. They make assembly and disassembly faster—fewer threads per inch means fewer turns of the wrench.

Coarse threaded fasteners are readily available in more sizes than fine threaded ones. If you are building a new conversion, pick one form to use and stay with it. You might have to switch thread types if a component has threaded holes with a different form.

The Long & Short of It

I've defined all of the parts of the bolt except the number 1 1/2 inch, which is the length. Since you will be concerned with whether the bolt is long enough or short enough for your application, you should know how to measure the length of a bolt. Both the hex head and socket head bolts are measured from the bottom of the head to the end of the bolt. In contrast, the flat head bolt is measured from the flat, top surface of the head to the end of the bolt.

Bolts come in many different lengths, depending on head style, diameter, and thread type, coarse or fine. If you are starting a conversion from scratch, go to your local hardware store and do your design based on what's available.

Another thing to consider when deciding what length of bolt to use is the length of the body of the bolt. The body of the bolt is the unthreaded part between the head and the threads. The threaded part is the weakest part of a bolt. When the forces acting on a bolt holding two parts together are perpendicular to the length of the bolt, the bolt is said to be loaded in shear. The forces trying to shear or bend the bolt are concentrated where the two parts meet.

Choose a bolt that is long enough to place the body of the bolt where the parts come together. If this causes the body of the bolt to project out of the hole, use washers as spacers. Position the nut on the bolt so the last two threads are covered by the washers, and at least two threads project beyond the top of the nut.

The first two threads on the end of the bolt and the last two threads before the body are considered imperfect because they are not fully formed and can't give the same strength as fully formed threads. Like the top step on a ladder, they are there, but should not be used to bear a load. Manufacturers use a formula to determine the minimum threaded portion of a bolt. On some short bolts, this reduces or eliminates the body.

Making the Grade

Bolts are graded according to the amount of tensile force needed to make them begin to stretch. This kind of strength under tension is called "tensile strength." Raised markings on the top of the hex head tell what grade the bolt is. The strength of a bolt is determined by the metal it is made of and how it is treated. Let's look at the grade system and the things that determine a bolt's grade.

A Grade 2 bolt is the common hardware store bolt. Its hex head has no marks on it. This grade of fastener is made of low carbon steel and is not heat-treated. You should not use Grade 2 bolts in any EV application.

L to R: Round head, pan head, and flat head machine screws.

Grade 5 bolts can also be readily found in your local hardware store. In fact, many better stores don't even carry the lower Grade 2 bolts at all, and carry Grade 5 instead. Three raised, evenly spaced, radial lines on the hex head identify it. This bolt is made of medium carbon steel that is quenched and hardened after it is formed. Quenching involves thrusting a hot bolt into a liquid, usually an oil. This cools it rapidly and forms a thin layer of carbon on the surface, which strengthens the bolt.

Grade 5 bolts can be used throughout your conversion. They are best suited for use where there are shear loads acting on the fasteners, like bolting motor mounts to the frame. Grade 5 bolts are also very good in places like the suspension system, where the fastener needs to be able to absorb shocks.

Grade 8 is the highest grade assigned to hex bolts. Six raised lines on the head identify these fasteners. Grade 8 bolts are made of medium carbon alloy steel and are also quenched and tempered to a high degree of hardness. This hardness makes them brittle, which makes them less suitable for shear and shock loads than Grade 5. They should be used where there are tension loads only; that is, in places where the forces acting on the body of the bolt are trying to pull it apart. Bolting battery racks to the frame of the vehicle is an example.

You might have trouble finding Grade 8 fasteners in hardware stores that are more oriented towards homeowners. If you live in a rural area, try a farm and ranch supply business. Their customers are into the kind of reliability that the right bolts in the right places give them.

The grade system is applied to hex headed bolts only. Socket head and flat head bolts are ungraded. However, they are made of the same alloy steel as Grade 8 bolts, are quenched and tempered the same way, and have a tensile strength rating that exceeds that of a Grade 8 bolt.

Bolts made of stainless steel are graded on a different system according to what type of stainless steel they are made from. Most hardware store bins will not specify the alloy, so this is kind of a moot point for the home fabricator. The alloys primarily affect things like magnetic qualities and corrosion resistance, not strength. In general, stainless steel bolts will have only about two-thirds the tensile and shear strength of Grade 5 hardware.

Stainless steel fasteners should only be used where corrosion resistance is necessary and load-carrying ability is not as important. Lack of availability, high cost, and low strength make specifying all stainless steel hardware for your conversion a bad idea.

The Finishing Touch

As you look through the bolt bins, you will notice that the bolts aren't all the same color. This is because the different types and grades of bolts have different finishes. Most Grade 5 bolts are zinc plated, making them a silver color. The zinc gold dichromate finish of the Grade 8 bolts makes them look lightly gold plated, which some people say is the reason they are so expensive. This color difference is there to show what grade the bolt is at a glance, so you don't accidentally use a Grade 8 bolt to do a Grade 5 job.

The socket head and flat head bolts have a black alloy finish that sets them apart from the graded bolts. Stainless steel bolts are not coated, so they are a natural, dull silver color.

It's All in the Details

Who knew a simple bolt could be so complicated? Now you know about sizing, head types, threads, and grades, as well as some tips about how and when to use each of the choices. I've covered all of this while talking about bolts and machine screws. Next time, I'll continue with the fascinating secret lives of nuts and washers. I'll also cover metric standards, and why that 10 mm machine screw doesn't want to work in your 10 mm threaded hole. Stay tuned!

Access

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Carroll Smith's Nuts, Bolts, Fasteners, and Plumbing Handbook, by Carroll Smith, 1990, ISBN: 0879384069, 224 pages, US$21.95 from Motorbooks International, 380 Jackson St., Suite 200, St. Paul, MN 55101 • 800-826-6600 or 715-294-3345 • Fax: 715-294-4448 • trade@motorbooks.com • www.motorbooks.com

Common Mistakes

& How to Avoid Them

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

Designing and installing a PV system that meets the minimum requirements of the *National Electrical Code* (*NEC*) doesn't take any more time, effort, or cost than installing a system that does not meet the code. This Code Corner will outline some of the common errors that are made in the installation of PV systems, and what could have been done to avoid them.

Color Codes

Back in the late 1800s, Tom Edison used DC electrical systems many years before Westinghouse and AC electricity came along. Early versions of the code addressed these DC systems, and DC has continued in the code ever since, although most of the attention has focused on AC systems in recent years. The early code and all subsequent revisions established that all (DC, and then AC) grounded circuit conductors be identified with white or gray colored insulation. Insulation identified with three white stripes along its length is also allowed.

Conductor sizes larger than #6 (13 mm^2) can be identified with white or gray marking at each termination because these conductors are nearly always made with only black insulation. The other frequently used color code is that equipment-grounding conductors be bare (no insulation) or have green or green and yellow insulation. There are no other color codes in the *NEC* that are commonly used in residential and commercial electrical installations. There are no specified color codes for ungrounded conductors, and there are no color codes associated with DC wiring.

Many PV installers throughout the United States feel that the DC wiring in a PV system should have red insulation for the positive conductor and black insulation for the negative conductor. The roots of this misconception may be in the automotive and electronics industries. Inappropriate color coding has been used in numerous PV systems that have grounded conductors and operate at voltages from 12 to 600 volts.

The photo (bottom left) is typical of recently installed systems observed on the East and West Coasts and in Phoenix, Arizona. Any PV junction box with no white conductors probably does not meet the code.

If the PV system were an ungrounded 12 volt PV system, the *NEC* has nothing to say about the color of the insulation on the two ungrounded conductors. Red and black would be perfectly acceptable. However, on grounded 12 volt systems and all higher voltage systems (which are required to be grounded by code), the grounded circuit conductor (usually the negative conductor) is required to be white, gray, or marked with those colors. As a matter of common usage in AC circuits, the first ungrounded conductor is colored black and the second ungrounded conductor is colored red, but these are not code requirements.

The reason why this misuse of color codes continues to exist is not known. For years, *Home Power* has been using

Not to code: improper color coding.

Not to code: grounded conductor switched.

Not to code: disconnect 10 feet in the air.

Not to code: DC250 mounted horizontally.

Not to code: triple whammy.

red and black color codes for readability and to differentiate DC wiring from AC wiring in system schematics. This may have contributed to the problem.

Disconnects—Which Conductors?

Disconnects (safety switches and circuit breakers) should never be installed in the grounded conductor of DC PV circuits. For that matter, they are not usually allowed in the grounded conductors of AC circuits either. When these disconnects are installed in this manner and operated, a grounded conductor from a PV array will become ungrounded and will still be energized when the PV array is sunlit. Since all grounded conductors (marked white) are assumed to be grounded (at earth potential), it may come as a surprising shock when one is touched and it turns out to be energized with respect to ground.

There is a common misconception that when both conductors of a circuit are ungrounded, it is not possible to get shocked by touching ground and one of the conductors. Distributed small leakage paths in PV modules and wiring will generally prevent a truly isolated, ungrounded circuit, and a definite shock potential usually results.

Many of the grounded SMA Sunny Boy and Xantrex PV-series high-voltage systems seem to get disconnects installed with the positive and negative conductors both switched. See the photo labled "not to code: grounded conductor switched" on the previous page. This may come about from the switch manufacturer's tech notes that say: "Use the outer two poles of the three-pole disconnect to achieve the 600 volt DC rating." In our PV systems, the two outer poles should be connected in series and then used to switch only the ungrounded (normally the positive) conductor.

As an aside, Square D has obtained a special listing on their H361/HU 361 30-amp, 3-pole, 600 volt heavy duty safety switch when used with PV systems. (See Access for details.) If the PV string short-circuit current is below about 12 amps, then each of the three poles can be used as a 600 volt disconnect without connecting the poles in series. One H361 (fused) switch could be used for all three PV strings connected to a Sharp 3,500 watt inverter. Up to three Sunny Boy 2500 inverters could use a single HU361 (unfused) disconnect. The Sunny Boy inverter cannot backfeed currents into the PV array, so DC fuses are normally not needed when only one or two strings of modules are connected to the inverters. Therefore, the unfused HU361 disconnect may be used.

Disconnects—Location & Orientation

The rule for mounting many disconnects seems to be "wherever it will fit." The *NEC* requires disconnects (switches and circuit breakers) to be located with the handles in the upper position no more than 6 feet, 7 inches (2 m) above the floor or ground. The manufacturer's instructions on many high current switches and breakers (like those used for large PV system disconnects and battery disconnects) require that they be mounted on a vertical surface and oriented so that the handle also moves vertically rather than horizontally. This must be done so that the internal arc suppression mechanisms function properly (hot arcs rise).

The photo (top right), a triple whammy, shows a disconnect and combiner box using black wires for grounded conductors, switching the grounded conductor, and mounted 10 feet (3 m) above the ground.

Installing PV systems safely and in compliance with the codes is not difficult. It takes some understanding of the requirements. After all, hundreds of thousands of new homes and electrical systems are installed every year throughout the country, and most are in full compliance with the *National Electrical Code.* Why should PV systems be any different?

Access

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Special listing information on the Square D H361/HU361 safety switch: www.squareD.com/us/products/safetysw.nsf/DocumentsByCategory/DD5F1F9416FA23668 5256D350071EC30 or go to www.sma-america.com and select Tech Updates

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Lights Out

Don Loweburg

It is no surprise to most people that occasionally the electricity grid goes down. As they say, "stuff happens." Trees blow down during storms, taking utility lines with them. Lightning strikes take out transformers. Vehicle crashes interrupt service. Substation transformers overload. Though the frequency of these events can be reduced by maintenance and prevention programs, such as tree trimming, safety barriers, easements, better equipment design, etc., they are generally regarded as "acts of god" or "accidents."

Recently, there have been several grid failures of a totally different nature. Most notable is the outage in New York on August 14, 2003. It lasted 24 hours and affected 50 million people. These system crashes are not limited to the United States. Another recent failure occurred in Italy, September 29, 2003, lasting 8 hours and keeping 54 million people in the dark. Sweden and Denmark also had an outage on September 23, 2003, lasting 2 hours, and affecting 4 million people.

Though there have been regional grid collapses in the past, the frequency of these recent events clearly exceed any historical norm. For example, during the last 31 years, regional outages were much less frequent. There have been three in the United States: California, August 1996; New York, July 1977; and New England, November 1965. The increased frequency of these grid failures indicates a larger, more pervasive problem. The transmission and distribution systems are becoming unstable. Failure in one area propagates to other areas. What is causing the erosion of grid reliability?

Mainstream Gets It Wrong

Most news media coverage of the 2003 New York blackout presented the outage as the expected result of transmission capacity shortfalls. Former Energy Secretary, Bill Richardson (now governor of New Mexico), said during a CNN interview, "We're a superpower with a Third World grid." *The Washington Post* headline for an article by Peter Behr on August 15, 2003 read, "System Crash Was Predicted." James Jelter of Reuters wrote, "Blackout Betrays Ailing North American Power Grid."

Mainstream media explanations of why the outage occurred universally focused on insufficient transmission capacity. The cure most often suggested was to increase the transmission capacity of the grid. This simplistic explanation and cure, however, was challenged by more rigorous authors and publications.

A Deeper Analysis

The North American Electric Reliability Council (NERC) revealed a deeper level of analysis when they wrote, "The grid is now being used in ways for which it was not designed, and there has been a quantum leap in the number and complexity of transactions. The users and operators of the transmission system, who used to cooperate voluntarily on reliability matters, are now competitors without the same incentives to cooperate with each other or to comply with voluntary reliability rules. As a result, there has been a marked increase in the number and seriousness of violations of these rules. All of these changes are jeopardizing the very stability of the electric system upon which our economy and our society depends and there is little or no effective recourse today to correct such behavior."

What is the misuse of the grid to which NERC is referring? The answer to this question is detailed in an article by Eric Lerner titled, "What's Wrong with the Electric Grid?" The article appeared in the October/November 2003 issue of *Industrial Physicist*. Lerner states, "Experts widely agree that such failures of the power-transmission system are a nearly unavoidable product of a collision between the physics of the system and the economic rules that now regulate it."

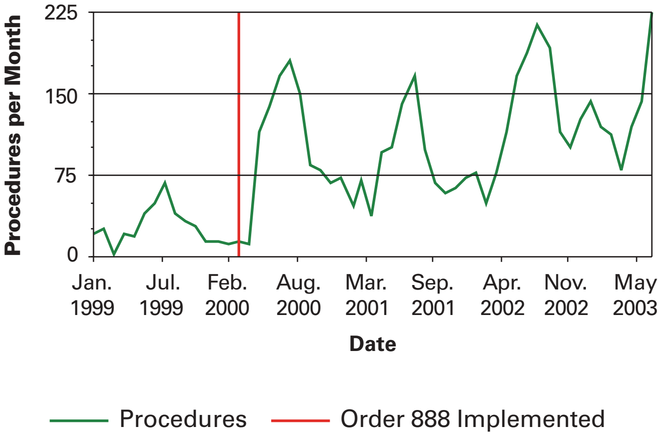
The economic rules he is referring to are deregulation and the corresponding increase in electricity "trades" now occurring. These rules allowed traders to "game" the electricity market in California two years ago at a cost of US$30 billion to ratepayers and taxpayers.

The physics of the grid (its design and structure as originally conceived) is intended to deliver electricity from a central point of generation radially outward to customers. Superimposed on the radial structure is a system of links that allow energy generated in one system to be moved to another system. Following the 1965 New York grid collapse, these interties were created with the understanding that they would increase system reliability. Today, these links, coupled with electricity trading, contribute to the instability of the grid.

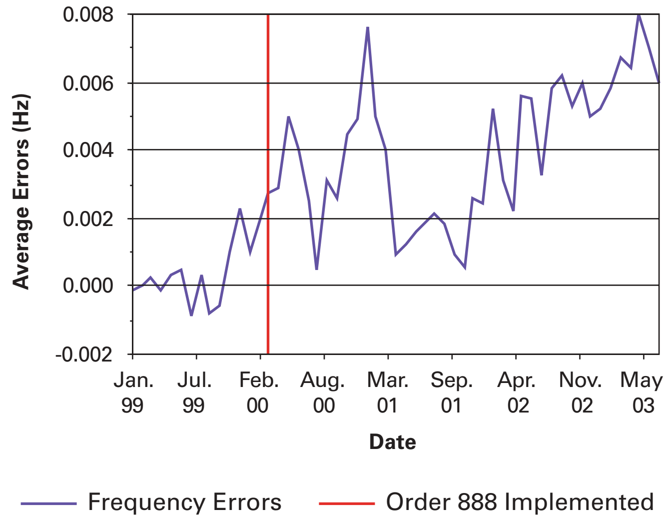
Mr. Lerner supports this conclusion by noting that, "Although power generation (for consumption) in 2003 has only increased 3 percent above that in 2000, generation by independent power producers, a rough estimate of wholesale trading, has doubled." He goes one step further by providing a "smoking gun."

He correlates the onset of trading, beginning with implementation of FERC (Federal Energy Regulatory Commission) Order 888 allowing wholesale wheeling (trading) in March 2000, with a significant increase in grid stress as measured by two indicators recorded by NERC. One indicator, TLRs (transmission loading relief procedures), is a statistic that includes relieving line loads

Transmission Loading Relief Procedures



Frequency Instability on the Grid



Graph data from North American Electric Reliability Council.

by shifting energy to other lines—usually associated with overloading transmission lines. Since trading began in late 1999, TLRs have increased by 700 percent.

A second documented indicator of grid stress cited in Lerner's article is frequency instability. As the grid becomes stressed, small frequency perturbations increase. Since wholesale trading began in late 1999, the documented rate of these perturbations has also increased about 700 percent (see graph).

Lerner's conclusion is that the grid was not designed for energy trading. He does concede that increasing transmission capacity would increase stability. However, he points out that the cost would be borne by ratepayers, since transmission and distribution continue to be regulated. This would be a major cost shifting to ratepayers since the unregulated generators and traders would not be paying for the transmission upgrades, though they would benefit. Having ratepayers pay the upgrade costs is yet another huge subsidy benefiting the generation cartels.

None of the above analysis could be heard or found in the major public media. The resounding media mantra was "more transmission capacity." This is not surprising, given that the dialogue is controlled by the utilities and energy holding companies. They, to be sure, would be well served by increased transmission capacity paid for by ratepayers. However, is this the best solution? Might there be another approach that provides superior reliability, lower cost, and allocates that cost fairly? That approach, really a new paradigm, is distributed generation.

An Integrated Systems Approach Needed

In my column in *HP98*, a national "Manhattan Project" for renewables was envisioned. Such an approach would be incomplete if it proceeded without duly embracing the benefits of distributed generation. In fact, distributed generation will be the necessary context in which renewable generation succeeds.

One of the primary benefits of distributed generation is that it significantly reduces the amount of energy lost in the transmission and distribution of electricity. Often generating plants are many miles away from the cities and customers they serve. Electric transmission losses can be as high as 20 percent. Distributed generation located at the point of use would not suffer these losses.

Imagine reducing the need for central generation capacity by 20 percent. Grid reliability would be increased substantially without the cost of transmission upgrades. If distributed cogeneration were used, an additional 30 percent increase in efficiency is possible due to waste heat recovery. Replace fuel burners with distributed fuel cells and even greater efficiencies are possible.

An additional unique benefit of distributed PV generation is that the daily output matches very closely the summer load requirements of the grid. PV output peaks during the midday peak demands caused by air conditioning and water pumping. This automatic match between supply and demand simplifies the job of "dispatch" at the central generating plant. Dispatch for utilities is always challenging because the large mechanical generating sources they depend on cannot be turned on and off quickly.

Another element of the distributed generation model is the possibility of microgrids. Microgrids could be composed of a mix of generation technologies, for instance, PV plus fuel cells operating on natural gas. Under normal conditions, microgrids could be connected to the larger utility grid. However because a microgrid would have standalone capability, it could be intentionally islanded if desired.

This capability would have a twofold benefit. The larger utility network would benefit under conditions of stress by being able to shed load in a systematic manner without leaving customers in the dark. Customers connected to a microgrid would benefit from the increased reliability of standalone capability during periods of utility stress. (For more on microgrids, see Access.)

Today, this country is at a critical point. In a sense, the lines are drawn. On the one hand, we have the nuke-carbon proponents and their preferred model of central generation and transmission. On the other are proponents of renewables and distributed generation. Fundamentally, the situation can be appreciated as an evolutionary transition. From this point of view, it is inevitable that efficiency and reliability will prevail. The only question is how long the transition will take, and how much suffering must be endured getting there!

In closing, I quote David Morris from his Web article, "Blackout: Repeating Energy History." He concludes, "We need to adopt a bottom-up approach. We need to establish rules that will channel entrepreneurial energy, investment capital, and scientific genius toward building a two-way electricity system, one in which millions of households and businesses become producers as well as consumers. We need to develop the rules that will enable and encourage a distributed, decentralized, democratic electricity system."

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"Blackout: Repeating Energy History," David Morris • www.tompaine.com/feature2.cfm/ID/8646

"What's Wrong with the Electric Grid?," Eric Lerner • www.aip.org/tip/INPHFA/vol-9/iss-5/p8.html

"A Micro-Grid with PV, Fuel Cells, and Energy Efficiency" • http://arizonaenergy.org/Analysis/DistributedEnergy/MicroGrids2.pdf • Slightly dated but a good introduction to the subject

Writing for *Home Power*

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

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- Load table.
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Nuclear Waste—NIABY

Michael Welch

The *Power Politics* column in *HP96* about my tour of the proposed Yucca Mountain high level nuclear waste repository near Las Vegas generated more comments than any other column I can recall. Most of the comments were positive, and many came with a question or two about radioactive waste.

A couple of comments came from people who believe that nuclear power is the primary answer to the world's energy problems. Still other comments came from people who seemed to have exactly the mindset that the column was really about—the belief that academicians and engineers should always be able to come up with a technological fix for any problem posed. One of these folks even went so far as to suggest that since I do not have background and training in chemistry (as he did) or nuclear physics, that I should not be commenting on things that I do not understand. But if the scientists understand this so well, how come after 60 years and hundreds of billions of dollars, no good solution has shown up?

Techno-Fix Is In

The practical application of the techno-fix mindset is that the way to solve a problem, no matter how large or difficult, is to simply throw extraordinary amounts of money at it. Dennis Kucinich said, "When our children fail competency tests, the schools lose funding. When our missiles fail tests, we increase funding." This approach is also being applied to the unsolved, and probably unsolvable, question of nuclear waste. And our government selectively applies this kind of funding only to industries that have a lot of influence, like the arms industry, which is very closely aligned with the nuclear power industry.

The main question I received about that Yucca Mountain tour article was, "OK then, what *are* we going to do with all the nuclear waste?" That is a really tough question, because there is no acceptable way to deal with it. The bottom line is that we have to quit assuming that some day there will be a technological fix, and that means we have to stop producing the deadly stuff. We must close down every nuclear reactor in the world as soon as possible—including those reactors that are making nuclear weapons materials. That way the problem of what to do with the waste will not become larger than it already is.

> *What I firmly believe in is NIABY—not in anyone's back yard.*
>
> *No community should have to put up with nuclear waste.*

No Solution Is Good

My answer to storing nuclear waste is to leave it right where it was produced. There are several components to my thinking on this. First, I am not a NIMBY (not in my back yard) environmentalist. In fact, there is a nuclear power plant local to me, and I even advocate that the waste be stored here, at "our" plant. What I firmly believe in is NIABY—not in *anyone's* back yard. *No* community should have to put up with nuclear waste.

But that ship has sailed, and there is already nuclear waste at various power plants throughout the United States. The potential for transportation accidents is probably the biggest reason for not moving it again. The opening of Yucca Mountain is referred to as a "mobile Chernobyl" by the independent press, and for good reason. All it takes is one serious slip-up in the more than 80,000 planned shipments of radioactive waste to turn another community into a nuclear waste problem.

Nuclear power presents obvious problems at the point of production, and moving most of the waste from the power plants to Yucca Mountain is not going to completely solve them. Those communities will still have operating power plants and the ensuing waste, and will still have contaminated equipment and environs. So, it does not make much sense to add yet another contaminated area (Yucca) just to remove some of the contamination from other communities.

Local bumper stickers say, "Nevada Is Not a Wasteland," and the Nevada desert should not be treated as such. Nevadans care just as much about their environs as those of us who care about our wetter surroundings. Moving the waste to Nevada would give final legitimacy to the intentionally flawed process that pinpointed Nevada as a "wasteland" and as the repository state. Nevada was not chosen because it is the best place for the waste to go. It was chosen because it had less political clout than the other states being considered.

Take the Bad with the Good

Nuclear waste is a burden, and to me the burden is rightfully borne by the same communities that "enjoyed" the benefits of the electricity produced by these plants. In the interest of fairness, communities should be willing to bear the negatives as well as the positives of nuclear power, rather than foisting the negatives on other communities.

With the exception of the transportation problems, none of these reasons by themselves are enough reason to keep the waste local. But when you put them all together, the argument is pretty compelling.

What about other methods of off-site disposal besides long-term storage in Nevada? Unfortunately, most require the same kind of transportation as the Yucca option, plus the results of the method itself. The most commonly mentioned idea is sending the waste to the Sun, or elsewhere in outer space. Talk about a transportation problem—plenty of rocket launches blow up in the atmosphere. Imagine scattering plutonium and other dangerous isotopes over thousands of square miles of Earth.

Vitrification is fusing the nuclear waste with glass or ceramic material, ostensibly to "lock" the waste into a form that will be more stable in the environment. This idea was popular in the 1980s, since it was France's preferred method of dealing with the waste. More recently, it has been somewhat discredited because there is little proof that the vitrification will lock the waste up as long as necessary. But this process is still being considered for some rarer, liquid, high level waste, such as is found in the leaking tanks on the Hanford, Washington, nuclear reservation.

Reprocessing is now France's preferred method of dealing with their waste, and they even offer it as an international service. This has also been tried in the U.S. and other countries, with pretty poor results. Not only is transportation still an issue, but the process itself produces hard-to-contain contamination, and it is also quite expensive. Since the main point of reprocessing is to separate the plutonium so that the rest of the waste can become reactor fuel again, there are nuclear weapons proliferation issues as well. And making new fuel from old just encourages the use of more nuclear energy.

The Answers—Kind Of

The big question is, how do you store reactor waste on-site in a (relatively) safe manner? Every commercial nuclear reactor has a spent fuel pool. They look like swimming pools, where the irradiated fuel rods from the reactor are stored until they need to be moved. Immersion in water is the best method of blocking the radiation so that it does not escape into the environment. It also carries away any radioactive particulates, which can then be recaptured in a filter, and then becomes additional radioactive waste. My opinion, and the opinion of many other environmental activists, is that the fuel rods should be stored indefinitely in those pools, where they can be monitored by human beings as long as we inhabit the earth.

There are site-specific exceptions to this "rule." The power plant near me sits on a major earthquake fault, and the fuel handling building, where the spent fuel pool is, will not survive an earthquake when (not if) one occurs. So for this plant, and other plants with site-specific problems, we should be using dry cask storage (DCS)—but still on the plant's site.

DCS works for fuel that has had time to cool down after being in a reactor. The casks are designed to handle earthquakes, and can also be designed as transportation casks, just in case there ever is a place to move the fuel. Once the fuel is moved to the casks from the pool, the casks can be lowered into specially designed belowground vaults for protection from the elements and terrorists.

The bottom line is that we need to stop producing this horrible poison called nuclear waste, so we won't need to store it anywhere. Unfortunately, the nuclear industry has too much power over our government. They have heavily influenced the new energy bill, and if it ever passes, they are lined up for US$7.5 billion in production tax credits to encourage the construction of new nuclear power plants, US$1.1 billion in direct subsidies for the development of a new reactor to produce hydrogen, and US$2.7 billion more for R&D to come up with the next generation of nuclear power plants.

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Power Factor—

Ratio of True to Apparent Power

Ian Woofenden

Derivation: From Latin posse*, to be able, and Latin* factor*, maker, doer.*

Electrons, or "charges," are the energy carriers in an electrical circuit. Charges are part of the material of the conductor, the copper or aluminum wire. They go in one direction around a direct current (DC) circuit. They go back and forth in an alternating current (AC) circuit. Charges don't leave the circuit, and they aren't used up.

In AC circuits, the direction of charge flow reverses many times a second. The voltage (electrical pressure) and amperage (rate of charge flow) go from zero to maximum in one direction ("positive"), back to zero, to the maximum in the other direction ("negative"), and then back to zero. We call this a "cycle, " and in the United States, AC is 60 cycles per second (Hertz or Hz for short).

When the voltage and amperage peak and then go to zero at the same time as each other, we say that they are "in phase." (See diagram below left.) This is what happens in circuits that have only resistance. But many AC circuits also have a couple of other electrical properties—inductance and capacitance. These push the voltage and amperage out of phase with each other, so that they peak at different times. We call these circuits "reactive," because some of the energy is bounced back at the source in a delayed reaction, due to the characteristics of inductors and capacitors. Reactive loads include motors, fluorescent light ballasts, and many electronic devices.

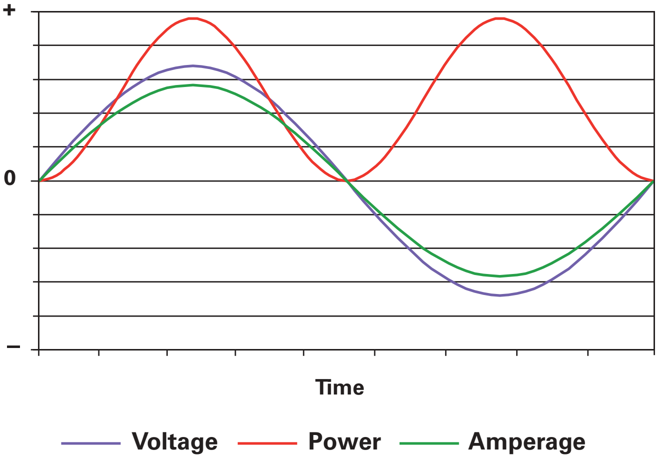
Power, the rate of energy flow, can be calculated by multiplying voltage and amperage (electrical pressure and charge flow rate). So theoretically, if your source voltage is 120 and your amperage is 10, you are generating energy at the rate of 1,200 watts. (We'll ignore the intricacies of rms, techies.)

In a reactive circuit, it's not that simple, because the voltage and amperage are not in phase. The second diagram (below right) shows a circuit where the voltage and amperage are not in phase—they peak at different times, and the power actually goes negative for a portion of the cycle (shaded area). With the same voltage and amperage out of the generator, the actual power available to the load will be less in this circuit.

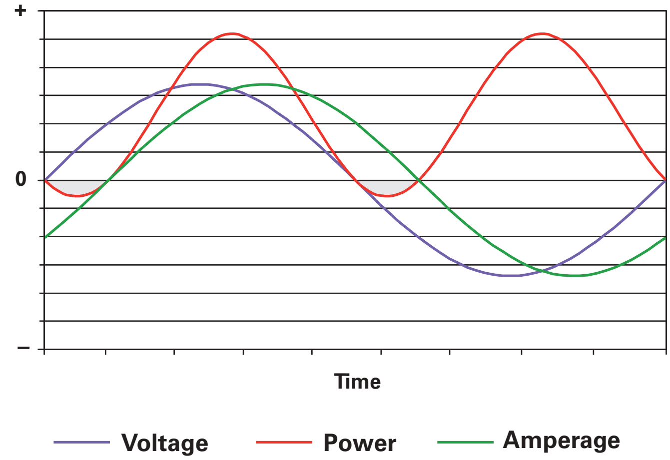
The generating source has to produce the full amperage in either case. But less power is available to the load when voltage and amperage are out of phase. Some of the charges are just moving energy back and forth unnecessarily, and this creates an illusion of power, known as "reactive power."

We call the product of volts times amps in a reactive circuit "apparent power" (also called "volt-amps", and abbreviated "VA"). We call the power that is usable to the load "true power" (watts, abbreviated "W"). The ratio of

Resistive Load (PF = 1.0, V & A In Phase)



Reactive Load (PF = 0.8, V & A Out of Phase)



apparent power to true power is called "power factor" (PF). A power factor of 1 is ideal. It is when the apparent and true power are the same.

$$W \div VA = PF$$

If we take the same 120 volts and 10 amps from the example above, but the load in the circuit has a power factor of 0.8, the power available to the load will actually be only 960 watts.

The excess energy in reactive circuits is not lost. It just "sloshes" around in the circuit, bouncing back to the source. But since losses in a circuit are tied directly to the charge flow rate (amperage), raising the amperage in a given size of wire means that the losses will increase. So a circuit with bad (low) power factor will need larger wires to keep the losses at the same level as a circuit with good (high) power factor.

On the physics side of things, I like to picture charges bouncing back and forth in a reactive circuit. They don't do the work they could because the driving force (voltage) is out of synch with the charge flow. "Watts" measures the energy flow from the generating source to the load. "Volt-amps" measures the theoretical maximum energy flow, including the illusory reactive energy that is bounced back to the generating source.

The practical lessons are that high power factor devices are always going to be easier on your generating sources—they will increase efficiency in your systems. And wire sizing must take into account the full apparent power that the load needs, even though some of it is recycled by the circuit.

My thanks to Hugh Piggott for going above and beyond the call in helping me with the technical end of this column. He says, "I have seen it compared to a glass of beer. The amount of beer in the glass is the apparent power. The liquid is real power. The froth is reactive power." Me? I don't drink the stuff, so I wouldn't know…

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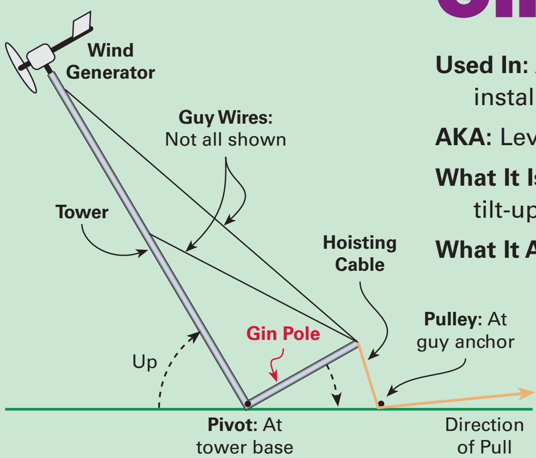
Gin Pole



Used In: All tilt-up and some guyed and freestanding wind generator installations

AKA: Lever arm, lifting pole, falling derrick, davit

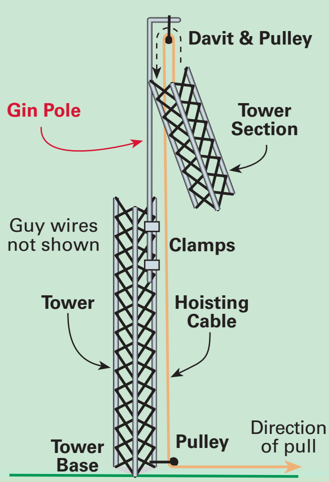
What It Is: A lever to raise a tilt-up tower or a temporary crane for a non-tilt-up tower

What It Ain't: A liquor survey

The phrase "gin pole" is used to identify two very different structures associated with wind generator towers.

In reference to tilt-up towers, the phrase refers to the lever arm that is used to lift the tower off the ground. Usually it is a steel pipe of the same diameter as the tubular tower pipe, and can be as long as the guy wire radius.

A gin pole makes it easier to raise the tower. Try tilting up a pipe or pole by pulling along the length of it and you'll find that something may break before anything lifts. Adding a lever at 90 degrees makes it easy to lift the pipe.



In reference to non-tilt-up towers, a gin pole is a temporary "crane" that sticks up above the tower. It allows you to lift additional tower sections and the wind generator without hiring an expensive crane.

Generally, two brackets are clamped to a tower leg with bolts, and provide a sleeve for the gin pole, which is pulled up through the brackets. A davit or block is added on the top, and a lifting line is threaded through before the pole top is raised out of reach.

The gin pole is then bolted securely in place before any lifting is done. After each section is in place, the gin pole and brackets are moved up to the next section. Temporary guy ropes are necessary to keep the tower stable.

—Ian Woofenden • ian.woofenden@homepower.com

The Worst at Work

Kathleen Jarschke-Schultze

Recently I read about the newest book in the *Worst-Case Scenario Survival* series. It deals with problem scenarios in the workplace. It tells you how to stay awake during meetings, unstick a candy bar from a vending machine, thwart a lunch thief, and the like. Hoo boy, that's nothing like *my* RE powered, remote workplace.

Commuting

People who hear that I work from home always think that makes for a cushy job. I will tell you that it is a double-edged blade. Sure, I don't have the commute. This makes me wonder which would be worse—commuting over dirt roads, skinny country roads, mountain passes, and freeways, or in-town driving? Of course winter conditions always make mountain driving worse. That's the kind of commute I would have. But maybe the incredibly snarled traffic problems I see on the morning news would be worse. Yikes!

We live in a county that has twice as many cows as people. (This has been documented.) The whole county is open range, meaning that livestock can be found wandering anywhere, including in the roadway.

Yreka, our county seat, used to have only one stoplight. The arrival of Wal-Mart spawned another stoplight. Instead of turning it on immediately, the county covered the light with feed sacks for about four weeks. For the next step of integration, they turned the light to flashing yellow for another three weeks. Finally, they brought the stoplight up to speed and all three colors are working now. You have to ease country folk into change, you know.

Whenever I go to a bigger city (anything over 35,000 population), it seems there are stoplights on every corner. And you never see a herd of cows being driven down Main Street.

Home Alone

People who travel to a workplace don't realize on a conscious level that when you work at home, you never leave home. Say you have a job away from home. You leave a clean house, and eight or nine or ten hours later, you return. Your house is still clean.

When I work at home, my house gets lived and worked in 24/7. To cope, we have what we call our "piling system." Any and all things tend to get piled, waiting for me to return to that task because I've been called away to another task. This goes for both business and home-related tasks.

On weekends, I am still at work. I can't go home; I'm already there. The same piles are looking at me, waiting to be dealt with. Sure, I can get a few household chores done during the workweek between phone calls, shipping, and computing. But, I have to be ready to be interrupted at any moment. I usually wear an apron with a dishtowel attached. Then when one of the phones rings, I can dry my hands as I hurry to answer it. I can only vacuum after or before business hours because I can't hear the phone.

Basically, I cannot be more than three rings away from the phones or customers can become perturbed. When I am outside doing chores, I have a snap-on tool belt. It carries a wireless phone, notebook, pen, and a pair of garden clippers. The wireless gets lousy reception when I am all the way out at the chicken coop. That is not the worst of it though.

Worst-Case Scenario #1

About a year ago, I was home alone sitting at my desk. I could hear the wind in the trees outside. Automatically, I glanced out the window toward the Whisper 1000 wind turbine spinning atop a 60 foot (18 m) tilt-up tower. I felt that zing of fear when I saw that a top guy cable had come loose, and the turbine was swaying and bending the tower more than I thought possible. Grabbing a pair of leather gloves, I ran out the door towards the pole. My brain kept saying that it was going to snap at any minute. How can it bend that far and not break?

I reached the base of the tower and found the loose end of the guy cable. It was an upper guy that vibration had twisted out of its turnbuckle. I grabbed it and ran to the anchor and turnbuckle. Immediately I realized that I was in no way strong enough to pull the cable and start its threaded bolt end back into the turnbuckle. The wind generator is a vital part of our RE system that keeps our home and office running. What would I do?

Solution

I ran to the shop and scrambled around until I found a cable clamp lying on the vise bench. I kept looking around until I found a crescent wrench. Running back to the tower, I could see it still waving and flailing wildly in the wind. I never stopped to think about how dangerous the situation could be. At the least, I should have thrown the stop switch on the turbine, and been more careful and methodical while all this was going on. But my life usually is a cautionary tale.

I grabbed the loose guy cable and brought it as close to the turnbuckle as I could. I slipped the U-bolt of the clamp over that cable and the bottom guy cable attached to the same anchor. I slid the saddle onto the U-bolt, threaded on the two nuts, and tightened them with the crescent wrench. That stopped the immediate threat of losing the wind turbine and tower. It still swayed back and forth, but not in such a large frightening arc.

I ran back to the house and called our neighbor, Stan. Breathlessly, I told him what happened and finished with a forced casual, “When you have a minute, could you come help me reattach the guy cable?”

Stan responded, “I’ll be there in two minutes.”

When Stan arrived, I returned to the tower and its slackened guy cable. A come-along would have been a really good tool to have for this job, but we didn’t have one. I didn’t think to clamp on a temporary safety cable so we wouldn’t be holding the cable only by hand again. We loosened the cable clamp. Both wearing leather gloves, we pulled the cable over to the turnbuckle. Stan dug his feet in and held it there while I tried to start the cable bolt into the threads of the turnbuckle. After several tries, I ran to the shop and got a can of WD-40 while Stan held the cable. After spraying the cable bolt and turnbuckle, it took a few more tries to get the bolt started into the threads.

Once it held, I used the crescent wrench in the center hole of the turnbuckle to tighten the cable. I later found out that this is not the correct method to tighten a turnbuckle. It should be tightened at the ends, not the middle. At the time, it seemed like the easiest way for me to quickly get it safe enough for Stan to let go of the cable.

I threaded a small length of baling wire through the upper and lower guy turnbuckles at the anchor to prevent any reoccurrence. We checked the other turnbuckles for loosening, and applied preventative baling wire. Disaster was averted. Since I was at work, I had to go back to the house/office and check the phone message machine and return all of the calls that came while I was occupied with saving our wind turbine and tower.

When Bob-O returned home, he used some lengths of cable in figure eight patterns (instead of the baling wire) to secure all the turnbuckles—better late than never! This was the first (and only) tower that Bob-O ever made himself. In a classic case of the shoemaker’s children going barefoot, he had not found the time to complete all the details of securing our tower—until this happened.

The tower is down again at the moment, but intentionally as we wait for some free time to replace the old turbine with a Whisper H80. We will be adding another full set of *well-secured* guy cables and anchors. Lesson learned.

Worst-Case Scenario #2

A couple of years ago, Bob-O was on the phone with a customer when he glanced out the window. To his great surprise, he saw a mountain lion taking down a deer on the road, across the creek, thirty feet away. He told the customer, “Something is happening outside. I have to go. I’ll call you back.”

I grabbed my 110 pound (50 kg) Airedale dog and locked her in the bedroom. (First disaster averted.) I looked out the window again. There was quite a struggle happening. Bob-O grabbed a gun, hoping to shoot into the air and stop the cougar’s attack. He started in the direction of the struggle.

I was watching the writhing animals and realized that it was not a mountain lion killing a deer. It was two mountain lions fighting. There was snarling, growling, and flying fur. Then both cats were lying in a still tangle in the morning sun on the dirt road. As we watched, their tails started twitching. With several growls, they jumped up. One ran up the road and the other took off directly up the side hill.

Solution

We had already performed the solution. We didn’t go near the fighting cats, and I put my terrier in a safe place. Next I called the neighbors up the road and warned them to not let their small children play outside alone, if at all. When Bob-O went across the road to check the area where the battle took place, he found many tufts of golden fur and a bloody claw torn off and lying in the dirt. When he got back to the house, he called the client, apologized for the interruption, and continued their conversation.

I know these are not typical workplace scenarios. But I have found that when you live remotely with renewable energy, you need to be able to land on your feet, laughing. Expect anything; it just might happen. Now if I could only talk Bob-O into a candy bar vending machine for our office/dining room.

Access

Kathleen Jarschke-Schultze is fermenting an unassuming little Pinot Bob-O from her micro-vineyard at Chateau Schultze in Northernmost California. c/o *Home Power*, PO Box 520, Ashland, OR 97520 • kathleen.jarschke-schultze@homepower.com

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.

AUSTRIA

Mar. 3-5 '04; World Sustainable Energy Days; Wels, Austria. European Green Electricity Forum, "Megatrends of Sustainable Energy," & an exhibition fair. Info: O.Ö. Energiesparverband, Landstraße 45, A-4020 Linz, Austria • +43-732-7720-14380 • +43-732-7720-14383 • office@esv.or.at • www.esv.or.at

CANADA

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. 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 technologies. Info: see SEI in COLORADO listings. Coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

GERMANY

Mar. 5-7, '04; Erneuerbare Energien 2004; Böblingen, Germany. Conferences & workshops on RE market situations. Info: see RENEXPO entry below.

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 2123 • info@windenergy-hamburg.de • www.windenergy-hamburg.de

Oct. 21-24, '04; RENEXPO 2004; Augsburg. Hydro power, decentralization, biofuels, solar, biogas, energy-efficient construction. Info: Erneuerbare Energien Kommunikations und Information Service GmbH, Unter den Linden 15 • 72762 Reutlingen, Germany • +49 (0)71 21-30 16-0 • Fax: +49 (0)71 21 - 30 16 -100 • redaktion@energie-server.de • www.energy-server.com

MEXICO

Mar. 2-9, '04; Build a Solar Culture Where the Sun Shines; Akumal, Mexico. A hands-on workshop in solar theory & installation. Info: RENEW Wisconsin, 222 S. Hamilton St., Madison, WI 53703 • 608-819-0748 • www.renewwisconsin.org

POLAND

Mar. 23-25, '04; ENEX New Energy; Kielce, Poland. Fair specific to RE, in conjunction with the ENEX Power Industry Fair. Info: Targi Kielce, ul. Zakladowa 1, 25-672 • +4841/365 12 12 • Fax: +4841/345 62 61 • enex@targikielce.pl • www.targikielce.pl/enex_start/enex.htm

SPAIN

May 16-19, '04; SCELL-2004: Intl. Conf. on the Physics, Chemistry, & Engineering of Solar Cells; Badajoz, Spain. 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

U.S.A.

Videos: 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. Appalachia: Science in the Public Interest, 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

Info on state & federal incentives for RE. 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

Feb. 23-28, '04; PV Design & Installation, Tucson. System design, components, site analysis, system sizing, & a hands-on installation. Info: see SEI in Colorado listings.

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

Mar. 1-3, '04; AEST 2004, Alternate Energy Sources & Technology; Marina del Rey, CA. For researchers & practitioners, on recent advances in RE. Info: IASTED, 4500 16th Ave. NW #80, Calgary, AB Canada T3B 0M6 • 403-288-1195 • Fax: 403-247-6851 • calgary@iasted.org • www.iasted.org

Mar. 8-13, '04; Women's PV Design & Installation, Santa Cruz, CA. System design, components, site analysis, system sizing, & hands-on installation. Info: see SEI in Colorado listings.

Mar. 12, '04; Intro to RE. Solar, wind, & microhydro for homeowners. Info: see SEI in Colorado listings.

Mar. 15-20, '04; PV & Installation, San Francisco. System design, components, site analysis, system sizing, & a hands-on installation. Info: see SEI in Colorado listings.

Apr. 8-10, '04; Understanding Grid-Connected Solar Electric Systems. Humboldt State Univ., Arcata, CA. For homes or businesses. Info: HSU Office of Extended Education • 707-826-3731

Apr. 16-17, '04; Utility Interactive PV workshop San Diego. System design, components, site analysis, & system sizing. Info: see SEI in Colorado listings.

Apr. 27-30, '04; Hydrogen: A Clean Energy Choice; Los Angeles. National Hydrogen Assoc. conference & expo. Info: NHA,1800 M St. NW #300, Washington, DC 20036 • 202-223-5547 • Fax: 202-223-5537 • HydrogenConference@ttcorp.com • www.hydrogenconference.org

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

May 14-15, '04; Solar Home Design for Net-Zero Energy. PV, solar thermal, passive solar for "Net-Zero" energy home in any climate. Info: see SóL Energy in International listings.

May 21-22, '04; PV Systems Design & the NEC. Learn to design code-compliant PV systems. Info: see SóL Energy in International listings.

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, Straw Bale Construction, RE for the Developing World, 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

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

Mar. 10-13, '04; NESEA Building Energy Conference; Boston Univ., Boston. Professional conference & trade show on high performance green building & RE. Info: NESEA, www.nesea.org/buildings/be

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 Discussion, Ferndale, MI. 2nd Wed. each month, 7-9 pm. Sustainability, energy efficiency & conservation, RE, green building, & consumer issues. Potluck. Free. The GreenHouse, 22757 Woodward #210, Ferndale, MI 48220 • 313-218-1628 • www.hometown.aol.com/ecadvocate

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

MISSOURI

Feb. 8, '04; Winter RE Fair; New Bloomfield, MO. Wind generators, PV systems, SDHW, passive solar, hydro power, green building, biodiesel, solar carts, & more. Free. Info: Missouri RE Center • 800-228-5284 • www.moreenergy.org

MONTANA

Whitehall, MT. Sage Mountain Center: sustainable living tours, seminars, workshops, PV, green building, more. SMC, 79 Sage Mountain Trail, Whitehall, MT 59759 • 406-494-9875 • cborton@sagemountain.org • www.sagemountain.org

NEW JERSEY

Apr. 17-18 & 24-25, '04; Grid-Connected Solar Electric Systems. For the home or small business. Info: see SEI in Colorado listings.

NEW MEXICO

Apr. '04; Natural House Building, Kingston, NM. Learn how to build with earth & straw. Hands-on sessions including straw bale, adobe, pressed block, cob, & natural plasters. Info: see SEI in Colorado listings.

NEW YORK

Apr. 12-17, '04; PV Design & Installation, Woodstock, NY. System design, components, site analysis, system sizing, & a hands-on installation. Info: see SEI in Colorado listings.

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

OREGON

May 14-16, '04; Living Better in the NW, Sustainable Solutions for the Rogue Valley; Jackson County Fair Grounds, OR. RE, transportation, organic farming, community design, science of sustainability, sustainable home building, & resource mngmt. Info: Tristan Ragsdale, ECOS, Southern OR Univ. • 541-552-8512 • ragsdalet@students.sou.edu

Jul. 10-14, '04; SOLAR 2004; Portland. American Solar Energy Society national conference. Info: ASES • 303-443-3130 ext.103 • www.ases.org • bchowe@ases.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

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

TENNESSEE

Apr. 21-24, '04; Solar Electric Design, Earth Advocates Research Farm (The Farm). Basic PV, hardware, system design, installation, & troubleshooting. Info: Ed Eaton, Our Sun Solar, PO Box 1876, Paonia, CO 81428 • 970-948-5304 • hareef99@yahoo.com

TEXAS

Mar. 22-27, '04; PV Design & Installation, Austin, TX. System design, components, site analysis, system sizing, & hands-on installation. Info: see SEI in Colorado listings.

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: e-mail for meeting times: HREG • hreg@txses.org • www.txses.org/hreg

UTAH

Apr. 12-17, '04; PV Design & Installation, Salt Lake City, UT. System design, components, site analysis, system sizing, & hands-on installation. Info: see SEI in Colorado listings.

VERMONT

Feb. 7-8 '04; Designing Solar Energy Systems Workshop; Warren, VT. Basics of designing & installing PV & SDHW systems. Info: Yestermorrow Design/Build School, 189 VT Rt. 100, Warren, VT 05674 • 802-496-5545 • 888-496-5541 • kate@yestermorrow.org • www.yestermorrow.org

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

Apr. 8-10, '04; Grid-Tied PV Design & Install workshop, Guemes Island, WA. System design, components, site analysis, system sizing, & hands-on installation. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Apr. 12-17, '04; Homebuilt Wind Generators workshop with Hugh Piggott, Guemes Island, WA. Learn to build wind generators from scratch; blade carving, winding alternators, assembly, & testing. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Apr. 18, '04; Intro to Renewable Energy workshop, Guemes Island, WA. Solar, wind, & microhydro for homeowners. Lectures and tours. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

WISCONSIN

MREA workshops. Mar. 6, Custer: Energy Efficient Construction; Mar. 13, Custer: Intro to RE; Mar. 27-28, Custer: Basic PV. Also, Alternative Constuction, Intermediate PV, Solar Domestic Hot Water, & Solar Space Heating. Info: MREA, 7558 Deer Rd., Custer, WI 54423 • 715-592-6595 • mreainfo@wi-net.com • www.the-mrea.org

Errata

After printing the HP98 *article, "Using DC in Your Off-Grid Home," we discovered that an error had been introduced during the publishing process. In the test data table on page 95, the efficiency figure for Solar Converters EQ12/24-20 should have been "93.8%," and the output volts should have been "12.5." We regret any inconvenience this may have caused our readers, and any misrepresentation of the fine products of Solar Converters, Inc. While we were too late to "stop the presses" for the printed version of our magazine, we were able to make the appropriate changes in the electronic edition of* HP98. *Michael Welch, for the* Home Power *editorial staff.*

Down about New Downloading System

Dear *Home Power*, Why exactly have you started asking for all sorts of information from people in order to download your online publication? I suspect I will start to get lots of crap in my e-mail, answering machine, and mailbox. For quite some time I have looked forward to the new *HP* coming out—it *was* one of the few good deals left on the Web. The information you provide is invaluable, and it leads a lot of people to step beyond a dream and into the reality of making their own energy from renewables. A great many people won't even bother anymore if a site requires registration to get in, and it is almost always an invitation to start getting spammed and worse. By taking the actions you did, you have closed the door to a lot of potential renewable energy users who will simply write you off as a loss because they can't get in without jumping through hoops to do so.

I can see no legitimate reason for you to ask for the information unless you intend to sell it. I am very disappointed to see you take this step, and hope you will reconsider and keep your publication open to everyone, even those who don't wish to identify themselves to you. Over the past year as a user of solar energy, several neighbors have asked me about the technology, and I have pointed them to your site to learn more. Now I cannot do that because I will not recommend that others do something I am loath to do myself. Your actions represent to me the loss of a great information resource. Craig Garrett

Hi Craig. Thanks for writing in. We have given away our online edition for many years, and are continuing to do that. For all of that time, we have not been able to receive proper credit for that extra circulation. We need to have those issue downloads become auditable, so that our advertisers will have an accurate and verifiable understanding of our circulation. Though our current advertisers understand the value of our large online readership, it's hard to use it as a selling point for new advertisers without having hard numbers.

We have always wanted to count this circulation, but until recently the companies that audit magazine circulation have not offered this option. Our new download system will allow them to verify the downloads, and count you and other beneficiaries of our free current electronic edition policy. The info we ask for is not for sale, as you suspect, but rather is for confidential circulation auditing. We, as an organization, are adamant about not doing e-mail, phone, or snail mail spamming, and we never will unless the person specifically tells us they want it.

There is an optional questionnaire that asks about demographics and your RE system when you download our free current issue. We use that info to identify trends in the RE industry so that we may become a better magazine and RE advocate. I hope that answers your questions.

We still have a large selection of free RE articles and files on our Web site, with no registration required to download them. We've also started offering all *of our back issues electronically for download for a fee. This will give readers access to information otherwise only available on our CD-ROMs and in the issues that are still in print. Our goal is also to spread renewable energy to as many people as possible, and we think these new changes to our Web site are a step in the right direction. Michael Welch • michael.welch@homepower.com*

Lightning Grounding

I have a Whisper 900 and a 95 foot, three-legged, self-supporting tower waiting to be installed to supplement my 900 watt photovoltaic array. I have one concern—lightning. Three wind generators in my area have been struck. The damage is substantial every time.

I've heard two explanations for the benefits of grounding the tower structure with respect to protection. One is that grounding will actually make the structure "nonattractive" to lightning. The other explanation is exactly the reverse, that the grounding system is actually catering to the lightning by providing the current a direct and controlled path to ground, and thus protecting valuable electric components and living structures from high voltage harm.

Which is the answer? The second explanation seems more plausible, but I have little knowledge of electrical behavior. If it is so, the prospect of 100 percent protection seems unattainable. Wouldn't it be necessary to have a lightning rod that extended higher than the generator blades? And wouldn't you have to anticipate the worst and use copper conductors of incredible thickness? Enlighten me, please! Jack Eastman, Fairfield, Iowa • jacktoni@kdsi.net

Hi Jack, Lightning protection is 30 percent applied physics, 30 percent luck (karma), 30 percent voodoo, and the disposition of the remaining 10 percent is unknown. There is no sure bet here.

From a physics standpoint, grounding metal structures bleeds off static charges that may accumulate during electrical storms. This places the metal object (tower, PV racks, or radio antennas) at the same potential as the ground. This reduces the likelihood of a direct strike. Lightning is just like any electricity, just incredibly intense, powerful, and quick. A lightning bolt looks for the path of least resistance to ground. If static charges build up on metal structures, they are at higher potential than the ground and attract lightning because they present an easier path of less potential difference.

From a physics standpoint, if an outside structure takes a direct lightning strike, the grounding conductors may or may not make a path for this strike to go to ground. Considering the amount of energy carried by a lightning bolt, the grounding conductor, all its connections, and grounding rod or plane must be capable of conducting tens of thousands of amperes in a microsecond. We're talking copper conductors as big around as your arm... Thinking that a #8 copper wire and a 6 foot ground rod is going to do this job is a fantasy. If gear gets a direct strike, there is sure to be damage.

I spent three years operating a commercial, 100 KW TV transmitter on top of 7,500 foot tall Mount Ashland. On top of this mountain, we had a 260 foot tall metal transmitting tower. This tower was protected by multiple grounds with cables over 4 inches thick feeding six huge ground rods. The electronics were guarded by every known form of isolation and protection—cost was no object. During lightning season, we'd sometimes take up to six direct hits daily. We always *lost some of the electronic gear inside the transmitter building. I've removed electronics with a hacksaw when they welded themselves to steel racks and conduits. I've watched blue fire coursing across the racks of delicate electronics while I sat on a wooden stool in the middle of the room too petrified to even consider moving or touching anything.*

From a karma and voodoo standpoint, I recommend thinking good thoughts and burning copious quantities of Nepali temple incense under wind generator towers and PV racks. And avoid listening to the Grateful Dead's "Fire on the Mountain" during electrical storms. Richard Perez • richard.perez@homepower.com

Excess PV Heat

I'm in the Orlando, Florida, area and I'm considering a grid-tied PV system to help reduce my utility bill. I can see a panel on my roof easily getting over 140°F on a sunny day here. If you've ever been to the central Florida area, one attribute of homes around here is that many have pools. Many of those homeowners with pools have installed solar water heating collectors to heat the pools and thereby extend their useful seasons in our area. A pool, in this case, represents a fairly large source of 85°F water. I would love to know if there's anyone out there using pool flow to cool their PV arrays and heat their pool. If I could drop the temperature of the cell by 10 or 20°F, what would I gain in conversion efficiency? Bill Bragg • Bill@searssiding.com

Hi Bill, I've never heard of anybody trying to heat a pool with the excess heat coming off PV modules. There have been a couple of designs in R & D incorporating air collectors on the back of PV modules for space heating. None of these made it to commercialization. Heating a pool normally requires about half the pool surface area in collector surface area (collectors made for the job), which is normally a good deal larger than a home PV array. The quick answer is, yes you can cool the modules with air or water and improve the output and gather the wasted heat; no, people don't do it on any regular basis because of the cost-to-benefit ratio. Too little heat is gathered and too little efficiency is gained to make the expenditure worthwhile, so far. The industry needs a new product or a good inexpensive way to modify modules to make the idea reality. Cheers, Chuck Marken • chuck@aaasolar.com

Places to Start

I was just watching a show on Tech TV, where you were discussing your efforts with home power development. I'm all for it! But my technical skills are measured in negative values... I was wondering how easy or difficult it would be for me to find somebody with the expertise and ability to tell me what I can do to make my home less dependant on the grid. I live in Montreal, Quebec, pretty close to downtown, in fact. My roof is available and I've got a backyard. Didier • research@thoughttechnology.com

Hello Didier, There are some great nontechnical ways to get started, and in fact these are the best places for everyone, even the technically minded, to get started. If you have a family, institute a reward-based system for your family members to encourage energy conservation. You can do things like getting them to turn off the lights when leaving rooms, and doing only full loads of laundry with just cold water. Turn down your water heater so that it doesn't produce scalding water that needs to be mixed with lots of cold just to use. Try line drying laundry instead of running it through the dryer; it even works well to hang laundry inside the home when the weather is poor. Just spend a weekend going around the house, looking for ways to conserve and implement conservation.

Then, get more energy efficient appliances. A big one is to swap out your incandescent lightbulbs for high quality compact fluorescent bulbs. Other big energy hogs are the washing machine, water heater, and refrigerator, which should be replaced with as energy-efficient models as you can find.

Next come the parts that most folks can't do themselves. Get a solar hot water system. These usually also make economic sense, with paybacks as short as four years. Have someone come out and look at your home for a possible solar or wind-electric system. This is the most expensive thing you can do, especially if you don't take care of the conservation and efficiency things first. You can research dealers in your area from our Web site. Michael Welch • michael.welch@homepower.com

Pole Mount for SDHW System?

I am considering installing a drainback solar water heating system, but am concerned about mounting the panels on the roof. We have a single peak, two-plane roof with the peak running north-south. It is relatively steep (8/12), with a standing seam metal roof over plywood. It is a tall, two-story house, with the gutters at about 21 feet off the ground. The south wall of the house faces another tall house across a 12 foot space, so putting the panels on the ground is out. Is it reasonable to do a tall pole mount system bracketed to the north side of the house that would support the panels (two 4 by 8 foot) above the roof peak? Or should I do a compound angle steel framework bolted into the trusses through the roof? Also, we have a lot of storm wind exposure. We are on the top of a hill in Seattle.

I am thinking of making my own drainback tank out of 2 to 3 inch copper pipe, rather than spending several hundred dollars on a tank. Have you seen any simple designs for the competent DIYer? The drainback tank would be located in a closet on the second floor, just below the attic, and the pipes would run up through the attic. The main water tank and storage tank are in the basement. Any suggestions? Thanks for your help. Brian Clark • bclark1111@worldnet.att.net

Hi Brian, A high pole mount for heating collectors is uncharted ground for us. Weight, wind load, and piping will all have some bearing on this. Three or four poles making a kind of trestle attached to the house is a possibility. We have done this before, but never as high as 20 feet plus. I would suggest a roof mount, even though it might be hard to do. I realize that an 8 in 12 metal roof will need some bracing to allow you to work on the roof, and the way the pitch runs is also a factor. Is it out of the question to mount the collectors high on the south gable?

A drainback tank is a project for a savvy do-it-yourselfer, but 3 inch pipe is probably not suitable. You should have a minimum of 2 gallons per collector, and 3 inch pipe will have a capacity of one gallon per 2.75 lineal feet, or 5.5 feet per collector. I have never seen a DB tank less than about 6 inches in diameter (1.5 gallons per lineal foot). Most are about 12 inches or so in diameter. Hope this helps. Chuck Marken • chuck@aaasolar.com

More Small System Articles

I enjoy most of your magazine, especially system descriptions used by people who share the reasons for their designs. Articles like Richard Perez's description on making battery cables have proved to be extremely helpful. I would like to see more examples of integrated home technologies—complete off-grid mechanical integration. In fact, I am surprised at the lack of articles on complete small-scale, self-sufficient homes. Most of what I recall is expensive systems for large homes that are not providing all their energy needs. For myself, I think sustainability in energy is about conservation and integration of systems. tulagaq@sasktel.net

Greetings, Home Power's *articles are written by our readers. We* love *publishing articles on smaller, super-efficient homes and systems. Look for an excellent article on a small system in New Mexico in an upcoming issue. And please send us your article submissions! See the* HP *Web site for our article submission guidelines. Ian Woofenden • ian.woofenden@homepower.com*

Tilting Large Arrays

Good folks, I'm a long-time reader, and have built a nice off-grid home using information gleaned from *HP*. After three years with my used panels and used batteries, I've very little to complain about except when I have to adjust my array for seasonal sun angle changes. I have sixty panels mounted in four groups of fifteen. The groups are hinged at one end of my ground frame, and the opposite ends are supported by steel tubing, as you can see in the photo.

When I change angles, I have to use three extra people to hold the sections up while I quickly switch to the longer or shorter support tubes. I may have worn out my spring and fall welcome with the one neighbor I have. He and his sons have been the muscle until now. Have you or your readers ever covered a solution to this, using something like a hydraulic ram or air-powered ram that could allow a one-person raising or lowering procedure? It's getting to be that time of year for me. Many thanks for your consideration. Jay Storer • pinezanita@volcano.net

Each section of Jay Storer's PV array takes several people to lift and adjust.

Hi Jay, We really haven't covered that problem before, but I have been aware of it ever since the first time I put together a large, temporary array on the ground, and then tried to tilt it up into the sun. I discovered that I, like you, needed four more people.

In looking at your array, I can suggest a possible solution, though it is going to cost you a bit up front. I would divide the array into smaller groups that you can handle more easily. Then you might even be able to do it by yourself, or with just one other person.

But if you really want to be able to mechanically change the tilt angle, I would not recommend hydraulics or pneumatics. Use screw-type actuators, similar to what is on trackers or dish antennas. They are available in various sizes. Just make sure that the ones you get have the right throw (length from totally closed to fully extended) and can handle the amount of wind and lift load your array presents. But that is going to be an expensive project, so maybe dividing the array up into smaller groups is the way to go. Let us know what you come up with. Michael Welch • michael.welch@homepower.com

Greenhouse Heating

I recently bought a copy of your magazine. I am overwhelmed by the amount of information I saw. Here is my situation. I have a 12 by 12 foot greenhouse in my backyard, which I heat using an electric, wall-mounted heater. My thought was to hook up a solar-electric panel, converter, and battery to a separate electric heater to complement the existing one. My problem is that I have very little knowledge of all of the options available, and the cost and the payback period. It costs me between $75 and $100 a month to heat the greenhouse. Is this a practical and cost effective solution in my situation? What kind of initial cost might I run into? Thank you for time and expertise. Sincerely, James Leonaitis • kneen@mindspring.com

Hello James, Electric heating with PV is very expensive. For example, if you run a small, 1,500 watt heater six hours per day, you need to come up with 9,000 watt-hours (9 KWH) a day. In the winter, you may get fewer than four sun hours every day, depending on where you live. That means that you need to get

2,250 instantaneous watts of real output, and you need a battery to store it in, since the heater probably runs mostly when the sun is not shining. An installed battery-based system is probably going to cost you around US$9 per watt, so you can see that it would be prohibitively expensive to do this.

There may be better ways. Solar hot water with hydronic heating for your greenhouse will probably be the most cost-effective, and will have a payback in a much shorter time than using PV. See the article in HP96 *on heating a large greenhouse with solar-hydronics, so you can see how they did it and consider it for your smaller greenhouse and home.*

Another option is to install a grid-intertied PV system without batteries that will offset some of your utility usage. This will cost less than a battery-based system, and will be a more efficient use of your PV panels. And with a system like this, you install the system you can afford, though the bigger the system, the cheaper it is per watt, and the more utility usage it will offset.

Finally, take a look at the article in this issue about an efficient greenhouse in Pennsylvania. They're using a double-layer system over their planting beds that in effect "adds another blanket." Michael Welch • michael.welch@homepower.com

Don't Bash Republicans

I don't understand you people. You say that you are about being "independent" of the great energy mongering utility companies, and teaching people to be less dependent on large corporations in your daily lives, but then you bash the very political group that can make your goals reality, that is, the Republicans.

Some examples: You demand that utility companies offer incentives such as net metering for installing RE systems, but then you support political candidates, specifically Democrats, who everyone knows are the lap dogs of the unions. And it is the unions that are making it increasingly difficult for independent people like me to build/contract my own house or to install my own RE system. In some parts of the country, it's impossible to do any building or installation unless you are a licensed tradesman in a union.

You bash President Bush because of his desires to drill in Alaska or in the Gulf to alleviate some of our dependence on foreign oil (and in turn strengthen the economic stability of the United States). After all, the United States is more dependent on foreign oil, and specifically, Middle Eastern oil, than it was 30 years ago. You say that if you drive an SUV, you are supporting terrorism. I say that if you don't allow the drilling of Alaska and thus perpetuate the dependence on foreign oil, you support terrorism. Incidentally, you may not like it, but oil is and will continue to be the primary fuel source for many years, so until alternative energy sources realistically come into play, why should we trash our economy and risk our economic stability as a country for just a few square miles of a place that most people, or for that matter animals, never visit?

If Democrats were in power, what would be the reality? Big, money grubbing, intrusive government! So long, independent living. The thing is, I have read in this magazine some really convincing economic arguments about RE. When you take into account government subsides and the unrealized, uncalculated costs of the way we produce energy (the cost of strip mining or oil spill recovery), RE is a viable alternative, and it's a viable alternative now! If you would control some of your more radical, extreme speech, I believe that of all of the political parties that would listen and adopt some of your suggestions, it would be the Republicans.

The key to their hearts and minds, and this is the way it should be, is to show that RE does make economic sense. If it makes money, the Republicans will champion it. The Democrats on the other hand, though on the surface they will openly embrace your cause, when the rubber meets the road and the balloon goes up, they are about power. They will not champion a movement that seeks to free people from government assistance and control. Instead they pass legislation that cripples individuals' ability to improve themselves and cripples companies' ability to grow. Just my two cents! David DeSandre • memphisdesandre@msn.com

Thanks for the feedback, David. Home Power *welcomes the full range of opinions as to how to best facilitate a renewable energy future. Although you didn't specify the authors with whom you so clearly disagree, publishing your letter ought to make sure it gets seen by all of them. Best regards, Scott Russell • scott.russell@homepower.com*

Sine Wave or Modified Square Wave

Dear *Home Power*, We have just recently subscribed to *HP* magazine and we love the information, and read it thoroughly as soon as we get it. We are getting ready to put together an off-grid solar-electric system. A very basic, but central, question we have is whether to purchase a modified sine wave inverter or a true sine wave inverter?

Some people, including a Xantrex support technician, have said that modified sine wave inverters work equally well, and there are just a few appliances/devices that do not run well on them. Other respected people have suggested that modified sine wave inverters may cause an appliance motor to run slightly hotter and therefore reduce the life of the appliance. Do you have a suggestion or a recommendation of an authority with whom we can speak? Who the heck knows what's up with inverters? Thanks, Nancy and Lars, homesteaders in Southwestern Colorado

Hi Nancy and Lars, First of all, let's be honest about the terminology. Years ago, the marketing departments at major inverter manufacturers came up with the phrase "modified sine wave" for a product that should have been called "modified square wave." The waveform of these inverters is closer to a square wave than a sine wave. Now manufacturers are calling their new inverters "true sine wave" or "pure sine wave"—the next generation of media hype, an escalation in a verbal arms race that can only lead to mutual assured concept destruction. Look at the number of steps in the wave, and the THD (total harmonic distortion). Buy an inverter with a high quality waveform.

I recommend that you not buy a modified square wave inverter. An inverter is a key component in your system. Don't skimp on quality here! The only *advantage of a modified square* *wave inverter is cost. But as with everything cheap, the full price isn't in dollars. You'll get reduced performance from all your appliances—they'll run hotter and not last as long. Some things may even fry.*

I think of modified square wave inverters as "Third World electricity." The popular Xantrex (formerly Trace) DR series was named after the Dominican Republic, which has very poor grid power quality. Modified square wave inverters are a step up to those folks, but a big step down from U.S. grid power quality.

Even within the so-called "sine wave" inverters, there are variations in quality. Xantrex's reliable SW series has lower power quality than some other inverters on the market, such as the Exeltech and OutBack lines. HP *is working on an inverter comparison article. We're considering not even covering modified square wave inverters. That should tell you that we think they are old technology, and not suitable for modern RE systems. Ian Woofenden • ian.woofenden@homepower.com*

Hello Nancy and Lars, I'd like to second Ian's comments on inverters. Only consider sine wave models! Over the last 30 years, I've owned and operated well over a dozen inverters—about half of these were modified square wave. For the last six years, I've run nothing but sine wave models and I'd never go back. Not only are my appliances happier, they are also more efficient when powered by a sine wave inverter. For example, both our deep well pump and our microwave oven are around 30 percent more efficient. This means more water pumped for less energy, and food is heated faster while using less energy. If you consider the savings in energy alone, the sine wave inverters pay for themselves very quickly. Richard Perez • richard.perez@homepower.com

Heating with Biodiesel

I read with interest the piece in *HP97* on heating with biodiesel. We heated our home all last winter in Corvallis, Oregon, with B100 without any of the serious problems noted in the article. Our Lennox furnace is probably the original one installed in this 1959 home. Our pump hasn't seized or leaked. I had to decommission our underground fuel tank because we had a tiny leak (or I contaminated the sample with my homemade soil sampler, a piece of schedule 80 PVC driven into the clay with a stick of wood), so I just cut the lines to the old tank, attached two automotive fuel hoses to the feed and return lines at the pump, and stuck the hoses into a barrel in the garage.

The high lubricity of the B100 has it crawling up the hoses, creeping past clamped hoses, and a tiny dribble drains back from the nozzle when it is shut off. I catch that in a pan. I experimented with SVO (straight vegetable oil) filtered from local restaurant waste by our biodiesel co-op, Grease Works, but even with a homemade preheater, the stuff wouldn't burn. It's either too thick to go through the filter or doesn't atomize properly to burn. Rather than try to figure out what the problem was, I decided to be satisfied burning a blend of 80 percent B100 and 20 percent SVO. It seems to be working fine. We are on our second barrel of this blend. It reduces the cost, and at least the SVO is truly a local waste product.

Another tactic that I've used is to install a second air-to-air heat exchanger in the furnace flue pipe. I bought a Magic Heat unit designed for in-house stoves, but mounted it in a sheet metal box so I could duct the return air from near the floor in the house, thus avoiding blowing garage air into the house and avoid messing with the balance of the furnace circulation system. The Magic Heat has its own thermostat that starts the fan after the furnace circulation system kicks on and turns it off before the furnace system kicks off—perfect to avoid cooling the flue gasses too much. We also bought and installed a carbon monoxide detector just in case there was something that I didn't understand. The amount of hot air this thing blows into the house is amazing. And to think we were losing all that up the flue pipe. Steve Cook, Corvallis, Oregon • steveandterric@peak.org

Hi Steve, Thanks for sharing your experiences. It is my understanding that seals will sometimes take a while to start leaking, so maybe one winter was not enough to know for sure. On the other hand, I would not be surprised if it never leaks. I think that leaks from deteriorating seals are rare, even in older vehicles running biodiesel. A good strategy is to wait and see, keeping a close eye on it, and if it ever develops a leak, worry about it then. Of course, if we can get the manufacturers to switch their seals for all these applications, there will never be a problem.

As far as adding a heat recovery system to your flue pipe, I had completely forgotten about those things, having written them off years ago for their primary application—capturing heat from a wood heater flue. I wrote them off because they cooled the flue gases too much, allowing buildup of combustibles on the inside of the flue, and the units made it nearly impossible to clean the flue. But this should not be a problem with your oil heater's flue.

It's a great idea for older heaters, but maybe not such a good idea for newer heaters that are designed to be as efficient as possible. I don't know all the ins and outs of flue gas, but it is hard to imagine that the newer heaters would not take advantage of every possible BTU that can be had from the unit. In other words, if they are letting some heat go up the flue, there must be a good reason for it, like maybe a minimum gas temperature for appropriate evacuation out of the unit. Michael Welch • michael.welch@homepower.com

Solar Shingles & Trackers

I have a couple of questions that developed after this year's Solar Tour of homes. Many people had solar-electric panels mounted on rooftops on new construction houses. Why not use solar shingles and eliminate roofing shingles? The folks I asked said it was unproven technology. My second question is, why is no one using trackers? Only one person did and his was adjustable only for seasonal variances. At a latitude of 45 degrees, would not a tracker make good sense? Dan Cosgro, Bend, Oregon • cosgro@bendcable.com

Hello Dan, The solar shingles and roofing (thin-film and crystalline) cost about the same per watt as do conventional modules, while they do not have the proven track record that conventional modules have. So the question is, "How much electricity will these shingles be making some 20+ years from now?" Considering the cost of PV (which is large), most folks are conservative and go with the proven technology.

I personally use trackers here—four of them (about 64% of our modules are on trackers). Some folks like them; some don't. This *preference is usually based on maintenance issues—trackers require some maintenance. I figure that we get an annual energy boost of more than 30 percent on the modules we have on trackers here. To me this is worth occasional maintenance. Richard Perez • richard.perez@homepower.com*

Hi Dan, The solar shingle products I've seen have an additional problem beyond track record. They have lots of connections and lots of roof penetrations. I'm glad I won't be the guy to install and troubleshoot these systems. The laminated metal roofing product looks better to me, since all the connections can be made at the roof peak. But it's a bit early to tell how well this thin-film product will last. Crystalline modules have been in the field for 30-plus years.

I tend to be critical of trackers. They make sense in some applications, and they are certainly fun, and boost output in the short term, especially in summer. But putting a 30 to 40 year product (PVs) on a 10 (?) year product is questionable to me, and the calculations used to promote trackers don't ever seem to include the maintenance, troubleshooting, repair, and replacement, or the fact that the increased output in off-grid systems is mostly when we don't need increased output. I like crystalline PVs because they are reliable, durable, and long lasting. Putting them on trackers downgrades that simple perfection. Ian Woofenden • ian.woofenden@homepower.com

Alternating Battery Banks

I have many technical questions from time to time, and I cannot find a consistently adequate source of information here, as I live on a rural island with few trained people. Most people in the solar field here have specific knowledge gleaned from their own idiosyncratic experiences, and they are often unable to given specific information that is different from what they have experienced themselves.

For example, now that I have started with a small system for my son, with a small wind generator, 400 watts, and several PV panels (600 watts total), I am experiencing discharged batteries after a few days, due to the overall cloudy weather this time of year. I wonder if alternating between two battery banks would be worthwhile as a partial solution. Any thoughts? Thank you for your time. Joe Bratton • hilocare@ilhawaii.net

Hi Joe, Having two battery banks is not going to help you. You seem to be having trouble keeping one battery bank charged up. How are you going to deal with two? The worst thing you can do for a battery bank is to discharge it and leave it discharged.

If the problem is actually not enough battery capacity, and you usually have enough solar and wind energy to keep all the batteries charged, what you need is increased capacity to get you through those periods of no sun. Instead of having two battery banks, you would be better off with one larger one. That way you never have to switch between the two, and all are ready to go when needed. And with a single, larger battery bank instead of two, there is no interruption to your loads from switching over.

I suggest first analyzing your loads to make sure you know what is using the energy. Then see if your generating sources actually can keep up with your loads. An off-grid system has a limited capacity, and you have to live within that or you will ruin your batteries. Michael Welch • michael.welch@homepower.com

Small Grid-Tied Systems

Hi guys, I read the magazine from cover to cover. It's great—keep it coming I was wondering the other day why I can't find a smaller inverter for a wind turbine. I mean if we set up a 400 watt or so wind generator, for example, and then wire it directly to a 400 watt inverter, would this work? Would we need some sort of battery buffer? What I am trying to say is that we want to put wind energy straight into the grid, less the battery hassle, and have a small backup system to boot. This in essence would give us a "generator priced" system that might lower the electric bill, save the planet, and with the little effort, be an emergency backup. Am I barking up the wrong tree?

Or how about 100 watts of solar electric modules plus the 400 watts of wind, and an inverter? We live in Canada, in an area where the average wind speed is 20 kph (12.4 mph). We pay 8.9 cents for electricity. We have more wind in the winter than summer. Also, how much noise does a small turbine produce, in layman's terms? Keep up the great work. Dennis Weimer, Regina, Saskatchewan • dennis.and.jackie@sasktel.net

Hi Dennis, You can only sell electricity to the grid with an inverter that is designed to do that. Small, inexpensive grid-tied systems are difficult to put together. Grid-capable inverters generally start in the 2,000 watt range. One Dutch company (NKF Electronics • www.nkfelectronics.com) makes small batteryless grid-tied PV inverters. I am not aware of anything comparable for micro-wind turbines. The entry level cost for a home-sized grid-tied PV system is generally in the $US6,000 to $10,000 range. In the last year, we've started to see batteryless grid-tied wind turbines, but the entry level cost is higher than a PV system, because of the tower cost.

When you plan a grid-tied system, a basic question you have to answer is whether or not you want backup for utility outages. If you want backup, you need batteries. Batteryless grid-tied systems will not operate house loads when the grid is down. On the other hand, batteries decrease the efficiency of the system, and raise the cost and maintenance.

Some poorly designed wind turbines are quite noisy. Well designed wind turbines are not at all noisy. I recommend that you hear one in action before you buy, since noise tolerance is very subjective. Ian Woofenden • ian.woofenden@homepower.com

Datalogging Systems

I've been wanting to write to *HP* for months now, but just never could break away from all the things I'm into long enough to do it. *HP95* put faces to names and that sorta made the *HP* staff seem like friends somehow. I first want to say that I think your magazine is super; I always find time to sit down and read it. I even read the ads!

About three years ago, I installed a 4 KW PV system on my house in southern California. I installed the forty Siemens SR100 panels on the roof myself, with lots of help from my sons and their friends. I was a little surprised at how hard it was to find electricians who were familiar with photovoltaic systems. My first attempt to hire an experienced electrician knowledgeable about PV systems ended in semi-disaster and we parted company. I finally located the Break brothers of Crescenta-Canada Electric in La Canada, California. These are two outstanding electricians (one of whom has a small off-grid system himself) who wired up the AC side of the system and made sure the two Xantrex SW4024 inverters were wired up to the grid and house properly. We have since become great friends (sharing RE seems to have that effect on people).

The system was permitted and inspected, and I have to say that I read and re-read all of John Wiles' articles on the *NEC* relating to PV systems before starting (an incredible wealth of information—thanks, John). There were a few pushups I had to do to get the permits though. The county folks didn't have a category for installing inverters; they didn't know whether to call it a transformer or a power panel. We settled on transformer because the permit was cheaper. Also had a nice lady from the county drop by to see if our property taxes would be affected. She haltingly asked me, "What's a photovoltaic?" adding that no one in her office knew the answer. To her credit, she was enthusiastic enough about the project to simply record it as "roof repairs," not wanting to have it subjected to any increase in taxes. (California has exempted photovoltaic systems from the property tax, but her office apparently hadn't gotten the word.)

I got my rebate from the California Energy Commission without too much trouble, but it's a lot of paperwork. I would advise California readers contemplating doing something like this to very closely track their expenditures because the CEC will want everything you have. And follow their guidelines! The rebate is worth it though. (I'm not sure what the current state of the rebate program is now since the big budget crisis hit in California, but there's info on the CEC Web site if anybody's interested. See www.consumerenergycenter.org/index.html, select Rebates, Grants, and Loans, and check out renewable energy rebates.)

One very pleasant surprise was how Southern California Edison responded to my request to grid tie. Contrary to what I had heard about electric utilities, they were *very* cooperative. Of course, I had to provide evidence of permits and inspections, but I had done that anyway. I had thought that since I was taking business away from them, they would be a real pain, but just the opposite was true. They were very courteous and helpful and promptly authorized the net metering grid tie. We are now considered a power generating facility.

It will take more than a few years to get payback from my system but, knowing that I'm immune to prolonged grid outages (I have four L-16s I use only for backup) and that my electric bill has been cut in half, I'm very satisfied with the system. And watching my meter go backwards during the day is just plain cool!

Now for the real reason I'm writing. I wanted to monitor my PV system on my computer. All our household computers are running under Macintosh or Linux operating systems, and I didn't want to give up my trusty Mac for a PC just so I could use one of the off-the-shelf applications available to do this kind of thing.

I did buy the Xantrex remote monitor module to get the data into the computer, but quickly found that it was just too slow and too clumsy (requiring sequential cycling to get the desired data) and unreliable (sometimes randomly changing the inverter state). The advantage of being able to remotely control the inverters was not something I needed (and I sure wouldn't use this device to control my inverters), and I found the devices definitely not worth $100 each (I spent $200 since I needed two, one for each of the two inverters).

Undaunted, I found a data acquisition module, 232SDA12, from B & B Electronics (www.bb-elec.com/data_acquisition/daq.asp) that provided eleven A/D channels, three discrete inputs, and three discrete output channels, and I used that for a while. I had to write my own software, but since the module gets commands and provides output in easy-to-handle ASCII text through an RS232 serial interface, it was pretty easy to do using a programming language no more sophisticated than BASIC. I ran out of discrete/digital channels on the B & B module, though, and had to look for a similar system with more channels. (I'm now using the B & B module on my PDA, and the free PDA application they provide, to monitor the status of an auxiliary solar-electric system I have. It takes very little energy and works great.)

I finally settled on a board provided by Integrity Instruments (www.integrityusa.com). Their ADC-1 board has room for sixteen discrete connections (input or output, user specifiable) and eight analog inputs. It also uses ASCII text input/output and an RS232 interface. I have been using it for quite a while now with excellent results. I found the people at Integrity Instruments extremely helpful and cooperative, and I heartily recommend their products.

The main problem with monitoring systems like this is getting all the sensors and signal conditioning right. I chose to do that myself because I felt I knew enough about it and wanted to save some money. It turned out to be a little trickier than I thought it would be because of the EMI/RFI put out by all my solar-electric equipment; trying to run milivolt level signals around without corruption cost me more than a few "life points." It took a while to get everything calibrated, but I now have all the status I want on my computer and can see how things are from the comfort of my house day or night, rain or shine.

I found it to be pretty doable and something a lot of your readers could do. I'm sure, though, that there are readers out there who can't or don't want to go the do-it-yourself way, and I wonder if Richard Perez, who likes "tinkering with Macintosh computers," has any info on off-the-shelf software or hardware for data acquisition that is Linux or Macintosh compatible. I'm sure other Mac users would be interested and would save people from having to go through all I had to. Any help for us fellow Mac users?

Sorry about being so wordy. Keep up the good work; I'm forevermore hooked on the magazine. H. Mac Grant • hmgrant@pacbell.net

Thanks for your fine letter, H. Mac. We're glad to hear about your system and adventures. When we have a datalogging task at

HP , we end up using PCs. We'd love to find comparable software and gear for Macs. HP Tech Editor Joe Schwartz says that LabVIEW is now available for Macs. This is a full-on DAQ design program, and doesn't come cheap. It's not something that one-time users would want to invest in.

Overall, your experience is rather typical of what I've seen for folks wanting to datalog their RE systems. There's a real hole in the RE product mix waiting to be filled—a plug-and-play datalogging system that nongeniuses can afford and install. Since our industry is still small and young, I guess it should be no big surprise that we don't have this yet, but I'm looking forward to maturity, and the ability to easily keep track of PV, wind, and hydro output, insolation, wind speed, etc. Regards, Ian Woofenden • ian.woofenden@homepower.com

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

Communications Off-Grid

Richard Perez

In the 33 years that Karen and I have lived off-grid, we've faced many problems. Transportation, energy, and communications head the list. Of these, communications has been the most difficult to solve.

Our home and office are located 7 miles (11 km) from the nearest paved road, and 6 miles (10 km) from the nearest phone line or utility power outlet. In the early days, communications meant a long hike to our neighbors, who were kind enough to collect our mail from our postal box on the highway. During the winter, we would sometimes go two months without picking up our mail. A telephone call meant a trip to the nearest phone booth about 12 miles (19 km) from us—the first 5 miles (8 km) were a hike, then a drive in a car.

In 1977, we installed a CB radio and this helped us contact our near neighbors. In 1979, Karen and I became amateur radio operators (hams) and this greatly extended our communications range. When we went into business in 1982, we began to use radiotelephone systems. Over the years, we have owned and operated seven different radiotelephone systems. All were very expensive and none of them worked as well as a hard-line telephone. Reliability was low and telecommunications speed for computers was very, very slow—never faster than 4,800 baud.

Cell Phones

The advent of cellular telephones has made our radiotelephone systems obsolete. Karen and I each have our own cell phone, and we use external antennas to link up to a local mountaintop cell site about 15 miles (24 km) from us. This has proved to be far more reliable and much cheaper than operating our own radiotelephone system.

The external, cell phone, beam antennas are of the Yagi design, with fifteen elements each. They look like a small TV antenna and are about 3 feet (0.9 m) long. They cost around US$200 each and greatly boost the operating range of the cell phone.

Each antenna is fed by special, low loss, RF coaxial cable called "Heliax." This cable is about 1/2 inch (13 mm) in diameter and costs about US$1 per foot. A short, thin coax adapter connects the large diameter Heliax to the cell phone. As with all antennas, these should be located as high as possible (we have ours mounted on a mast on the roof), and pointed at the nearest cell site. By using these antennas, our cell phones went from no signal at all inside the house, to a full-scale signal that is rock solid into the cellular telephone network.

Richard & Karen's satellite Internet dish and one of the two cell phone antennas at their off-grid home/office.

Satellite Internet

Computer communications were still very slow until the advent of direct-to-satellite systems. Three years ago, we installed a StarBand 360 system. This system is detailed in *HP84* , page 108. With this StarBand system, we were able to directly connect to the Internet via a satellite. This system required a Windows-based PC to operate—it would not play directly into our Macintosh computers. We used the PC as a proxy server with a program called WinProxy—this served up the Internet to the various Macs on our local area network (LAN).

After virtually no Internet service at all, StarBand was great—speeds up to 500 KBPS on downloads and up to 150 KBPS on uploads. While the cost was high, about US$700 for the hardware with installation, plus US$70 per month, it was worth it. For the first time, our remote homestead had real computer telecommunications. This type of direct to satellite Internet access is really the only solution for off-grid folks, or for those without cable or DSL access and with slow phone lines.

It's easy to get spoiled by high speed Internet access. At our downtown office, we have high speed cable, and it runs far faster than the StarBand 360 service. I imagine that our business is much like other businesses—we are all doing more work online and continually becoming more dependent on the functionality of the Internet. Several months ago, I heard that StarBand began offering a higher speed service for remote home offices, called StarBand 480.

When I investigated StarBand 480 further, I discovered that in addition to greater speed, the service worked differently than the earlier StarBand 360 service. The 480 modem does not require a PC to operate. It would play directly into our LAN and into our Macs. For me, this was as big an attraction as the higher speed.

The PC server we were using on the StarBand 360 service was a pain. I was forced to deal with the Windows operating system and this PC server had to be operating all day, every day. At the time, laptops were far more expensive than desktops, and had fewer features. We also used the PC as a file server (the machine contained three, 60 GB hard drives and we routinely used them all), before the magazine's production moved to our office in town. This desktop server was consuming about 1.7 KWH per day to provide us with Internet access. Eliminating this server would save us enough energy to run a large refrigerator/freezer—roughly the energy equivalent of buying five, new, 100 watt, PV modules at our location.

So we recently upgraded our StarBand system to the new 480 service. Its modem draws 28 watts and has a power factor of 0.58. The service uses a modem that is very similar to a cable modem in function. With the 360 service, much of the computational telecomm housekeeping was being done by the computer, hence the necessity of having a Windows PC on line. The StarBand 480, however, does all this housekeeping inside the modem and requires no resident computer to baby-sit the modem. The 480 comes with four, 100 base T, Ethernet ports on its back. Since we have far more than four items connected to our LAN, we merely ran the StarBand 480 modem directly to our 16 port Ethernet switch. Here the signals are routed to the various Macs in our home office.

The StarBand 480 high speed satellite modem is Ethernet compatible, so it works with any networked computer, including Macs.

The speed difference is marked—downloads now proceed at least twice as fast and uploads go between four and six times faster. The speed difference is particularly noticeable on large files, and we send and receive many large files every day.

As is usual with higher speed Internet access, it's more expensive—the faster you go, the more it costs—more bandwidth means more money. While the hardware costs just a little more installed, the monthly fee is much larger. StarBand 480 service costs US$159.95 per month and allows Internet use by four computers simultaneously. We managed to cut this charge to US$139.95 per month by signing a three-year contract with StarBand.

Currently, the 480 service is only available to new StarBand customers. We got around this limitation by essentially becoming a new customer. We bought the whole 480 system—dish, microwave transceiver, and modem. By late spring, StarBand is planning to make the 480 service available to existing customers, and this will require merely changing out the 360 modem and replacing it with the 480 modem.

Other satellite Internet services will not support Macs at all, so I didn't even consider them. To say that we are pleased with the StarBand 480 system would be an understatement. It's far faster. We don't have to deal with the cranky, alien, Windows operating system anymore, making telecomm here more reliable. And we're busy finding uses for the 1.7 KWH of solar electricity we've saved by not running that PC all the time. Color us high speed and happy.

Access

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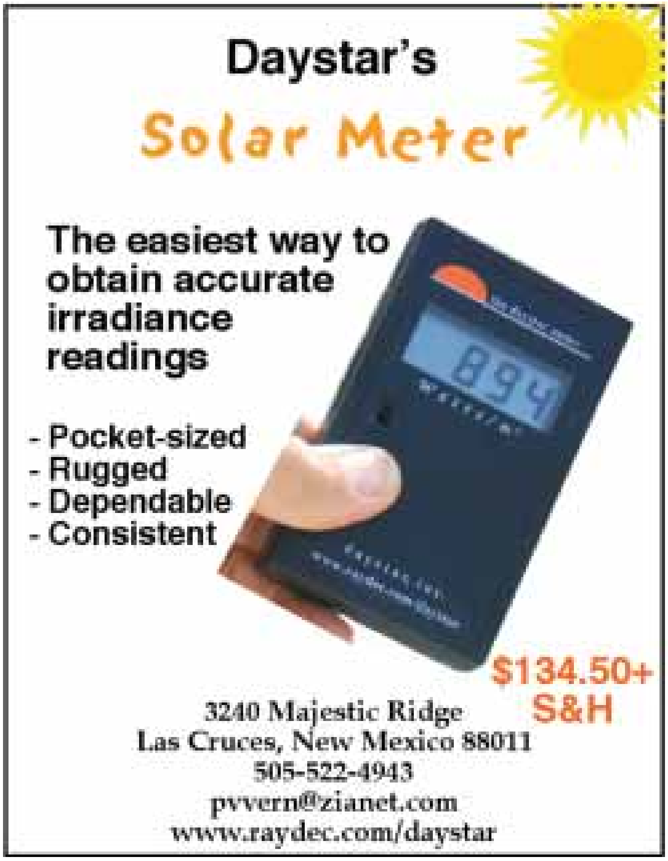

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Questions & Answers

Thin-Film Modules

Back in *HP73*, there was an article on laser-grooved PV cells and thin-film PV technology. It mentioned that thin-film cells might be around in about 2003. I'm wondering where thin-film technology is now, having seen things like the flexible cells for buildings being announced and only minute changes in tech over the last five years. When might we see truly affordable PV cells for the masses? Ed Wahl • wahl@cray.com

Hello Ed, There are currently a few U.S. thin-film manufacturers. UniSolar, First Solar, and Shell Solar all manufacture thin-film PVs. On the other hand, this year BP Solar closed down their thin-film operation, and discontinued the Millennia thin-film line.

UniSolar's laminates are designed to be installed on metal, standing seam roofs, and are gaining popularity, since they're a truly building-integrated product that looks great. But right now, the cost is comparable to crystalline PV technologies that have longer track records in the field. Basically, thin-film technologies are having a tough time breaking into the market, because they're competing against crystalline technologies that cost about the same, and we know will typically last for 30 years plus.

As far as truly affordable PV cells for the masses, that's really anybody's guess at this point. Inexpensive thin-film technologies have been "on the horizon" for more than a decade. The expectation for lowered cost is there for sure, but so far, no manufacturer has been able to deliver thin-film PVs at a cost significantly lower than crystalline PVs. Thin-film PVs do use significantly less raw material—about 1/500th when compared to crystalline PVs. But this materials savings hasn't resulted in lower cost PVs yet. Joe Schwartz • joe.schwartz@homepower.com

Splicing Aluminum Wire

Greetings folks, I must say, *HP96* is a stellar issue. Question: Can you e-mail me any *HP* article (or refer me to it) on splicing aluminum wire? I want to know how to do it, its pitfalls, how to waterproof the splice, etc. I don't have your CD set yet (twinkle in mind's eye). Thanks much, Andy, California, *HP* reader since 1987 • andyh@mcn.org

Hey Andy, Glad you're enjoying the mag. We have a great time putting it together. We haven't run an article on the topic, but it would be a good one. I typically use SPA-type connectors when splicing copper (CU) or aluminum (AL) wire. SPA connectors are stout AL butt splice connectors, with a pair of hex setscrews that make the mechanical/electrical connection. If CU wire is run to these AL connectors, an anti-oxidant must be used to minimize electrolysis, which is corrosion due to the contact between dissimilar metals. Once the setscrews are torqued down, I always wait five or ten minutes and then retighten them. Aluminum cable seems to "relax" a bit after it's compressed. Both the SPAs and the anti-oxidant are available in most hardware stores. Larger #2/0 to #4/0 SPAs will probably require a trip to an electrical supply distributor.

After the mechanical/electrical connections are solid, I wrap the connector and an inch or two of the spliced wire with several wraps of rubber tape. This will keep the splice dry. Over that, I apply a few wraps of high quality electrical tape to further protect the splice. Heat shrink tubing can also be used to weatherize the splice. See John Wiles' column in HP96 *for some other connector ideas. Joe Schwartz • joe.schwartz@homepower.com*

Don't Add More Batteries

I have a pretty ordinary off-grid home with PVs and a generator running through a Trace 4024 inverter. I am using a string of twelve Sun Xtender batteries from Concorde. I have the opportunity to acquire another string of batteries that would be different in capacity, size, and age from the original string. I am sure that there would be trouble with charging if I simply put them in parallel. What are the problems exactly and what is the solution? Thanks for your help, Forest Crumpler, off-grid in Tennessee • fcrumpler@cityofsunrise.org

Hello Forest, The problem with dissimilar batteries wired together is that the better ones do all the work of storing and delivering energy while the weaker ones absorb more energy on the charge cycle and do not give it back on the discharge cycle. This is very inefficient. Use either the new batteries or the old, but don't wire them together in the same battery pack. Richard Perez • richard.perez@homepower.com

Gas to Electric

Hello to all at *HP*, I am considering converting a riding mower from gas to electric. What I need info on is determining the size motor needed. Does a mower with a 16 hp gas engine need an equal size electric motor? From what I have seen in auto conversions, this does not seem to be the case, but how do you determine what is needed? I am planning to use most of the riding mower as is, with a belt driven transaxle and mower deck. Maybe this is too involved for a simple answer; if so, please point me the right direction and I will take it from there. Thank you and keep up the great job. Dennis Fry • fry@mwt.net

Dennis, You're right that you can't simply match electric horsepower to gas horsepower. That's because gas engines and electric motors are rated differently. Gas engines are typically rated for peak hp, while electric motors are generally rated for continuous hp.

Your best bet for sizing components would be to look at systems in similar electric vehicles. In your case, I would suggest looking at the Gorilla at www.gorillavehicles.com. This is a utility vehicle of a similar size to a riding mower, and can in fact be used with mower attachments. You might also get some help from the Elec-Trak Owner's Club at www.elec-trak.org. The Elec-Trak is a riding garden mower/tractor that is out of production, but still has many devoted users. Shari Prange & Mike Brown, Home Power *Transportation Editors • electro@cruzio.com*

DIY Solar Collectors

Great magazine! There's no other like it. I haven't seen any articles on actually building solar hot water panels. I know PV panels are too hi-tech for the backyard guy to build, but solar water heating panels are not so complicated.

I'm preparing to build a small building to mount water panels on, with a 200 gallon storage tank inside. I can get free glass and a free tank. I'd love the challenge of building my own (pipes, aluminum sheets, insulation, glass, etc.). Thanks for any leads. Paul Melanson, Nova Scotia Canada • Paul_Melanson@intertan.com

Hi Paul, Building an insulated enclosure with glass on one side is not rocket science and well within the realm of do-it-yourselfers. The only part of building a collector that might be considered high tech is the riser tube to absorber plate bonding. The tubes and plate must have good thermal conductivity or the collector will perform poorly.

There are a couple of ways that a do-it-yourselfer can build a decent collector from scratch, but the methods of bonding riser tubes to the absorber plate are somewhat sensitive—proprietary, trade secret type stuff. The way most collector manufacturers do this is with a constant weld, braze, or solder joint between the tube and plate. This is tedious and somewhat expensive if done by hand, but can be done with 95/5 solder if a copper absorber plate is used (this should not be a selective surface absorber, just black paint).

We have seen many plates in older collectors debond (the riser tubes separate from the plate), and assume that this is due to the manufacturer using a lower melting point 50/50 solder to make the joint. Some manufacturers have used a mechanical crimp to make the bond; some have used thermally conductive adhesives. Some of these have worked well; some have not.

There may be a how-to article sometime in the next year or so on building your own collector if we can convince the right people that divulging a little information really won't hurt their business. Any good points on the subject to help convince them are welcomed. Cheers, Chuck Marken • chuck@aaasolar.com

Equalization

Dear Richard, There is a discussion going on here on our 3 by 4 mile island (where all electricity is solar or wind with generator charging in winter, and all phones are cell phones), about the need for equalization when using one or more desulfators. I understand you to have reported that equalization is needed, if not to clean the plates, but also to stir up the acid, if I understood the third-hand report correctly. The folks at InnovativeEnergy.com, which makes the desulfator we are using (several versions are made by different companies), answered my inquiry: "No equalization is necessary. The primary purpose of equalization is to shed sulfation off the battery plates. The desulfator prevents any accumulation."

If the secondary purpose is to mix the acid, how much equalization is needed to do this, as distinguished from necessary to effect the primary purpose, that is, to clean the plates? The reason I ask is that often equalization is done with a generator, which takes fuel. Is there an optimum for merely mixing the acid that doesn't require so much added energy? Sincerely, Bill Appel, Waldron, Washington (and a faithful reader) • APPELLLB@aol.com

Hello Bill, Equalizing charges are necessary even if an electronic desulfator is in use. The equalizing charge brings all the cells in the battery up to the same state of charge—full. The electronic desulfator aids this by breaking up large sulfate crystals. Both are good tools for long and efficient battery service—using one doesn't mean that the other is unnecessary. See my article on battery care and maintenance in HP98. *Richard Perez • richard.perez@homepower.com*

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Debunking the Top 12 RE Myths

Solar Hot Water History

Investment Analysis PV vs. Stock Market

Off-Grid PV Powered Adobe Getaway

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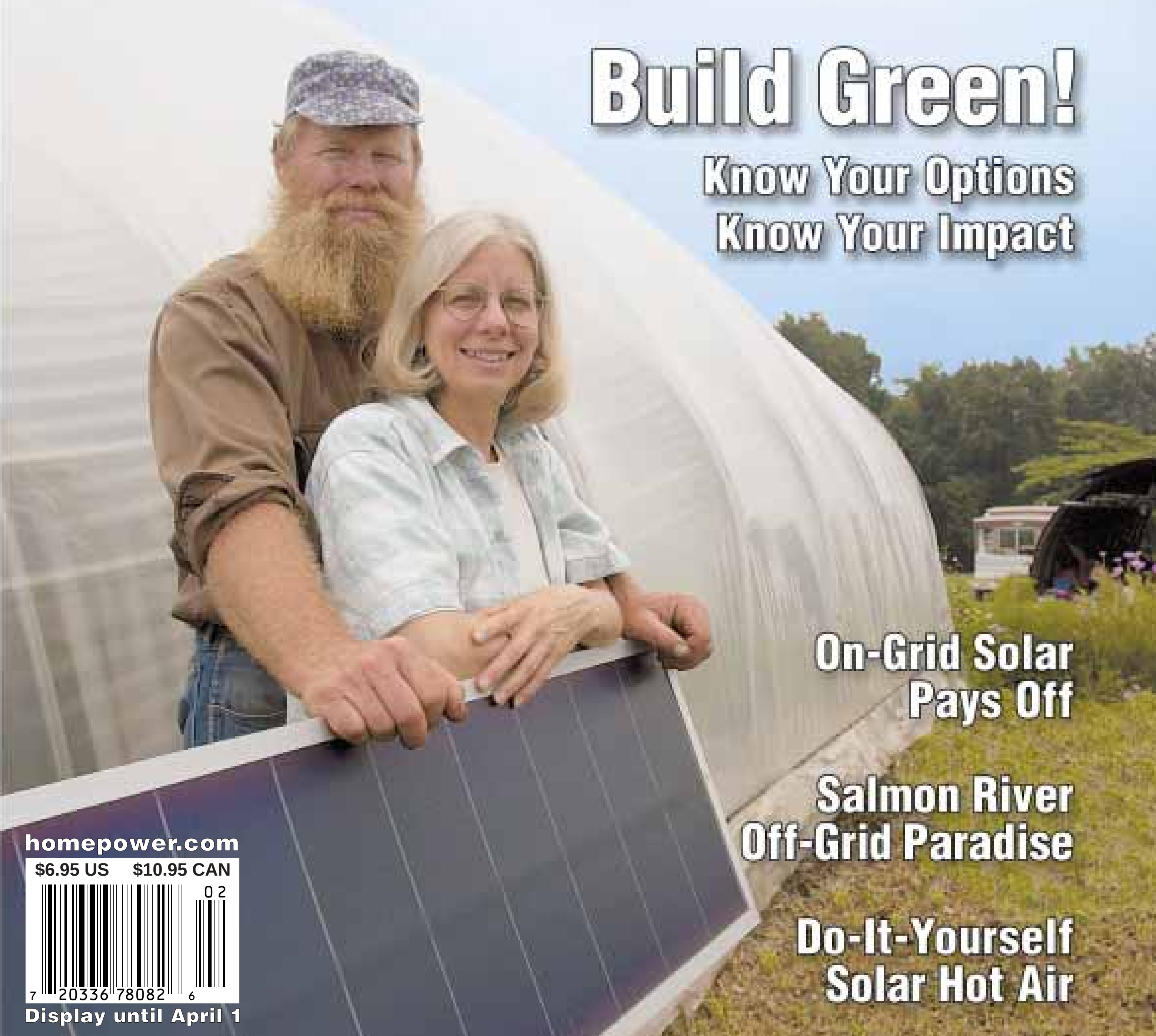
Issue 99 February – March 2004



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Energy Survey

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

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

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

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

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

Electric utility grid use:

☐ I have the utility grid at my location.

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

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

☐ I sell my excess electricity to the grid.

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

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

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

HP99

Feedback

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

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

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