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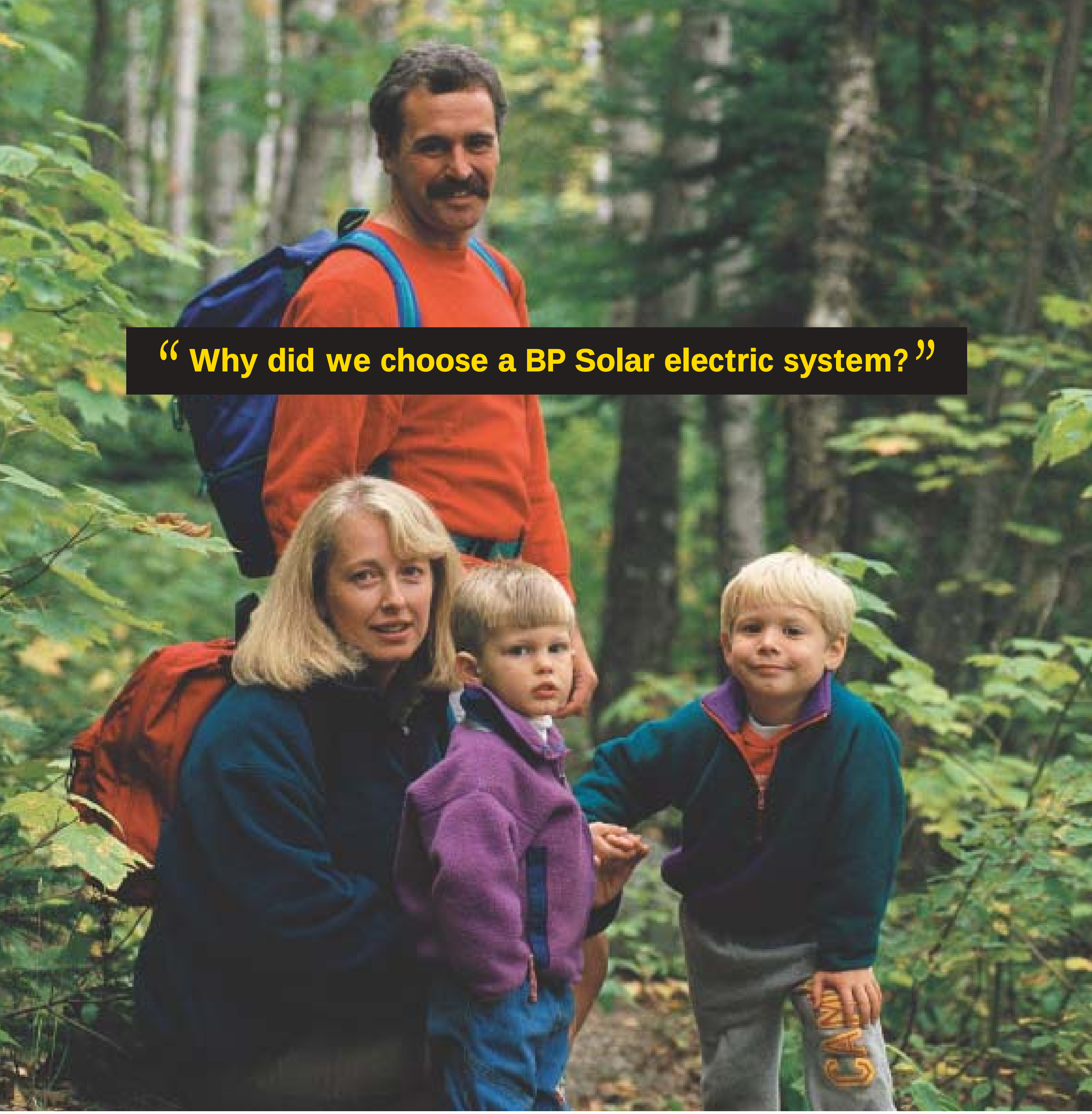
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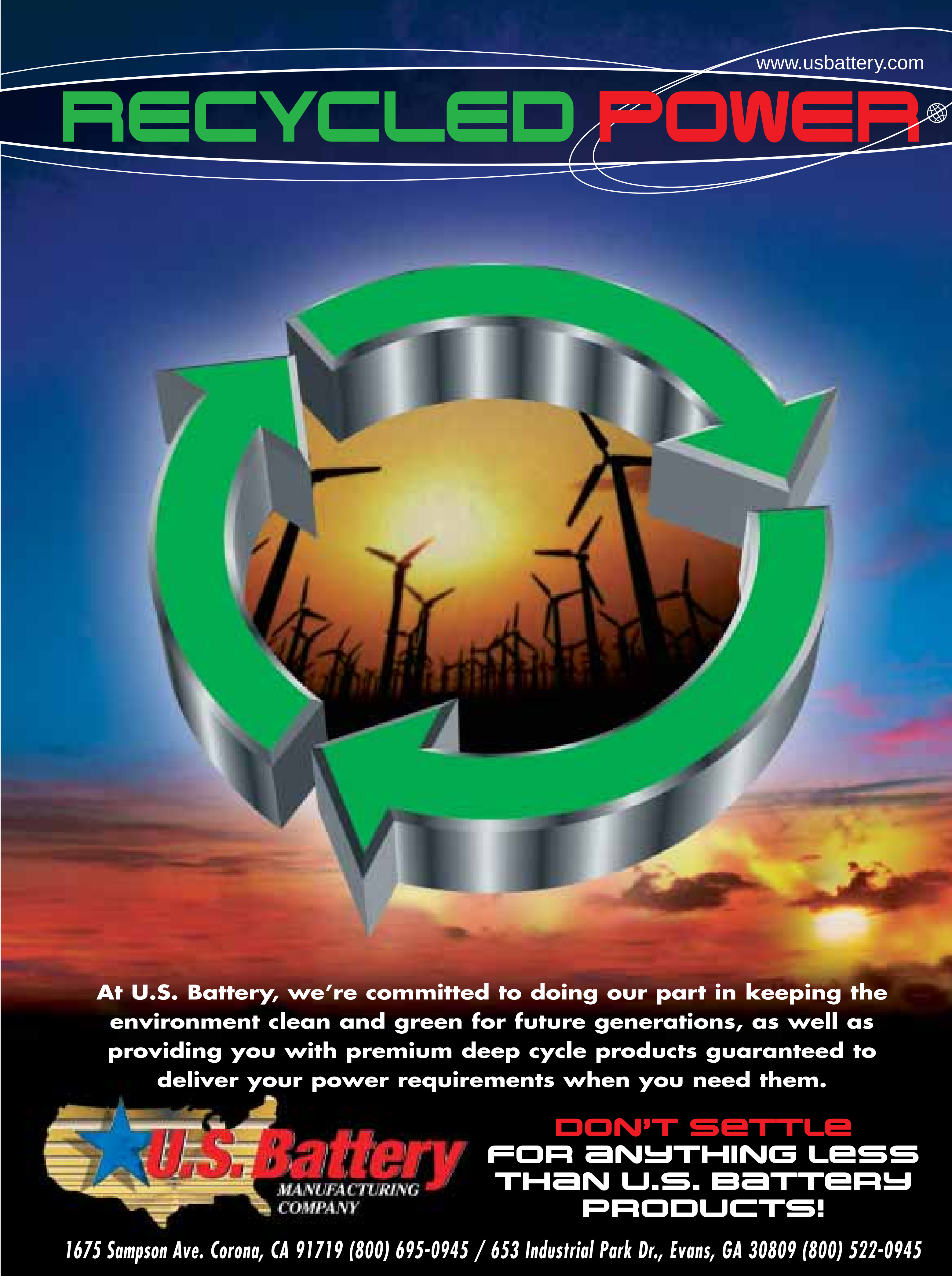
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HP98 contents

On the Cover

Dane and Minga Wigington in front of their PV array—near Lake Shasta, in northern California.

Regulars

By opening her door to people attending Ashland, Oregon's Tour of Solar Homes, Risa Buck opened a lot of minds to renewable energy and sustainable living.

Folks living with renewable energy (RE) systems know that they work. So what's the best way to educate people who are curious about RE? Show them these systems at work!

This is exactly what happened on Saturday, October 4, 2003 with the American Solar Energy Society's eighth annual national Solar Tour. Forty-five states and over 160 cities participated in this year's tour. Newcomers to RE had an opportunity to see sustainable technologies in action, and talk with people who live with the technologies every day.

Here in southern Oregon, the city of Ashland, the Bonneville Environmental Foundation, and *Home Power* magazine co-sponsored and organized a tour of six local homes and businesses. Almost 100 people from our small southern Oregon community took part in the tour.

In this day and age, when a lot of people don't even know their neighbors, the recent solar home tours stood out in stark contrast. Homeowners opened their doors to people they had never met, and shared their sustainable homes and lifestyles.

As a result, the national Solar Tour went way beyond its goal of spreading the word about renewable energy—it helped to bring communities across the U.S. a little bit closer together. And *that* is a great way to spend a Saturday afternoon.

— Joe Schwartz for the *Home Power* crew

Think About It

Purely from a financial standpoint, people on the grid
without solar hot water are way behind the times,
and people with solar electricity are just a little ahead of their time.

—Andy Kerr, Solar Tour host

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Taking the Off-Grid

Dane Wigington
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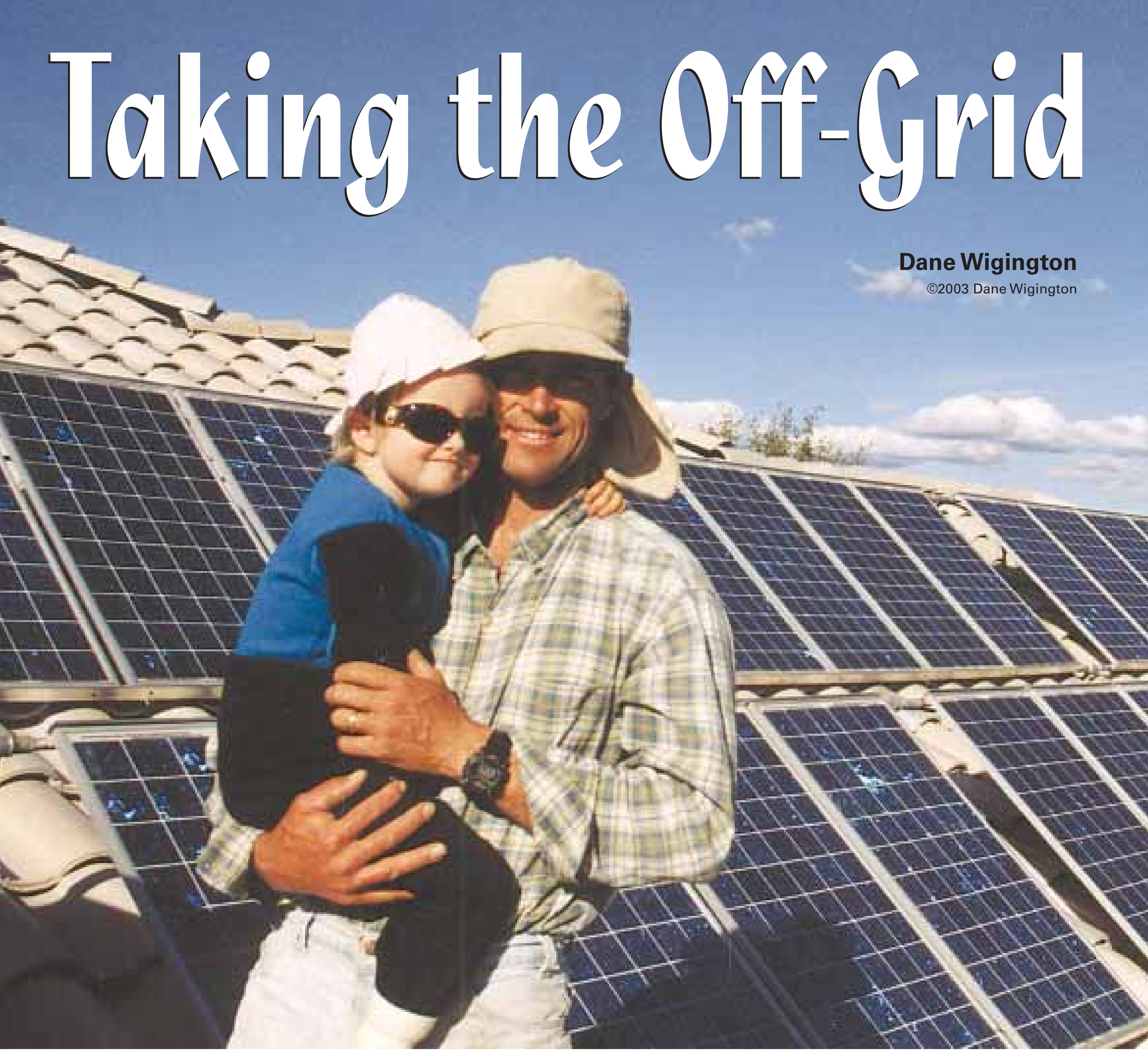
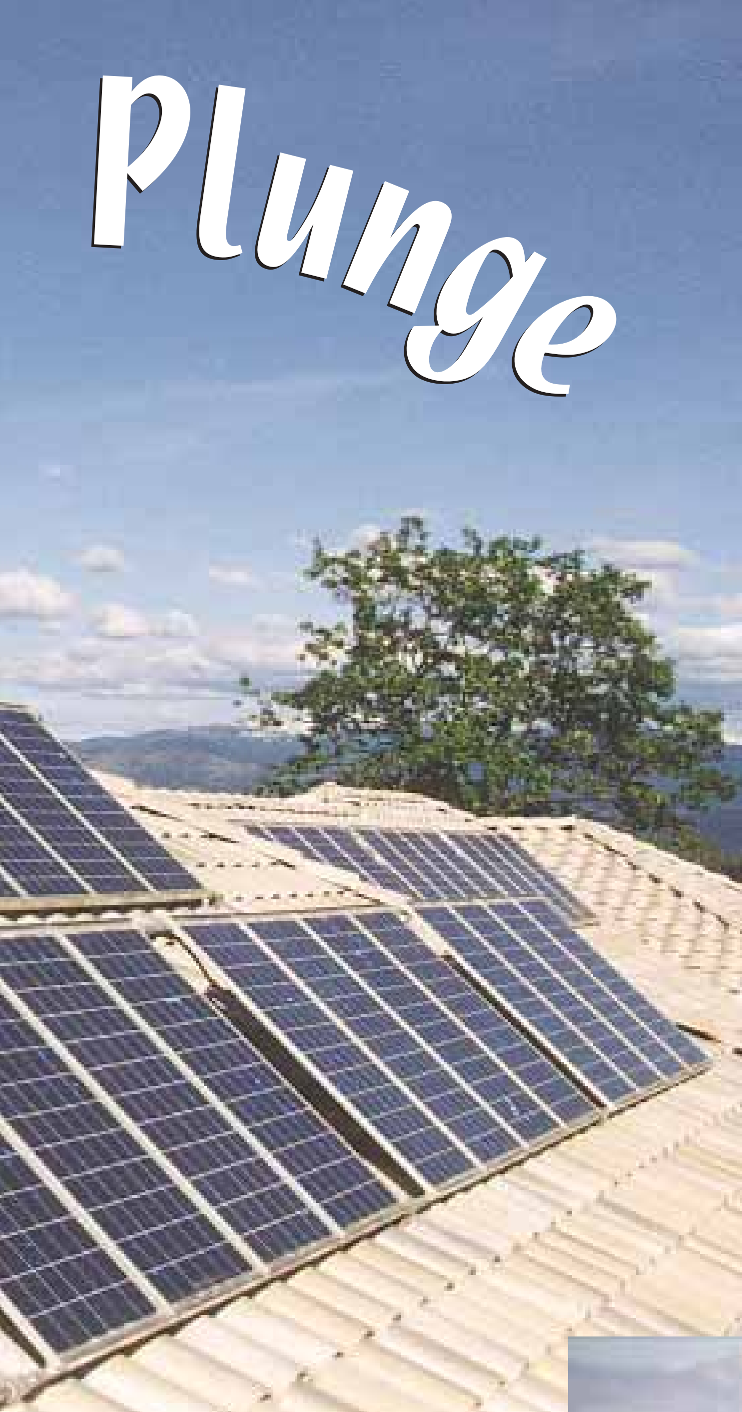


Dane Wigington and his daughter Minga, on the roof with 5,118 rated watts of photovoltaic luxury.

"Leap then look" has always been my subconscious motto. Sometimes this method has had definite pitfalls, but with my wife and my renewable energy system—so far so good.

Plunge



Next to the Pit River arm of Lake Shasta in Northern California is some of the most gorgeous terrain I have ever come across. It is also some of the most reasonably priced. After purchasing many contiguous parcels totaling nearly 2,500 acres, it was time to start on our new home. We had made a very sincere and ongoing effort to be environmentally concerned and aware for many years. So I was leaning strongly toward renewable energy for our family's needs from the start of this project.

When I received the PG&E estimate for line extension, renewable energy became the obvious choice. The thought of paying US$80,000 to the utility was a bit hard to swallow. With a distant background of having worked for the IBEW on two of the first solar-electric facilities in the U.S. in the early 1980s, I figured it was high time to put together my own solar-electric system.

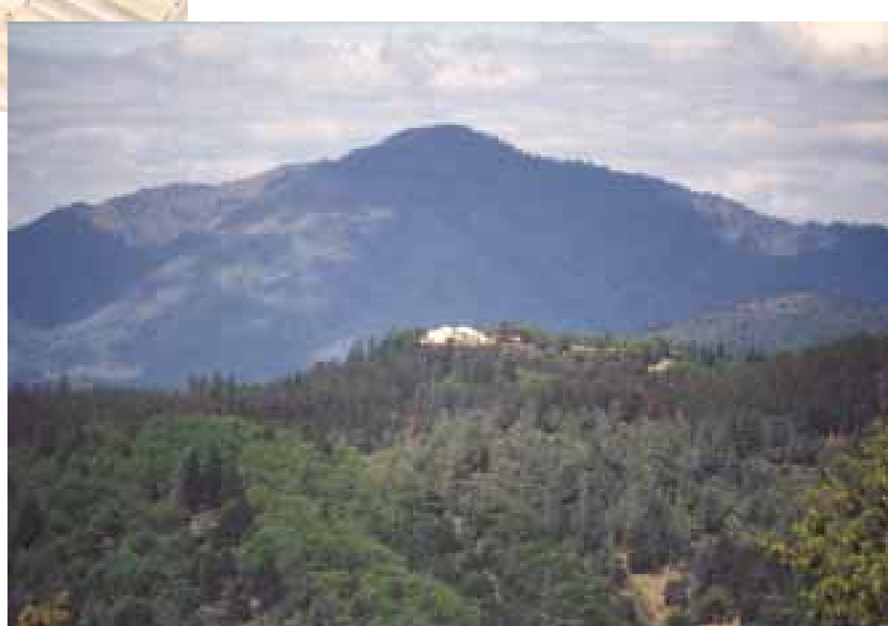
Making Connections

After a multitude of calls and conversations with solar vendors, I was eventually fortunate enough to connect with Joel Davidson and Fran Orner at SOLutions in Solar Electricity. The industry seems to have an abundance of friendly, helpful, and courteous individuals, but Joel repeatedly went well beyond generous with his time and advice. Having started on the right track, we have not looked back, and have no regrets about choosing to use renewable energy.

I figured that if the system we purchased from SOLutions was good enough to power our home, it should also be strong enough to build the home. It wasn't rocket science, right? Set up a few temporary PV arrays, a few wires into the controller, a couple of strings of batteries, and finally the inverter. No big deal—and that's about how things went.

Sure there are always a few bumps in the road, and some unexpected fireworks while connecting wires. My experience in the electrical arena was nearly 20 years back, so it all felt somewhat new. In the end, I found PV to be quite forgiving to the rookie, as long as you show due care for those really important positive and negative hookups. The bottom line? We were able to construct our residence using solar electricity and only one inverter. At times, up to seven carpenters were at work, each with a circular saw. (Luckily they never all hit the trigger at once.)

The Wigington estate has perfect views and perfect solar exposure.



The 4,200 square foot Wigington residence and efficient modern amenities prove that solar is up to the task.

The Components

We were building a big home, and I wanted big power, and that's what Joel sold us. The system includes two stacked Trace 5548 inverters, 5.1 KW of Photowatt PW1000 and Sharp ND-L3E1 panels, a Pulse PC 500 power center with charge controller, and 48 Surrette S-530s for storage. I later added two Air 403 micro wind generators, which sometimes help us through the long, dark, rainy, and windy nights.

Firing up our Honda EM6000 propane generator for additional charging has become a thing of the past. It was only used during construction when I just had sixteen "deep-cycle" marine batteries for storage. Even starting the 3 hp submersible pump in our well is easily accomplished with the stacked inverters. (Trace did not recommend or condone this size pump, but it works fine, nevertheless.) Our second EM6000, (the backup, backup generator—I was nervous) is now officially and permanently retired without ever having been started. The PVs are that good.

Even the 85 mph (38 m/s) winds that struck our place last fall could not slow them down. It launched our two main temporary arrays (complete with extensive 2 inch galvanized pipe frames) off the tops of our construction

Wigington Loads

Item	Watts	Hrs. / Day	Days / Wk.	Avg. WH / Day
Well pump, 3 hp	3,600	2.0	1.0	1,029
Kitchenaid 25 c.f. fridge	1,600	1.1	7.0	1,760
Freezer, 15 c.f.	950	1.0	7.0	950
Surveillance system	38	24.0	7.0	900
Lighting	200	4.0	7.0	800
Dishwasher	1,000	1.5	3.0	643
Welder	4,000	1.0	1.0	571
Central alarm system	15	24.0	7.0	350
Central vacuum system	2,400	1.0	1.0	343
Clothes washer	600	1.0	3.0	257
House pump	1,000	0.3	7.0	250
Personal computer #1	250	1.0	7.0	250
Personal computer #2	250	1.0	7.0	250
Steam bath	3,500	1.0	0.5	250
VCRs, answ. machines, clocks, etc.	8	24.0	7.0	199
Clothes dryer	400	1.0	3.0	171
Copy machine	900	0.3	1.0	39
Year-round Subtotal Avg. WH / Day				9,012
Winter Only				
Fireplace blower	120	12.0	7.0	1,440
Winter Total Avg. WH / Day				10,452
Peak Summer Heat Only				
2 Swamp coolers	1,200	3.0	7.0	3,600
Well pumping for tree watering	3,600	3.0	7.0	10,800
Summer Total Avg. WH / Day				23,412

trailers, landing them face down with the pipe on top. Not one single panel was broken. We were lucky, and amazed by the durability of the panels.

Loads

Though some consider "off-grid" to mean the capacity to run a 20 watt fluorescent bulb and a 12 inch black-and-white TV, I wanted conventional creature comforts for my family, coupled with conventional architecture for our structure. This includes a 27 cubic foot side-by-side refrigerator (Energy Star), central heating (90% efficient, propane), a 61 inch Hitachi HDTV (also Energy Star), two computers, three garage door openers, central vacuum, central alarm, extensive lighting, two Master Cool ducted swamp coolers, etc.

Our system has easily met these needs, and we typically only see a 10 to 15 percent depth of discharge (DOD) on the battery bank. During periods of rain, this may increase to 30 percent. It's a fairly large system to be sure, but sometimes bigger is better. The entire cost of all my system's components, including all related materials, was still US$35,000 less than the PG&E line extension, and we have made very few sacrifices.

Spot returns from an inspection of the wind generator towers.

Tech Specs

System Overview

System type: Off-grid PV/wind hybrid
Location: Near Lake Shasta, CA
Production: 460 AC KWH per month average
System Performance Metering: Xantrex TM500 battery monitor

Photovoltaics

Manufacturer and model: Photowatt PW1000, Sharp ND-L3E1
Number of modules: 46
Module STC wattage: 105 W (PW1000) and 123 W (ND-L3E1)
Module nominal voltage: 12 and 24 VDC (PW1000), 12 VDC (ND-L3E1)
Array STC wattage: 5.1 KW
Array nominal voltage: 48 VDC
Array combiner box: Pulse w/8 and 10 amp breakers
Array disconnect: Pulse PC 500 enclosure with one 60 A PV disconnect
Array installation: Roof mounted, facing true south

Charge Controller

Manufacturer and model: Pulse 60 A. PWM

Wind Turbines

Manufacturer and model: Two Southwest Windpower Air 403s
Rotor Diameter: 46 inches, (1.15 meters)
Average KWH/month at 12 mph: 46 KWH/month
Peak KW rating and windspeed: 400 watts at 28 mph (12.5 m/s)

Inverter

Manufacturer and model: Two Trace SW5548s
Nominal DC input voltage: 48 VDC
Nominal AC output voltage: 120/240 VAC

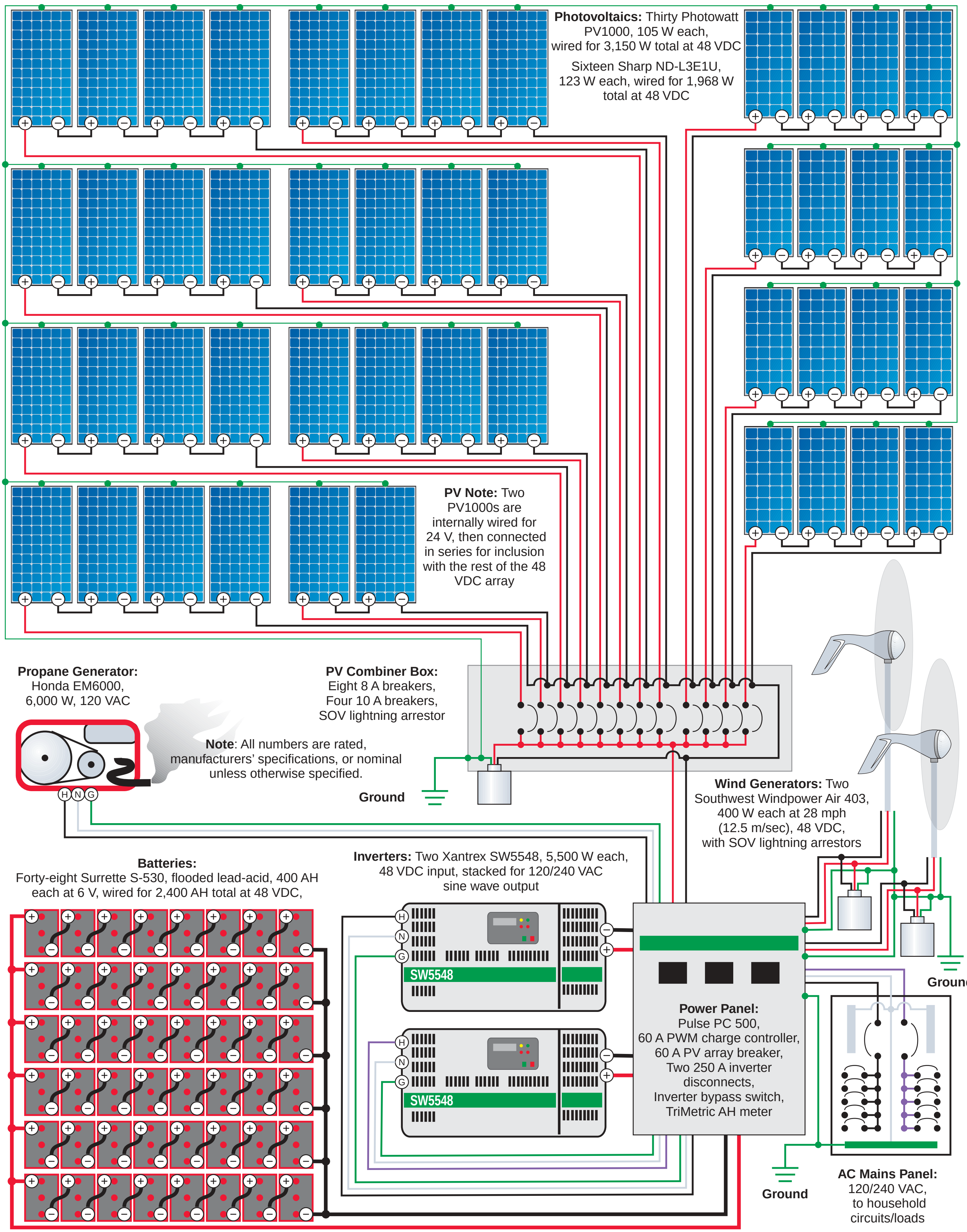
Battery

Manufacturer and model: Surrette S-530
Battery type: Flooded lead-acid
Individual battery specifications: 6 VDC nominal, 400 AH at the 20-hour rate
Number of batteries: 48
Battery pack specifications: 48 VDC nominal, 2,400 AH

Engine Generator

Manufacturer and model: Honda EM6000, propane
KW rating: 6.0
Nominal output voltage: 120 VAC
Average annual run time: 10 to 20 hours

The Wigington Photovoltaic System



The Bottom Line

Solar electricity is good for the planet. Our intent in moving to the woods and purchasing so much acreage was to preserve something, not to exploit it. This may sound a bit contradictory when considering the size of our residence (4,200 square feet; 390 m^2) and the architecture. Part of my intent was to show some solar "fence sitters" that you don't have to live in a tin roofed, strawbale barn to make a difference (not that anything is wrong with that!).

Nor do you have to hold a masters degree in engineering to do your own RE system. The whole experience was extremely rewarding. It's obvious to me that our planet is in peril. Is there a more immediate and logical solution than harnessing solar, water, and wind energy? This off-grid rookie doesn't think so.

We intend to set aside most of the land we have acquired in this pristine area as a preserve. We have not subdivided a single plot of the Shasta land, and have also restricted the few parcels we have resold so they can never be subdivided. We hope to sell a few existing smaller parcels (10 to 80 acres) to renewable energy neighbors. My brother and one of my closest friends have already purchased land and are planning solar homes like ours.

Dane Wigington's substantial battery bank carries his home through night and cloud cover.

System Costs

Item	Cost (US$)
32 Photowatt PW 1000 PV modules	$12,800
48 Surrette S-530 batteries	8,640
16 Sharp ND-L3E1U PV modules	6,900
2 Trace SW5548 inverters	5,900
Honda EM 6000 propane generator	2,650
Pulse PC 500 power center/charge controller	1,450
2 Southwest Wind Air 403 wind generators	1,090
PV roof mounts, pipe, & materials	800
Battery cables	459
3 Pulse combiner boxes	375
Trace TM500 battery monitor	300
Installation, done by owner	0
Total	$41,364

As for the rest, since many people don't feel that they have the experience to undertake such a project, I plan to start construction of another RE home on our ridge as soon as possible, and it will be available for purchase. Renewable energy will be a condition of entry into the neighborhood. The hilltop sites around us are prime solar and wind locations, and I feel ever more motivation to make an environmental difference for the better.

Nearly every day, new information surfaces about the increasing destruction of our host, planet Earth. The consequences of our irresponsibility as a species are already impacting hundreds of millions of people around the globe. I certainly believe it's high time for all of us to do what we can to help.

To a solar bozo, this is luxury too.

Honorable Mentions

I have already talked about the invaluable help I received from SOLutions in Solar Electricity, but there are others (see Access). Something about this industry attracts helpful people. There is no other way to explain the extraordinarily high percentage of just plain good folks who are involved in it. I think the common denominator is this: they care and believe in what they are doing—ingredients that are an increasingly rare commodity in today's struggling world.

Access

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Moving Up to More Energy

Rudy Ruterbusch

Four years ago, we decided to install a small home energy system at our log home in the northern Great Lakes region. We had existing utilities, but we wanted to switch to renewables. The problem was deciding how much equipment we needed and how much wind and sun we had.

The Ruterbusches—Jill, Matthew, Rudy, Jason, and Steve the dog—generate 97 percent of their electricity.

We knew how much electricity we were using—the utility company was keeping good records on that for us. We attended the Midwest Renewable Energy Fair in 1997, which helped us design a small system that provided us with a backup DC electricity source (see *HP80*). This gave us hands-on experience, and we started making some of our own energy right away. We thought by using our small system for a couple of years, we could figure out how much energy it could reliably produce. Then we would know exactly how much more equipment it would take to run the entire house.

Small System Lessons

Our small system consisted of four Trojan T-105 batteries wired for 440 amp-hours at 12 volts DC, an Air 303 micro-wind generator, and a Solarex VLX-53, 50 watt PV panel. Later we added two more panels, for a total of 150 watts. Our goals were to determine how much wind and sun was available at our site and to learn what components would work best in our location and for our seasonal (8 months per year) use. We can now report what we learned and where we are today.

Based on two years of data collection, we now know that our 150 watt solar-electric array reliably produced about 1/2 a kilowatt-hour (KWH) each sunny day, and our Air 303 averaged another 1/4 KWH when it was running. Eventually, after several regulator failures due to high wind, we decided to remove the Air entirely and shop for a more robust wind generator.

Efficiency Measures

We spent another year getting our house ready for renewable energy. This included changing all the lightbulbs to compact fluorescents; replacing our 220 volt electric water heater with an Aquastar, solar preheated, propane unit; and changing some small electronics to 12 VDC, running them directly off our existing batteries. We also replaced the refrigerator with a 14 cubic foot (1.3 m^2) Crosley AC model from the local appliance store. While not as efficient as a Sun Frost, it paid off for us because it is used seasonally.

According to the utility company, our home uses between 4 and 6 KWH of electricity per day when we are home, and less than 2 KWH when we are away. With the data from our small system and two years of utility bills, it became simple math to design a full-size solar and wind-electric system to power our entire home.

A wind generator balances the available energy resources.

Our new larger system is now operating. A Southwest Windpower model H-40 (formerly World Power Technologies H-900) wind generator sits on top of a 75 foot (23 m) Rohn 25-G tower. Ten Kyocera KC-120 panels are on a fixed rack, and twenty Trojan L16P, 360 amp-hour batteries are wired for 1,800 amp-hours at 24 volts. A Xantrex SW4024 provides AC electricity for the entire home.

System Design

We wanted to design a system that could reliably produce about 7 KWH of energy per day when it is sunny or windy. In the summer, we generally have five sunny days out of seven. In the fall and winter, our windy season, we generally have windy days averaging 16 knots (18.4 mph; 8 m/s) over 24 hours, three days out of seven. (This data was acquired from the National Weather Service, and Coast Guard Station observations at Manistee and Frankfort, Michigan.)

We calculated the 7 KWH value by simply taking seven days of electricity use, or about 35 KWH according to our utility bills, and dividing by five, the number of days each week we expected to have a near full day's production from either the wind or sun. This way we could count on two days each week with little to no electricity being produced, and still have sufficient excess available to power the house and replenish the batteries on days with good wind and sun.

Our 1.2 KW solar-electric array receives eight to ten hours of sun on clear days in the summer, producing the equivalent of about six hours of direct noontime insolation each day. This should theoretically produce about 7.2 KWH on clear days, but is closer to 5 KWH per day when conversion and PV temperature derate losses are taken into account. Our wind generator operating at one-third its rated power, or 300 watts for 24 hours, also would yield 7.2 KWH of energy.

In actual operation, we've found that our two days per week of cloudy or calm days were never spread evenly throughout the month, but rather tended to cluster in groups. This would always leave us with a week of poor production and deeply discharged batteries at some point in the month.

After nearly a full year of use, we found that our system could comfortably run our home about 28 days each month. The other two, we simply switched back to the utility, and waited for the batteries to "catch up" again.

Adding two more solar-electric panels made the utility almost unnecessary.

To help compensate for this shortcoming, we recently added two additional panels. This increased our total solar-electric capacity to 1.4 KW. These panels are connected to the system via the solar input terminals included in the Southwest Windpower EZ-Wire controller. We still have to switch over to the utility once in a while, but those events occur less often, and we can recover faster now.

We were discharging to 45 percent state of charge before switching the house to the utility manually, and allowing the wind and solar-electric systems to fully recharge the battery bank. We still have the same policy, but we only hit the 45 percent mark once in the last year since adding the extra two panels and making additional energy saving changes to the house, like timer switches on bathroom lights and CF lights in the crawl space.

Component Selection

Selecting components for a home energy system is a process that should occupy a significant amount of time. There are many considerations, most of which are not evident when you first start designing your system. With the experience we gained operating our small 12 volt equipment for two years, we were able to select components that ultimately worked at our site, produced the energy we expected of them, and did not fail prematurely or detract from the natural beauty of our home.

Our H-40 wind generator is rated at 900 watts at 28 mph (12.5 m/s). Having the regulator at ground level was desirable to us, given our track record with the Air 303, which has the regulator internal to the wind generator nacelle (housing).

The Rohn tower is 75 feet (23 m) tall, the highest we could go without a variance from the building department and another community hearing on the subject. We might one day want to add more sections, or upgrade to a larger turbine. So the tower guy wires were spread out to allow up to a 105 foot (32 m) tower using the same anchors. The tower and underground wires are sized to allow an additional 30 feet (9 m) of run up a taller tower, and upgrading to a larger turbine as well. The extra cost for the larger wiring was less than US$100, and moving the guy wire anchors in the original plan cost nothing, since we had not broken ground yet.

We were originally going to use Trojan T-105 batteries, since they give you the best short-term bang for the dollar, and we already had them installed in our 12 volt system. Spending less money and having interchangeable parts made sense. Reality set in when we calculated the sheer number of batteries, interconnects, and cells to water, and we balked.

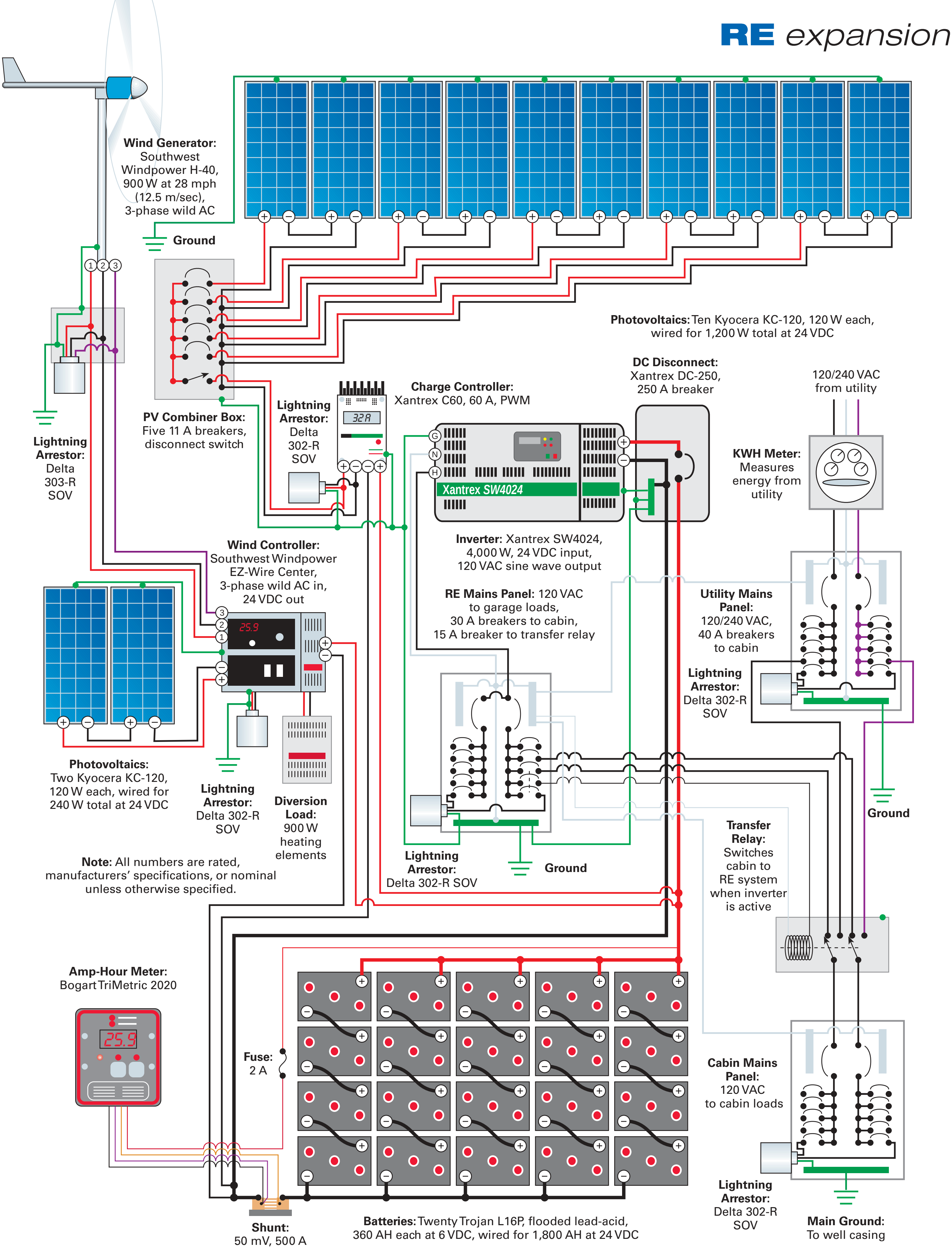
So we spent the extra dollars and now have twenty Trojan L16Ps, which save on space, complexity, and have more reliability in the end. They are wired for 1,800 amp-hours at 24 volts DC.

The Xantrex SW4024 inverter caused us some setbacks at first, but our new grounding configuration (see sidebar) seemed to overcome all of our problems. We originally wanted something simpler, a stand-alone sine wave inverter that could provide about 3,000 watts of continuous electricity and had a programmable low voltage cutout. At the time, the Xantrex inverter with its myriad programmable features was the best buy for our requirements, even though it had features we didn't want to purchase or learn how to operate.

We have the DC wiring and disconnects arranged to allow the easy addition of a second inverter. As manufacturers continue to add additional choices, we might purchase a competing unit one day and compare the two in actual operation.

The Kyocera KC-120 PV panels seemed like a perfect fit for us. We could have a 1,200 watt rated array with just ten

The system components are installed neatly. Good metering helps the Ruterbusches and housesitters keep track of system performance.



Wind Generator: Southwest Windpower H-40, 900 W at 28 mph (12.5 m/sec), 3-phase wild AC
Ground
Photovoltaics: Ten Kyocera KC-120, 120 W each, wired for 1,200 W total at 24 VDC
PV Combiner Box: Five 11 A breakers, disconnect switch
Lightning Arrestor: Delta 303-R SOV
Lightning Arrestor: Delta 302-R SOV
Charge Controller: Xantrex C60, 60 A, PWM
32 A
DC Disconnect: Xantrex DC-250, 250 A breaker
120/240 VAC from utility
KWH Meter: Measures energy from utility
G
N
H
Xantrex SW4024
Inverter: Xantrex SW4024, 4,000 W, 24 VDC input, 120 VAC sine wave output
Wind Controller: Southwest Windpower EZ-Wire Center, 3-phase wild AC in, 24 VDC out
25.9
RE Mains Panel: 120 VAC to garage loads, 30 A breakers to cabin, 15 A breaker to transfer relay
Utility Mains Panel: 120/240 VAC, 40 A breakers to cabin
Lightning Arrestor: Delta 302-R SOV
Photovoltaics: Two Kyocera KC-120, 120 W each, wired for 240 W total at 24 VDC
Lightning Arrestor: Delta 302-R SOV
Diversion Load: 900 W heating elements
Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.
Lightning Arrestor: Delta 302-R SOV
Ground
Ground
Transfer Relay: Switches cabin to RE system when inverter is active
Amp-Hour Meter: Bogart TriMetric 2020
25.9
Fuse: 2 A
Cabin Mains Panel: 120 VAC to cabin loads
Lightning Arrestor: Delta 302-R SOV
Shunt: 50 mV, 500 A
Batteries: Twenty Trojan L16P, flooded lead-acid, 360 AH each at 6 VDC, wired for 1,800 AH at 24 VDC
Main Ground: To well casing

Technical Specifications

System Overview

System type: PV/wind hybrid standalone with utility backup

Location: Elberta, Michigan

Production: 175 AC KWH per month average

Percentage offset by PV system: 97 percent

System performance metering: Bogart Engineering TriMetric monitors battery SOC; Xantrex C60 digital amp-hour totalizer monitors PV array; Omron digital amp-hour counter monitors wind generator amp-hours

Photovoltaics

Manufacturer and model: Kyocera KC-120

Number of modules: 12

Module STC wattage: 120 W

Module nominal voltage: 12 V

Array STC wattage: 1,440 W total

Array nominal voltage: 24 VDC

Array installations: Main array—10 modules roof-mounted with aluminum L-brackets on a south-facing carport roof at 51 degrees tilt; supplementary array—2 modules on homemade manual tracker

Array combiner box: Square D weatherproof junction box

Array disconnect: GE general duty safety switch, 2-pole, 30 amps, 240 V, AC or DC

Charge controller: Xantrex C60 with digital metering option, PWM

Wind Turbine

Manufacturer and model: Southwest Windpower H-40

Rotor diameter: 7 feet (2.5 meters)

Average KWH/month at 12 mph: 100

Peak KW rating and windspeed: 900 W at 28 mph (12.5 m/s)

Charge controller: Southwest Windpower EZ-Wire control center

Tower: Rohn 25-G

Tower type: fixed, guyed lattice

Tower height: 75 feet

Inverter

Manufacturer and model: Xantrex SW4024

Nominal DC input voltage: 24 VDC

Nominal AC output voltage: 120 VAC

Battery

Manufacturer and model: Trojan L16P

Battery type: flooded, lead-acid

Individual battery specifications: 6 VDC nominal, 360 AH at the 20 hr. rate

Number of batteries: 20

Battery pack specifications: 24 VDC nominal, 1,800 AH

Main DC disconnect: Xantrex DC-250

Lightning Protection

Surge arrestors: Six total; five Delta 302-R, a 2-hot wire model, with an additional single ground wire and one Delta 303-R; a 3-hot wire arrestor with one ground. The three-wire model is installed at the base of the tower to catch all three legs of the wind generator output. The two-wire models are located at the two incoming solar array lines, the breaker box in the garage, the breaker box in the house, and the utility box in our shed.

modules. This made wiring and installation simple. The KC-120 has a very easy-to-use junction box mounted on the back, with bypass diodes already installed on the terminal strip inside. They even come with weathertight strain reliefs that fit into the knockouts on the box. Once you purchase your interconnect wires, everything almost snaps together.

The Xantrex C60 is a good charge controller. With the optional digital readout, even our neighbors enjoy coming over when we are away to fill in our log sheets in the control room. About once a month, when we get low wind and sun for a few days, we switch the house to utility electricity and activate the C60 equalization mode. The solar-electric array then runs full available current to the batteries, for several days if need be, until the batteries are equalized. The equalization feature is easy for anyone to operate.

We also installed a TriMetric meter to keep track of our battery state of charge. Although a bit complicated to

Twenty L16P batteries store the energy for use during extended periods without much sun or wind.

program, it has worked out very nicely for us because its one-button operation allows simple access to the three main functions—a digital readout of volts, net charge and discharge amps, and percent state of charge. Once again, our neighbors are happy to get this information for us when we are away, and leave the more complicated features for me to operate. It has worked flawlessly for two years now.

Wind Installation

Our large system installation was done in two phases. First we installed the tower, H-40 wind generator, batteries, and inverter. The wind system went in first because we had been awarded a grant from the Michigan Department of Energy (DOE), covering about 25 percent of the cost of the wind generator and batteries.

We had to make a deadline and stay on a fairly tight budget, so we left the entire solar-electric array for the following spring. Initially, only sixteen batteries were installed to save on time and budget; the other four were added nine months later. The wind generator, batteries, and inverter were running by May 30, 2000. We passed our electrical inspection a few days later.

PV Installation

When spring came, we learned that we had been awarded another grant from the Michigan DOE. This paid about half the cost of the panels. Again we had a budget and a deadline to make, and we immediately installed the entire 1.2 KW solar-electric array on a fixed rack on the garage roof.

The rack was fashioned from aluminum L-brackets and stainless hardware. It was actually mounted on top of a carport that was added to the south wall of our garage the previous fall in preparation for the solar-electric array. We preferred to mount our solar-electric modules on top of a porch or carport roof to eliminate the possibility of a leaky roof over a finished space inside our home.

John Heiss of Northwoods Alternative Energy and I built and installed the entire array in two days. It worked perfectly the day we threw the switch on, and it still works the same way today. The only attention I've had to give to the array in two years is trimming the trees to the south of our garage.

System Costs

Item	Cost (US$)
12 Kyocera KC-120 panels	$6,250
20 Trojan L16P 360 AH batteries	3,000
Xantrex SW4024 inverter	2,400
SW Windpower H-40 wind generator	1,500
Used Rohn 25-G, 75 foot tower	1,400
Underground wiring	475
Panel racks	265
Xantrex C60 charge controller	240
TriMetric meter	160
Xantrex DC-250 disconnect	150
6 Surge arrestors	120
Misc. grounding rods & hardware	110
AC circuit panel & breakers	94
Misc. hardware	85
Battery wiring	80
Lumber	50
Misc. wiring	45
Battery room lighting	44
Total System Value	$16,468
Solar grant (credit)	-3,600
Wind grant (credit)	-878
Bottom Line	$11,990

Keeping Track

Our system has been operating for a little more than two years now, and for the most part, it needs very little attention. Our batteries need water about once each season, and aside from occasional breakdowns (see sidebar), all we do is keep track of energy production and battery levels about once a day, and forget about it.

We have included highlights from our log sheets over the last seven months. We rarely make what we expected on each sunny day throughout the course of the summer. There are two main reasons for this.

First, while our solar-electric array is capable of producing 5 KWH on a good day, because days like that tend to come in clusters, the batteries tend to fill up, and the C60 tapers off the charge in the afternoon. This renders some of the available solar electricity useless, and we can't get it back a week later when we need it. So on cloudy days, we can't make full production, and on clear days, we can't store it. At the end of any given month, some of our solar energy is wasted.

Performance Log Highlights

	Solar					Wind		Total
Month	# of Days	KWH / Day	KWH / Month	Best Solar Date – KWH		KWH / Day	KWH / Month	KWH / Day
May	31	3.2	99.4	26th	5.0	1.7	53.1	4.9
June	30	3.4	101.8	18th	5.2	1.6	46.9	5.0
July	31	5.0	153.6	14th	6.0	0.9	27.6	5.8
August	31	4.2	129.0	11th	6.1	1.1	34.9	5.3
September	30	2.7	82.3	26th	4.4	1.6	47.7	4.3
October	31	1.8	57.2	14th	4.3	2.2	69.4	4.1
November	30	1.3	39.6	17th	2.8	2.8	84.6	4.1

Inverter vs. Lightning

For the most part, very few changes or additions occurred in our first summer with the big system, but there were some setbacks. First, our original inverter arrived damaged in the box. Sending it back cost us several weeks' delay. Then, nine days after we passed inspection, the replacement inverter died one night while I was away. So we sent it back to be repaired. Two months after reinstalling the inverter, it died again one night while it wasn't even operating. Xantrex installed a second replacement control board, and sent us a bill for US$575 for repair work and shipping.

Xantrex claimed that lightning hit our system twice that summer, but nothing else on the property was damaged. Most of the installers I have talked to say the Xantrex SW4024 is very susceptible to static discharges, and any radio engineer you talk to will tell you that a sandy soil is horrible for dissipating static buildup, like from a tower standing up in the wind all day.

It seemed like something needed to be done. We consulted with our wiring inspector, our installer, Xantrex, and a retired radio tower engineer who lives in the area. We decided to install a grounding block inside our DC-250 disconnect box that was attached to the side of the inverter, and bond AC neutral, DC negative, and chassis ground to it. We then ran a #4 (21 mm^2) bare copper wire from the block to the head of our steel well casing, and have had no problems since then.

We learned that the three most important things to remember when hooking up a Xantrex inverter are, "grounding, grounding, and grounding." It has been eighteen months, and the inverter is still working fine.

I concluded that the real problem at our site is not lightning strikes, but static buildup. The control board in a Xantrex sine wave inverter is apparently very sensitive to static discharges, and you need a ground location with more absorption ability than an 8 foot (2.4 m) ground rod stuck in the dirt. This makes a more attractive path for small discharges that may be building up in your system, before they have a chance to discharge across sensitive components in the control board. It's much like a large heat sink is used to protect semiconductors from overheating.

We have also installed an array of surge arrestors around the property. The following summer when our solar-electric array took a direct hit during a thunderstorm, the only damage was the C60 charge controller. It was also the only piece of equipment that didn't have an arrestor directly attached to it. It has one now.

Second, in the interest of wind generator longevity, we tend to switch off the machine on clear days if the batteries are nearly full. This avoids some of the wear and tear on our wind generator and tower on days when we don't need the extra 50 to 100 amp-hours. It also shows up at the end of the month as a shortcoming, since our amp-hour meter only knows how much energy the wind generator produced, not what was available.

By the time 30 days have come and gone, our system only produces about 175 usable KWH, instead of the 220 or so the equipment is capable of. Then we need to borrow another 20 from the utility. Our system and usage is probably a good argument for utility intertie if there ever was one, but we are not going there right now. The utility requires additional equipment to sell back, but so far we can't find anyone to tell us exactly what it is. They buy back at the wholesale rate, which we're told is about one quarter the amount we are paying them. And with the problems we have had with lightning/static damage to the inverter, we have been reluctant to hook our inverter to the utility grid.

97 Percent

We learned a great deal in the course of the last four years. Our biggest lesson was that you can never fully research a project like this. You have to gather all the information you can, and at some point start putting things together. This is why building the small system first made so much sense. Our original plan for a household-sized energy system was so much different five years ago than the one we have today. This is mainly because we learned so much trying to get our small system working properly.

Using renewable energy to power your home requires more than just hardware. You have to make some lifestyle changes as well. Doing laundry on a sunny afternoon rather than at night reduces wear on your batteries, and showering in the morning makes less use of your solar water heater than showering at night. We've found that with just a few habit changes, we can squeeze about 97 percent of our home's energy needs out of what we have now. That's not bad—next year we're shooting for 98.

Access

Rudy and Jill Ruterbusch, PO Box 195, Elberta, MI 49628 • 231-352-7839 • windycabin@aol.com

John Heiss, Northwoods Energy Alternatives, PO Box 288, Lake Leelanau, MI 49653 • 231-256-8868

What the Heck? 10

Relay

A relay (top) and a much larger relay called a contactor (bottom). The relay can be exposed when mounted in an approved base; the contactor should be inside an enclosure since it has exposed terminals.

Used in: All types of electrical control circuits

AKA: Contactor, solenoid, magnetic switch, servo-electric switch

What it is: A switch controlled by electricity

What it ain't: A team sports event

A relay is used for turning electrical and electromechanical equipment on and off. It can be used for turning on pumps, blowers, dampers, and valves, or for energizing another electrical circuit. Relays allow a source of low power to control a high power device, saving the cost of running heavier wire.

Normally open (NO) relays have a coil of wire built in that is an electromagnet. When voltage (coil voltage) is applied, the electromagnet pulls the switch contacts closed (turns on). The switch contacts are spring-loaded, and will snap back off (open) when the coil voltage is turned off. Normally closed (NC) relays are also available. Some relays are "ratcheting" or "latching," which means that they change their state with a single pulse of electricity, rather than relying on a constant source of energy to maintain their state.

Relays are often used to isolate two pieces of equipment. An example is two pumps that you want to turn on at the same time in some circumstances and have one or the other turn on alone in other circumstances. This type of control sequence can easily be designed with the use of relays. A single relay can have multiple input and output contacts to control many devices at once and simultaneously turn some things on and other things off.

Relays are common in automobiles, air conditioners, and many appliances of different types. Renewable energy systems may incorporate relays in automatic transfer switches, diversion charge controllers, inverters, and differential thermostats.

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

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

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

PowerCenter Controller

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

Typical Performance: 5.2 kWh DC per day

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

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

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Heat from the Earth

A Heat Pump Primer

John Lynch

Heat pumps are devices that supply more energy than they consume by extracting low-grade heat from the surrounding air or water. Heat pump systems can supply as much as 4 KW of heat output for just 1 KW of electrical energy input.

A ground source heat pump, in heating mode, extracts heat from the moisture in the ground and transfers it to the air inside a building. In cooling mode, the heat pump extracts heat from the air within a building and transfers it to the earth outside the building. This article deals primarily with ground source heat pumps in heating mode.

Earth as Solar Collector

The earth absorbs about 50 percent of the solar energy that it receives from the sun. The amount of this stored energy that can be extracted from the earth is greatest in soils with a high moisture content. At a depth of a few feet, the soil temperature varies very little throughout the year.

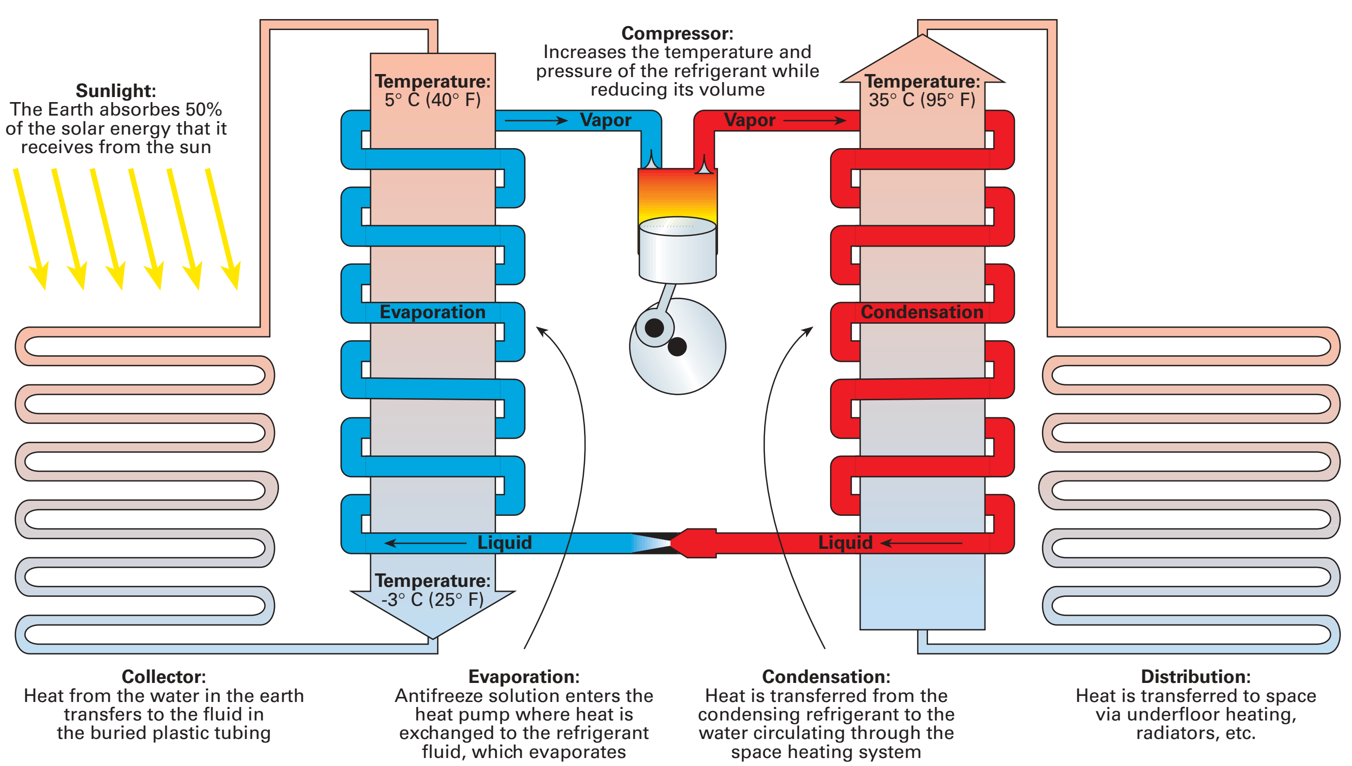
Heat is extracted from the soil by means of a fluid contained in inexpensive, buried, plastic tubing (polyethylene or polybutylene). The hardware consists of a heat pump connected to lengths of small-diameter pipes (known as the collector). These are buried underground in your garden or driveway, or in a river or lake. Water (with antifreeze in very cold climates) circulating through the pipes "absorbs" low-temperature heat from the ground. The heat pump extracts the heat from this water, concentrates it to high-temperature heat, and transfers it to the area to be heated.

A heat pump is similar in operation to a refrigerator, except that the refrigeration cycle is reversed when the heat pump is heating. Many of the components are the same—condenser, compressor, and evaporator. The footprint and noise level are also comparable to a fridge, and the units can be located indoors or outdoors.

Collector

Various possible configurations for the collector are shown in the diagrams. The choice of collector may be constrained by the availability of experienced contractors to install the optimum set-up for your application. This may affect the cost and performance of the system.

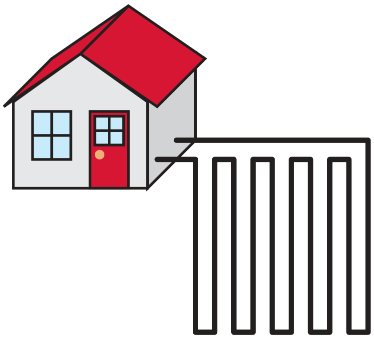
Heat Pump Operation



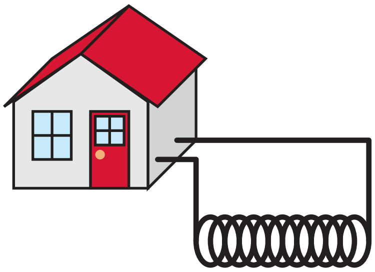
Ground-Coupled Loop Configurations

Horizontal Closed Loop:
4 feet deep

Vertical Closed Loop:
80 to 180 feet deep



Spiral Closed Loop:
4 to 6 feet deep



Pipes are laid at a depth of 3 to 5 feet (0.9–1.5 m). If the pipe is buried too deep, it reduces the ability of the incident solar energy to replenish the heat absorbed from the earth by the fluid in the collector pipe. It is important that the ground loop be absolutely watertight, since any leak in the system will be expensive to find and repair. Once finished, the buried ground loop is maintenance free and invisible—a source of self-sustaining energy on your very doorstep.

Open loop, vertical bore collectors can be more economical where the borehole can be combined with sinking a well for domestic water. The water must be clean and noncorrosive.

Length of Ground Loop

The length of a ground loop collector pipe depends on:

- Which method of earth coupling is used: horizontal, vertical, spiral loop, open loop, etc.
- Pipe material: usually polyethylene, polybutylene, or copper
- Diameter of pipe
- Underground soil/water temperature, which depends on:
  - Depth of the horizontal trench or vertical borehole
  - Climate
  - Source of the heat: river, lake, groundwater
  - Wetness of the soil: wet, average, light, dry
  - Type of soil: sand, gravel, silt, clay, loam

For example, a 10 KW system, designed for a 2,000 square foot (186 m^2) dwelling (in a moderately cold climate, with average insulation) requires approximately 1,300 feet (400 m) of horizontal pipe. This would require approximately 1/4 acre of ground for a simple horizontal loop, with a single pipe buried in the trench. This amounts to six times the floor area of the house.

Sizing Heat Pumps

Heat pumps can be equipped and set up for combined heating (winter) and cooling (summer) or equipped and set up for heating only. The main equipment difference is that the heat pump, which has both heating and cooling capability, has a reversing valve to change the direction of the refrigerant flow.

Heat pumps equipped and installed for combined heating and cooling are sized to satisfy the cooling requirements of the building. Heat pumps equipped and installed for heating only are sized to satisfy the heating requirements of the building.

Terms & Definitions

Heat Pump: Device that “pumps” heat from a low-temperature heat source to a higher temperature heat distribution system, such as underfloor heating, etc.

Ground Source Heat Pump (also known as ground-coupled): A heat pump that absorbs its low temperature heat from moisture trapped in the earth or from water in a pond, lake, river, or well.

Collector: The outdoor series of pipes that absorbs the low-temperature heat from the earth, lake, pond, well, etc.

Degree-Day: A heating degree-day is the difference between 65°F (18°C) and the average of the high and low temperatures in a given day. The higher the number, the more fuel will be used in heating your home or building. Example: A day with an average temperature of 50°F will have 15 degree-days of heating for that day.

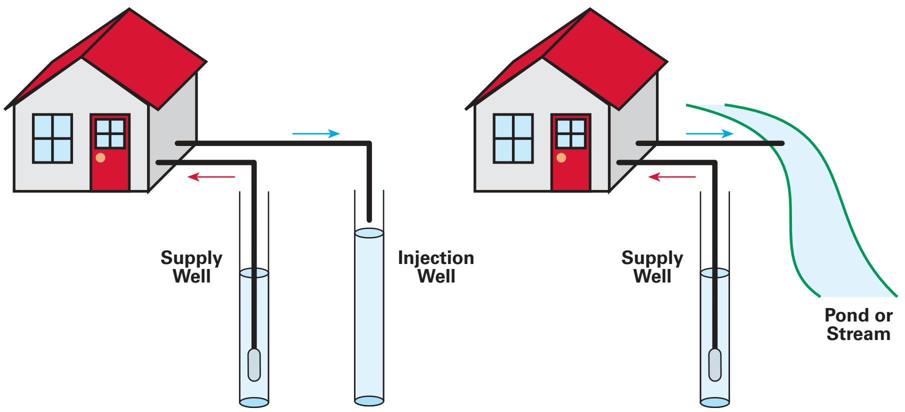
Geothermal Energy: The heat stored within the earth, due to the earth’s natural heat flow. The term geothermal heat pump is mostly used by government or federal institutions and usually refers to large-scale heat pump applications.

Ground Coil, Ground Loop, Earth Loop, Collector: Outdoor lengths of pipe (usually plastic) buried in the ground and usually filled with water. Antifreeze is added in colder climates.

Groundwater Loop Configurations

Two-Well, Open Loop

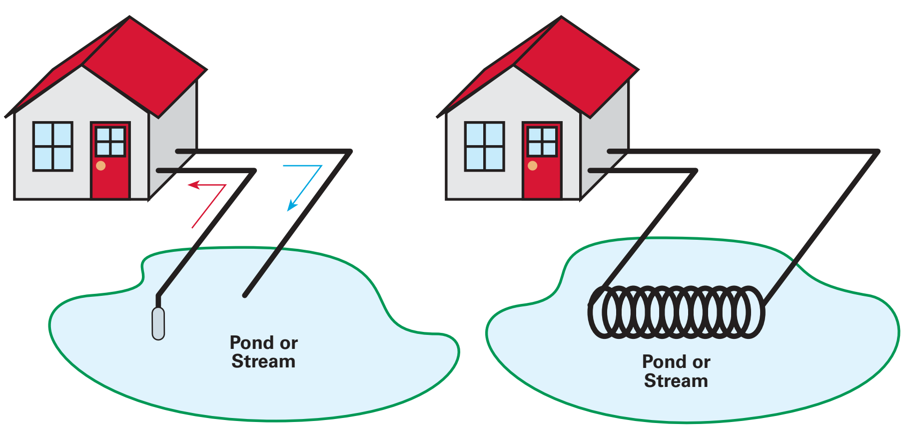
Single-Well, Open Loop



Surface Water Loop Configurations

Surface Water, Open Loop

Surface Water, Closed Loop



Collector Loop Suitability

Item	Horizontal: Closed Loop	Horizontal: Open Loop – Pond, Lake, or Sea	Vertical: Open or Closed Loop Boreholes, or Two Wells*
Extremely cold climate	Not OK	OK	OK
Mild climate	OK	OK	OK
Large site needed	Yes	No	No
Performance (COP)	Good	Better	Best
Cost	Mid	Low	High

*Open loop, vertical bore can be more economical. See text.

It is not economical to size the heat pump to meet the peak demand (a few days per year). An oversized heat pump will cost a lot more and will cycle on and off repeatedly, thereby reducing reliability. So heat pumps are usually sized to meet 60 to 70 percent of the maximum heat load of the building, and may need auxiliary heating capability to meet the heating requirements in winter. The auxiliary heating source you choose will affect the overall performance of the system. Many heat pumps have electric resistance heating built in, which may not be the most efficient choice.

The heat pump operates over long periods and can be run at night to take advantage of night-rate electricity. In this case, the building should be designed or adapted so that the floors and mass of the building are used to store the heat generated at night. This thermal mass then releases the heat slowly during the day. Auxiliary heating (such as conventional electric, oil, gas, etc.) will generally be needed to supplement the heat pump output during extremely cold periods.

The following information is needed to select the most suitable type and size of heat pump:

- Regional weather data
- Cooling/heating load of the building
- Earth or ground water temperatures
- Water content of the soil: wet, average, dry
- Type of soil: sand, gravel, silt, clay, loam

Performance

The performance of an electric, compression heat pump at a given set of temperature conditions is referred to as the coefficient of performance (COP), and it is a key indicator of how well it does its job. COP is defined as the heat delivered by the heat pump, divided by the electricity used by the compressor.

The quoted COP for modern heat pumps is usually in the range of 3.5 to 6. The COP is critical to the performance, efficiency, sizing,

Source Efficiency

Source	Temp °C	Temp °F	Efficiency
Sea water	10	50	Higher
Well (vertical hole)	8	47	
Groundwater or lake	7	45	
Horizontal earth loop	4	39	
Air	-5	23	Lower

Order may vary depending on local climatic & geographic conditions.

Distribution Efficiency

Method	Temp °C	Temp °F	Efficiency
Underfloor or wall heating	30	88	Higher
Hydronic convectors with fan	45	113	
Traditional radiators	55	131	
Domestic hot water	60	140	Lower

electricity consumption, amount of heat delivered, and payback period of a heat pump.

The specified COP applies at the specified inlet temperature (usually 0°C; 32°F) and outlet temperature. In practice, the actual temperatures will vary continuously. The heat delivered by the heat pump is controlled dynamically by the heat pump's control electronics in response to the outdoor air temperature and the heating requirements of the building.

Heat pumps are most efficient and cost effective when designed and installed in newly constructed dwellings rather than replacing an existing heating system. In a new-build situation, the heat pump system can be optimized by installing underfloor or wall heating. The cost of the groundwork for the collector is less when it can be done at the same time as site preparation, landscaping, or well drilling.

The smaller the difference between the temperature of the heat source (earth) and the temperature of the heat delivery system, the greater the efficiency of the heat pump. From the tables, you can see that a system using seawater as the source and underfloor heating for distribution will have better performance (COP) than any other combination.

Suitability

Ask yourself these questions to determine if a heat pump could work for you:

- Do you consume a lot of energy for heating?
- Do you need near-continuous heat for a high comfort level?
- Are you planning a new house or major remodel?
- Do you have sufficient ground area or water source to lay out the collector?
- Can a trench or well be dug without difficulty?
- Do the savings over other high efficiency systems give a reasonable payback?
- Do you want to reduce greenhouse gas emissions and reduce fossil fuel consumption?

Heat pumps are not for the do-it-yourself enthusiast! The selection, specification, sizing, and installation are all critical to the efficiency, performance, and reliability of the system. Go with a pro!

Laying and burying a ground source loop that uses a spiral or slinky tubing configuration.

Photos courtesy of Stephen Vance.

Manifolds distribute collector fluid to, and recombine it from, multiple ground loops.

Payback

Heat pump systems are more expensive to install than conventional heating systems. To evaluate the cost effectiveness of a heat pump system compared with a conventional heating system, you need to look at the additional capital costs and the annual savings. A useful figure is the payback period, which is the number of years it takes for the annual savings to pay back the additional capital expense.

Simple payback is easy to calculate. Subtract the cost of installing a conventional heating system from the cost of installing a heat pump system and divide by the annual cost savings:

$$\frac{C_{HP} - C_{CS}}{S}$$

where C_{HP} is the installed cost of the heat pump system; C_{CS} is the installed cost of conventional heating system; and S is the annual savings.

Energy Units

1 KWH (kilowatt-hour) equals:

3.6 MJ (mega Joules)

3,412 BTU (British thermal units)

0.03412 therms (1 therm = 100 ft.^{3}—unit of measure of gas)

0.286 ton (refrigeration industry measure of cooling capacity)

For example, let's look again at 10 KW systems for 2,000 square foot (186 m^2) dwellings, both with underfloor heating (so that we are comparing the same standard of heating, in terms of comfort level). Calculations are in Euros (€1 = US$1.16).

Energy Usage

As an approximation, the electrical energy usage of heat pumps is the total heat load of the building divided by the COP of the heat pump. Therefore, a household requiring 20,000 KWH of energy annually to heat, equipped with a heat pump with a COP of 4.0, will consume 5,000 KWH of electricity annually to drive the heat pump.

Of course, the heat generated is highest in the cold season, and a 10 KW (COP = 4) heat pump will consume 2.5 KW of electricity at its peak. During the cold season, this may add up to 35 KWH per day. This means that these systems are not appropriate for off-grid use, except in exceptional circumstances. The peak and even continuous demand for electricity makes it difficult to integrate with renewable energy systems.

The table shows typical heat requirements in three American cities. Dividing these figures by the COP of your proposed system will give you an estimate of energy consumption of the heat pump.

	Billings, MT		Seattle, WA		Colorado Springs, CO	
Month	Degree Days	KWH Heat Required	Degree Days	KWH Heat Required	Degree Days	KWH Heat Required
July	20	86	52	225	11	47
August	25	108	50	216	20	86
September	205	888	139	602	163	706
October	516	2,236	362	1,570	471	2,041
November	909	3,940	571	2,474	827	3,580
December	1,195	5,178	735	3,186	1,083	4,693
January	1,280	5,546	729	3,160	1,114	4,828
February	1,001	4,338	593	2,570	915	3,965
March	876	3,796	564	2,440	816	3,536
April	575	2,491	423	1,833	568	2,461
May	312	1,352	266	1,150	306	1,326
June	90	390	131	567	76	329
Total	7,004	30,353	4,615	20,000	6,369	27,600

The inside-the-home cost of installing a 10 KW heat pump system is €6,600, and the cost of ground loop is €2,900, for a total of €9,500. Subtract from that the inside-the-home cost of installing a oil-fired boiler system, €6,500.Thus the additional capital cost of a heat pump system is €3,000.

Inside-the-home costs for both systems above include heat pump or boiler, underfloor heating, circulating pump, distribution piping, and incidental electrical and mechanical items.

Let's assume that cheap, night-rate electricity (1 eurocent per KWH) is used 70 percent of the time and normal rate electricity (2.75 eurocents per KWH) is used 30 percent of the time. Referring to the adjusted costs in the table below, the average cost per KWH, using a ground source heat pump will be: (1.0 x 0.7) + (2.75 x 0.3) = 1.53 eurocents per KWH. This is less than one-half the adjusted price of the next cheapest source of energy, natural gas at 3.53 eurocents per KWH. This represents an annual running cost of €306 for the heat pump, and a payback of about seven years.

If natural gas is not available, the next cheapest is fuel oil, with an annual cost of €871. In this case, a heat pump will yield an annual savings of €565 in fuel costs. The payback period is 3,000 ÷ 565 = 5 years. The economic viability depends on the price and availability of fuels locally. Subsidies are available in many states and countries to promote heat pumps as a form of renewable energy. The costs quoted in the table reflect the current fuel prices in Ireland. Fuel costs vary widely from country to country. The U.S. average electricity cost is presently at about US$0.08 per KWH, and the average price for residential gas is US$10.02 per 1,000 cubic feet.

If the cost of maintenance and the cost of replacing the equipment over the longer term are taken into account, the payback period becomes shorter. A heat pump system has minimal maintenance, high reliability, and long life.

Heat pumps offer a very attractive alternative to conventional heating systems, especially for sizeable new homes or self-built homes in out-of-town locations where gas lines don't exist. The extra expense is easily justified by the short payback period. Users can look forward to high

Heat Pump Pros & Cons

Advantages

- Cuts heating costs (40–70%)
- Increased comfort and control: 24 hour steady, comfortable heat and humidity at near-ideal temperatures
- With underfloor heating, no drafts or dust from air convectors or radiators (very suitable for asthma sufferers or people with respiratory problems)
- No smells, smoke, or soot from oil or gas
- No ugly oil storage tanks
- No chimney or boiler room required
- Low maintenance: no boiler, furnace, or chimney to clean. Simple, reliable technology
- Environmentally friendly technology: dramatically reduces the demand for fossil fuels and the generation of greenhouse gases from oil, gas, and propane fuels

Disadvantages

- Higher capital/equipment cost for system, but when the savings are taken into account, an efficient system can pay back the difference in three to five years
- May need supplementary heating for coldest periods
- A heat pump to service a large dwelling (> 5,000 square feet; 465 m^2) may require three-phase electricity supply
- Unsuitable for most off-grid uses

Heat Pumps vs. Conventional Systems

Technology	Unit of Supply	Gross Calorific Value (KWH / Unit)	Average Price / Unit (Eurocents)	Delivered Cost (Eurocent / KWH)	Efficiency Averages*	Adjusted Cost** (Eurocent / KWH)	Annual Cost / 20,000 KWH
Fuel oil/gas boiler or furnace	Litre	10.55	39	3.70	85%	4.35	871
Natural gas boiler or furnace	100 C.f.	1.00	88	3.00	85%	3.53	706
Electricity day rate	KWH	29.31	11	11.00	100%	11.00	2,200
Ground source heat pump, standard rate electricity	KWH	1.00	11	11.00	400% COP = 4.0	2.75	550
Ground source heat pump, cheap rate electricity	KWH	1.00	4	4.00	400% COP = 4.0	1.00	200

*In most locations in the U.S., the average COP is between 3 and 3.5, instead of 4.0.
** Cost per unit of energy delivered to the heating distribution system from the heat source (Adjusted cost = Delivered cost ÷ System efficiency).
€1 = US$1.16

Photo and installation by Unipipe (www.unipipe.ie).

A 10 KW, 34,000 BTU Nibe 1110 heat pump, about the size of a washing machine, can heat an average detached home.

comfort levels in a dust-free, fume-free environment, with minimal system maintenance.

Access

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RETScreen International Customer Support, Renewable Energy Decision Support Centre, Natural Resources Canada, CANMET Energy Technology Centre - Varennes 1615, Lionel-Boulet, Varennes, Quebec, Canada J3X 1S6 • 450-652-4621 • Fax: 450-652-5177 • rets@nrcan.gc.ca • www.retscreen.net • Free renewable energy project analysis software

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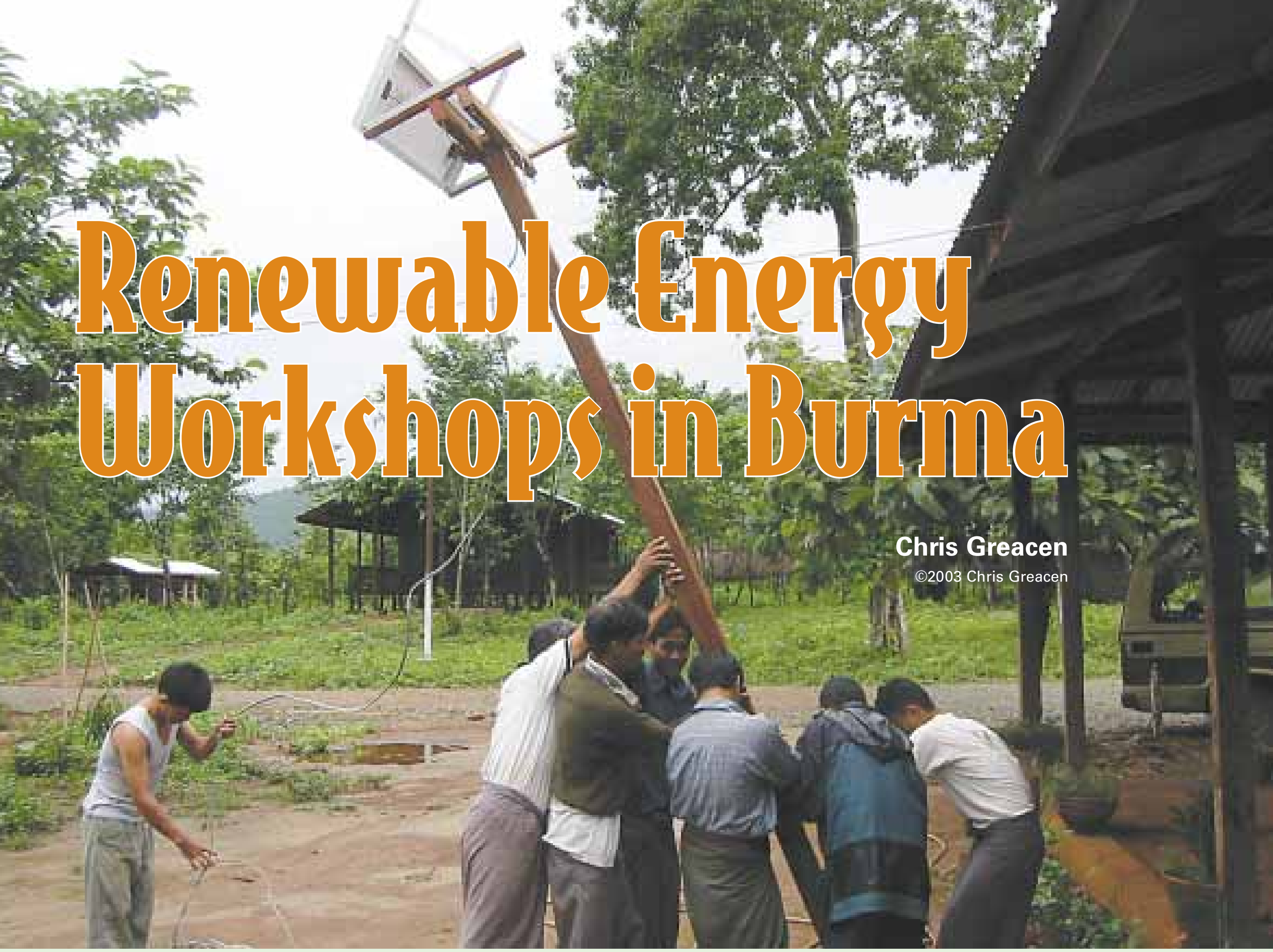
International Ground Source Heat Pump Association, Oklahoma State University, 499 Cordell S., Stillwater, OK 74078 • 800-626-4747 or 405-744-5175 • Fax: 405-744-5283 • www.igshpa.okstate.edu

Renewable Energy Workshops in Burma



Chris Greacen

Burma is primed for renewable energy—all it needs is a little education and financial support.

Due to years of isolation from the international community, rural Burma has been cut off from the renewable energy revolution that has been sweeping the rest of the Third World. A series of renewable energy installation workshops over the last few years has started to change that.

With generous funding of £5,000 from the Ashden Trust, two hands-on renewable energy workshops were conducted in June 2002. One was for thirteen participants in Myitkyina, Kachin State in northern Burma, and another for fifteen participants in Toungoo in central Burma. The workshops emphasized both theory and practice of solar-electric system installation and maintenance.

In the course of the workshops, participants installed three, 55 watt solar-electric systems. Two were in rural NGO training centres—the Metta Training Centre in Alam, 17 miles (27 km) north of Myitkyina, and the Shalom Centre, 15 miles (24 km) north of Myitkyina. The third system was installed at the Thaw Thi Kho Clinic in Toungoo.

Workshop participants ready to install a 55 watt (peak) solar-electric system at the Metta Centre in Alam, Myitkyina.

System Design Principles

In designing the systems and specifying equipment for the installations, I emphasized locally available equipment, high quality, and expandability.

Local equipment procurement makes the systems easier to repair and replace. It also reduces expenses and uncertainties associated with customs and immigration. I used solar modules and charge controllers purchased from a dealer in Yangon, Burma's capital, instead of bringing them in from my home base in Thailand. All other materials (wire, 12 volt lighting ballasts and bulbs, inverter, and connectors) were available in regional towns, as well as Yangon. I purchased many of these materials in Yangon because prices were lower and availability more certain. Heavy or fragile items, such as batteries and fluorescent light tubes, were purchased in regional towns.

Author Chris Greacen (center) and PV vendors in Yangon test PV panel output.

I used high quality solar modules and controllers, and searched out materials (wire, solder, crimp connectors) to make high quality connections. Besides improving the reliability and expected life of the system, emphasizing quality has an educational objective. After completing the installation, workshop participants know what a quality installation should look like, and how to do one. Poorly installed solar-electric systems are alarmingly common in developing countries (maybe not yet in Burma, but possibly in the future). These generally function, albeit poorly, for a while, but they waste precious electricity made by the expensive solar panels. When the systems stop functioning properly, they give renewable energy a bad name.

Related to system quality is the issue of battery depth of discharge. In many solar-electric systems, the batteries suffer early death because users chronically overdischarge them. To avoid this common problem, I used charge controllers with a low voltage disconnect (LVD) function that disconnects 12 volt loads before battery voltage falls to dangerously low levels. Using the LVD function required the use of 12 volt lights.

Finally, I wanted the systems to be expandable. Racks were made large enough to accept a second module. Charge controllers were sized to accept additional lights and solar-electric modules for future expansion.

Low tech supports high tech—building a PV mounting rack with hand tools.

Component Specification & Transport

I chose Siemens SM55 modules for the systems. These have 36 single-crystal cells in series. Unfortunately, the solar-electric company in Yangon offered a considerably better price for Siemens SM50-H modules, which have only 33 single-crystal cells. Most of Burma is quite warm during much of the year, and I have seen 33 cell modules in tropical developing countries fail miserably at charging 12 volt batteries because of the modules' temperature-induced voltage drop. Do these 33-cell modules really work when it is sunny and the ambient air temperature is 30°C (86°F)? I suspect not, but would love to hear some reports from the field.

The design for each system was more or less the same: one 55 watt PV module, a charge controller (Siemens S12 or Steca Solsum 6.6), several 12 volt lights, a Burma-made "300 watt" inverter, and a 12 volt, 120 amp-hour "deep-cycle" battery.

Rev. Saboi Jum from the Shalom Centre helped me transport the solar-electric equipment by airplane (train would have taken several weeks) to Myitkyina. He happened to be on the same flight and was traveling with no checked baggage. Using his baggage allowance (and political clout) avoided significant overweight baggage charges. The flight to Myitkyina took all day, since the airplane was grounded for four hours in Mandalay due to inclement weather.

Myitkyina Workshop

The Kachin Baptist Convention (KBC) Development Department Office hosted the training at their main office in Myitkyina. Because foreigners are only allowed to stay in certain registered hotels located in urban or semi-urban areas, having the workshop in Myitkyina was logistically convenient. More important, KBC has considerable experience in hosting workshops of this nature. The KBC provided facilities for the workshop, workshop materials, lodging and meals for workshop participants, local transportation, and the services of Nang Doi, an excellent English-Kachin translator. The KBC contacted participants for this year's workshop, including community leaders, farmers, and technicians.

Six of the twelve workshop participants had attended the workshop that I taught in February 2001. Five of the six had worked on renewable energy projects of one kind or another since that workshop. I was very impressed by these activities, especially given the fact that they had very little to work with. Several had also built and used solar ovens in their communities.

La Wuam had built a hydraulic ram pump (but had problems with the flapper valve, just as we had in the workshop). Tu Ja had tried to build a windmill using a bicycle dynamo (and remains very interested in this project). Zau Sam had built many bamboo waterwheels for his educational work with children.

Htoi San had begun work on a second village microhydro, but stopped for lack of funds. He also had installed the solar-electric system at the Kachin Theological College. For his microhydro project, he was doing surprisingly advanced work. He was using an induction motor as a generator (he had seen this done in China at the border near his village), and had experimentally determined appropriate amounts of capacitance to provide excitation current. He was very interested to see a book on this subject that I had brought, by coincidence.

Most workshop days were a mixture of theory (taught in the classroom) and practice (in the field). Considerable attention was paid to developing a theoretical understanding of basic electricity concepts—current, voltage, resistance, power, and Ohm's law.

Mounting the PV array at the Metta Centre in Alam, Myitkyina.

The control board built by workshop participants at the Thaw Thi Kho clinic in Toungoo (see schematic).

We then built on these concepts to develop an appreciation for the need for low resistance wiring and electrical connections for low voltage electricity applications. We also covered basic system design principles, and learned what features of solar-electric system components are most important for long-term system sustainability. Finally, we covered maintenance and operations procedures.

Metta Centre Installation

In the field, each solar-electric installation took about one and a half days to complete. We started with the installation at the Metta Centre. The Metta Development Foundation is one of the few local NGOs that exist in Burma. It works to assist Burmese communities to recover from the impact of decades of civil conflict. Two of the renewable energy workshop participants were from Metta.

The centre trains farmer-teachers in multi-month training courses on integrated farming methods. The farmer-teachers return to their villages to set up field schools. The Metta Centre itself is a working example of the successful application of these natural farming methods. Starting with land that had been abandoned as unproductive and barren, Metta has adapted natural farming methods to produce impressive crop yields.

The Metta Centre is many miles away from grid electricity. The solar-electric installation will be used to power lights for evening meetings and to power two computers used to write reports. A microhydro system using a 1 KW, AC Chinese turbine was installed last year. Stream flow is insufficient to provide adequate electricity year-round, so the system only functions during the wet season.

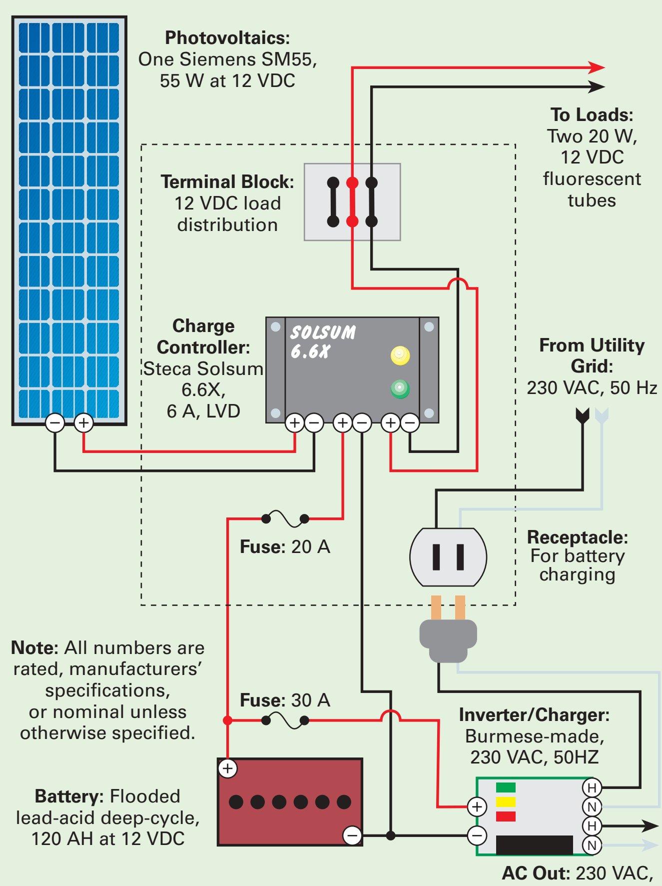
The center also has a diesel generator that is used only occasionally because of the high cost of diesel fuel. For lighting, lamps and candles are used most of the time. The solar-electric system at Metta included a battery charger to take advantage of electricity from both the diesel and microhydro when they are operating. The microhydro and diesel are not run at the same time; a transfer switch is used to run one or the other.

For the solar-electric installations, participants broke into three teams. One team was assigned the task of mounting the solar module. The second team was in charge of wiring for the 12 volt lights. The third team wired the battery, fused disconnect, and charge controller. The system will be maintained by two Metta Centre workers who attended the five-day installation workshop.

Shalom Centre Installation

Our second installation was at the Shalom Centre, about 9 miles (15 km) north of Myitkyina. The Shalom Center provides a forum for a variety of peace and reconciliation

Thaw Thi Kho Clinic System



Soldering with DC straight off the battery.

activities following the cease-fire between the Kachin Independence Organization (KIO) and the Burmese military. It is also involved in efforts to find sustainable development opportunities for the Kachin people to replace the current reliance on resource extraction—teak logging, gold mining, and jade mining.

We installed a solar-electric system at the night watchman's house at the Shalom Centre. Though the center has a diesel generator, it is seldom used because of the high cost of fuel and generator maintenance. The solar-electric system will provide reliable and affordable lighting for evening meetings at the Shalom Centre.

The center is located far from grid electricity. Using a transfer switch connected to the centre's generator, electricity from the solar-electric system will power lights in a key meeting room at times when a few lights are needed, but turning on the generator would be overkill. The system also powers a 12 volt fluorescent light for the watchman's house. One of the renewable energy course participants is responsible for maintenance at the Shalom Centre, and will look after the operation of the system.

With the successful completion of both installations behind us, we held a review and question and answer session. It covered participants' interest in less expensive renewable energy technologies—hydraulic ram pumps, hydroelectricity, biogas, and simple wind turbines. In the closing ceremony, I donated the tools that we had used in the installation, as well as several books and *Home Power* compact discs on renewable energy to KBC.

Thaw Thi Kho Clinic Workshop

Following the closing ceremony at Myitkyina, I returned to Yangon and traveled by bus with translator Pienne Pien to the town of Toungoo. Even though only 60 miles (100 km) north of Yangon, the bus ride takes 8 to 10 hours because of poor roads. I taught the three-day, solar-electric installation workshop to sixteen participants. As in Myitkyina, each day was a mixture of theory and practice.

The Toungoo workshop participants were diverse. About half worked with the Thaw Thi Kho clinic in one way or another, and will need to understand the limitations of the system. These included nurses who will be operating the lighting system at night, a hospital

System Costs

Item	Each (Kyat)	Shalom Centre Qty.	Shalom Centre (Kyat)	Shalom Centre (US$)	Metta Centre Qty.	Metta Centre (Kyat)	Metta Centre (US$)	Thaw Thi Kho Clinic Qty.	Thaw Thi Kho Clinic (Kyat)	Thaw Thi Kho Clinic (US$)
Siemens SM55 PV module, 55 W	330,000	1	330,000	$386.42	1	330,000	$386.42	1	330,000	$386.42
Siemens SR12 charge controller, 12 A	83,000	1	83,000	97.19	1	83,000	97.19	0	0	0.00
Steca Solsum 6.6 charge controller, 6 A	56,000	0	0	0.00	0	0	0.00	1	56,000	65.57
Battery, 12 V, 120 AH	35,000	0	0	0.00	0	0	0.00	1	35,000	40.98
Battery, 12 V, 120 AH	34,000	1	34,000	39.81	1	34,000	39.81	0	0	0.00
Wire, connectors, transfer switch, etc.	15,500	1	15,500	18.15	1	15,500	18.15	1	15,500	18.15
Inverter, Burma-made, 300 W	11,500	1	11,500	13.47	1	11,500	13.47	1	11,500	13.47
Aluminum angle iron (rack materials)	11,000	1	11,000	12.88	1	11,000	12.88	1	11,000	12.88
Light fixture (20 W) & ballast (12 VDC)	1,800	2	3,600	4.22	2	3,600	4.22	1	1,800	2.11
Fluorescent tube, 20 W	1,500	2	3,000	3.51	2	3,000	3.51	2	3,000	3.51
	Totals		491,600	$575.64		491,600	$575.64		463,800	$543.09

technician who was responsible for the generator and electrical wiring, and hospital administrators and managers. The participants also included several pastors and deacons from churches in Toungoo and surrounding villages who were interested in applications of renewable energy for their rural parishes.

One participant, Hektor, was an accomplished marine electrical engineer who worked on merchant ships in Singapore. He was on leave and is looking forward to retirement in his hometown of Toungoo. Hektor's presence made it much more possible to squeeze a week's worth of curriculum into three days. Because of his language and technical abilities, he was able to communicate difficult concepts to other participants who were not well versed in English or electricity.

Thaw Thi Kho Clinic

The Thaw Thi Kho Clinic was started in the year 2000 and provides critical health services every year to more than 7,000 people who are unable to afford private health care or the government hospitals. The clinic is open 24 hours a day, 7 days a week, and accepts all patients, regardless of religion, ethnicity, or ability to pay. Most patients are Karen hill tribe villagers. Many patients come to the clinic at night because they have journeyed a long distance from their villages, or come after work in the fields.

Government electricity is available only eight hours a day, and may come in the morning, afternoon, or night. The solar-electric system we installed provides electricity for three multipurpose lights that illuminate two checkup rooms, the waiting room and reception area, the pharmacy, and an area used for giving injections. Nurses and doctors who worked the night shift at the hospital were especially excited because now they will no longer have to rely on candles. The grid provides electricity for sporadic battery charging.

Integrated Education

I ran the Toungoo workshop with morning theory sessions and afternoon installation practice sessions. This allowed me to have enough time for the installation, and to try to integrate theory and practice. As the first morning theory session began, one of the participants raised the question, "How many lights will the solar panel power?"

It's a good question, but one that is hard to answer. It depends, of course, on how big the lights are, how long and how frequently they are used, and how much sun there is. We used the question as a departure point to explore concepts of voltage, current, resistance, energy, Ohm's law, and system design practices, but with less depth than in Myitkyina.

For the installation, I had participants break into three teams according to their skills and interests. I played free agent, roving from team to team, observing and answering questions. One team's task was to install the solar array on the third-story roof and run the wire to the ground floor. Another team assembled and wired the controller, fuse, and terminal strips. The third team wired the 12 volt fluorescent light fixtures and switches.

Above: Installing the panel on the Thaw Thi Kho Clinic roof.

Below: The installation crew and clinic employees.

On the third day, we began with the hands-on activities in the morning session just in case we had any unexpected surprises that might slow down completion. We finished by lunch, and spent the remaining time discussing topics of interest to the participants: battery chemistry, care, and maintenance; microhydro-electricity; hydraulic ram pumps; and biogas digesters.

Chris and the Shalom Centre workshop installation team.

Lessons & Next Steps

In the course of conducting these workshops, I was particularly struck by two things. First, in rural Burma, solar electricity for medical clinics that serve marginalized (and often brutalized) minorities is an especially important application. A little electricity goes a long, long way in improving the working conditions of doctors and nurses, and provides convenience and comfort to scores of people when they are sick and vulnerable. For this reason, 2003 activities are focusing on training medics and providing PV systems for remote medical clinics—especially those hit hard by Burma's ongoing civil war.

Second, for all of PV's benefits (simplicity, reliability, and flexibility in providing essential electricity services), the reliance on high-tech imported equipment means it is very expensive for the average villager. Micro-credit programs are needed. But there is also a lot of merit in working to introduce simpler, low-tech renewable energy technologies based on local affordable materials. In 2003, our activities will include a 15-day, hands-on biogas digester workshop at the Metta Centre in Alam taught by Nepali biogas expert Govinda Devkota.

Grassroots Leadership Training Programme

Coordination and planning help for the Burma Sustainable Energy Project workshops was provided by Grassroots Leadership Training (GLT), a programme run by the Spirit in Education Movement (SEM). The GLT programme involves empowerment training and ongoing educational support for grassroots leaders of marginalized communities, such as the ethnic minorities and the rural poor in Siam and Southeast Asia. Every year since 1996, the GLT has worked with Metta, the Shalom Foundation, and KBC to provide three-month training courses for ethnic people in Burma.

The trainings reach across ethnic, religious, and demographic boundaries. They bring together participants from Karen, Kachin, Shan, Karenni, and Burman ethnic groups; Buddhists and Christians; and rural villagers and city dwellers. Participants engage in an in-depth critical look at the modernization process and consider development models that foster people's participation, environmental justice, and sustainability. Despite difficult circumstances in Burma, when they return to their country, the vast majority of participants develop projects that recognize and address the root causes of some of the issues they are facing.

Palang Thai & the Burma Sustainable Energy Project

The Burma Sustainable Energy Project is a project of Palang Thai, a Thailand-based, not-for-profit group dedicated to promoting clean and democratic energy in Southeast Asia. Our other projects include the Thai Net Metering Project, work on building remote grassroots micro-hydro projects, and public-interest analytical work on electricity sector restructuring in Thailand.

Filling the Gap

The renewable energy workshops in Burma fill a crucial gap by providing practical, experience-based knowledge about rural sustainable energy technologies and practices that have proven useful in other areas of the developing world. Ethnic minorities in rural Burma have been cut off from the rest of the world for several decades. They are hungry for information, particularly information that is useful in helping them meet basic needs and foster models of development that will not impair the environment.

Access

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The Kachin Baptist Convention (KBC) Development Department Office, Myitkyina, Myanmar (Burma) • +95-74-23439 • Myitkyina workshop host

Metta Development Foundation, PO Box 516, GPO Yangon, 510B, Lower Kyeemyindaing Rd., Kyeemyindaing Township, Yangon, Myanmar (Burma) • Phone/Fax: 95-1 22 87 80 • metta@mptmail.net.mm • www.metta-myanmar.org • Rural development; recipient of solar-electric system

The Shalom Centre, Myitkina, Myanmar (Burma) • Peace work; recipient of solar-electric system

Thaw Thi Kho Clinic, Toungoo, Myanmar (Burma) • Toungoo workshop host; recipient of solar-electric system

Grassroots Leadership Training (GLT), Spirit in Education Movement (SEM) • www.sulak-sivaraksa.org/project15.php • Burmese contacts; Toungoo translator

The Ashden Awards for Sustainable Energy, The Ashden Trust, Allington House, 150 Victoria Street, London SW1E 5AE, UK • +44 20 7410 0330 • Fax: +44 20 7410 0332 • info@ashdenawards.org • www.ashdenawards.org • Funding for 2002 training

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


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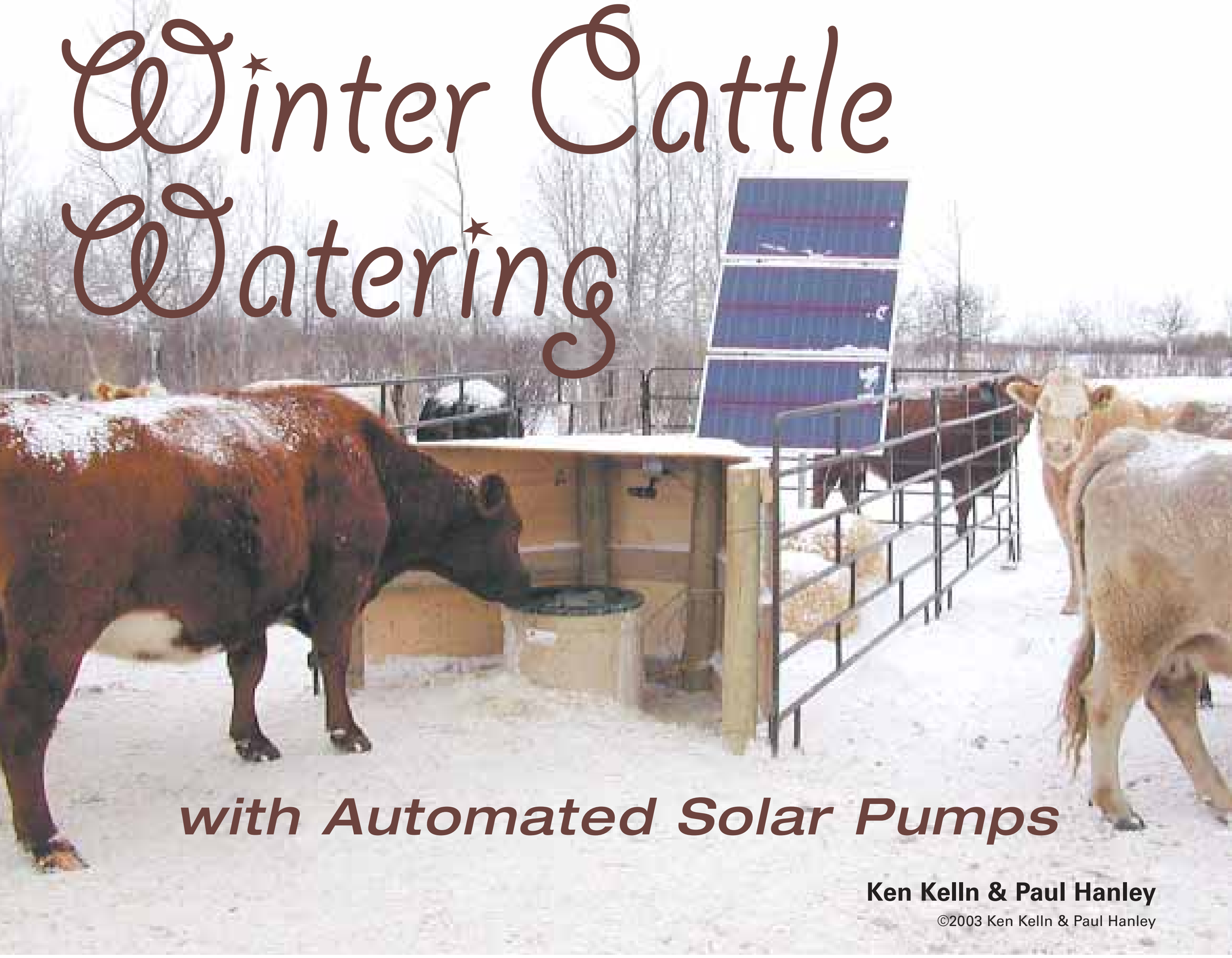
Winter Cattle Watering



with Automated Solar Pumps

Ken Kelln & Paul Hanley

Bessie and friends prefer the new solar powered watering hole at Termuende farm because it doesn't ice up in winter.

Good quality water—and lots of it—is a key to good health. This is true for animals as well as people, but often livestock have to depend on poor quality water, especially during the winter months. Solar energy is now being harnessed to provide better quality water for cattle, resulting in general health improvement and increased weight gain, and less damage to water sources.

Solar powered pumps have proven reliable, and are particularly cost effective for remote applications, such as pastures distant from the utility grid. Research shows that herd health is enhanced when water is pumped from wells, sloughs, ponds, lakes, and streams, instead of allowing animals to wade into water bodies to drink.

Winter watering in cold climates, such as the Canadian prairies and U.S. Great Plains, has presented a particular challenge to cattle ranchers, however, since it can be difficult to prevent freeze-ups of pumps and watering bowls. Several years ago, Kelln Solar of Lumsden, Saskatchewan developed a winter watering system that eliminates most of the freeze problems usually associated with winter watering of livestock. This system, which can be operated on solar electricity, is now working at 150 cattle ranches with excellent results.

How the Solar Pumping System Works

This watering system requires both a water source (either surface water, such as a dugout, slough, pond, or a seepage well) and also a "wet" well that is essentially a storage tank that receives water from the water body or seepage well. Water from the live or "wet" well is the direct source from which water is pumped into the watering bowl for animal watering.

The system uses a motion detector to activate a pump when an animal approaches. As long as there are animals present, the pump stays on. When the animals leave, it times out after 45 seconds and the bowl drains. To prevent constant starting and stopping, a delay is built in to allow the pump to continue running for a preset time. This delay allows the next animal to drink before the pump shuts off.

Water is pumped from a well casing into the bottom of a 24 or 36 inch (61 or 91 cm) diameter, double-walled water bowl. The water rises until it reaches a set of overflow holes that return excess water to the casing, so that water does not overflow onto the ground. All water in the bowl returns to the casing, draining through the submersible centrifugal pump (which is then off), preventing freezing.

Demonstration System

Kelln Solar installed a demonstration system at the Western Beef Development Centre's Termuende Research Farm near Lanigan, Saskatchewan in November 2000. The system, which was designed to water 130 animals, has functioned flawlessly since its installation.

For this system, a 200 foot trench was dug between a dugout (a pond dug for animal watering) and the location where the animals would be watered. A 2 inch poly pipe was installed in the trench below the frost line. To keep the pipe from getting clogged with dirt, one end was capped before we pushed it the last 6 to 10 feet (2–3 m) through the wet earth and into the dugout.

After we removed the cap, a screen was installed. A float was attached to keep the pipe out of the mud, but below the water surface or ice. The depth of the float, which is tied to a concrete anchor, is controlled by a rope. The other end of the pipe was attached to a 16 foot by 24 inch (5 m x 61 cm) fiberglass casing that is set vertically in the ground. The pipe connects to the casing 12 inches (30 cm) from the bottom, well below the frost line. Since the temperature below the frost line is approximately 40 degrees, the culvert acts as a heat vent allowing the hot air to rise, which also helps to prevent freezing. The bottom of the fiberglass casing was sealed with silicone.

Next we installed corral panels and a plywood wind shroud. The 2 inch steel post for the solar-electric array was set in concrete. We mounted the three, Uni-Solar, 64 watt, solar-electric modules nearly vertical to reduce snow cover on them, and to optimize for winter performance.

Four, Trojan T-105, flooded, lead-acid batteries are connected series/parallel for a 12 V system. They sit in an insulated battery box close to the array. We connected the control card to the batteries. Fused #14 (2 mm^2) wires from the PVs plug directly into the system's control card.

All Kelln systems come with a temperature-compensated regulator, low voltage disconnect, and a relay-operated motion eye, which can be substituted for a standard "pump-up" float switch. Instead of the custom motion eye used in the Kelln systems, some standard AC motion sensors with 12 volt relays can be modified to handle 12 volts. Heavy duty relays must be installed to withstand the on-off cycles of the system.

A molded, corrosion-resistant water bowl fits on the casing or live well. The Kelln, low-lift, C1 centrifugal pump is attached to the cattle watering bowl with 14 feet (4.3 m) of 1 inch poly pipe, and the pump and bowl are inserted in the 24 inch (61 cm) casing. The pump wires come out of the top of the casing and are protected from the cattle by being buried or installed in conduit.

A motion sensor was installed so that it points down, and only turns on when the cattle are 8 to 10 feet (2.4–3 m) from the bowl. The motion sensor wires and pump wires plug into the control card located in the battery box. No adjustments are required, since the motion eye is factory set to time out after 45 seconds.

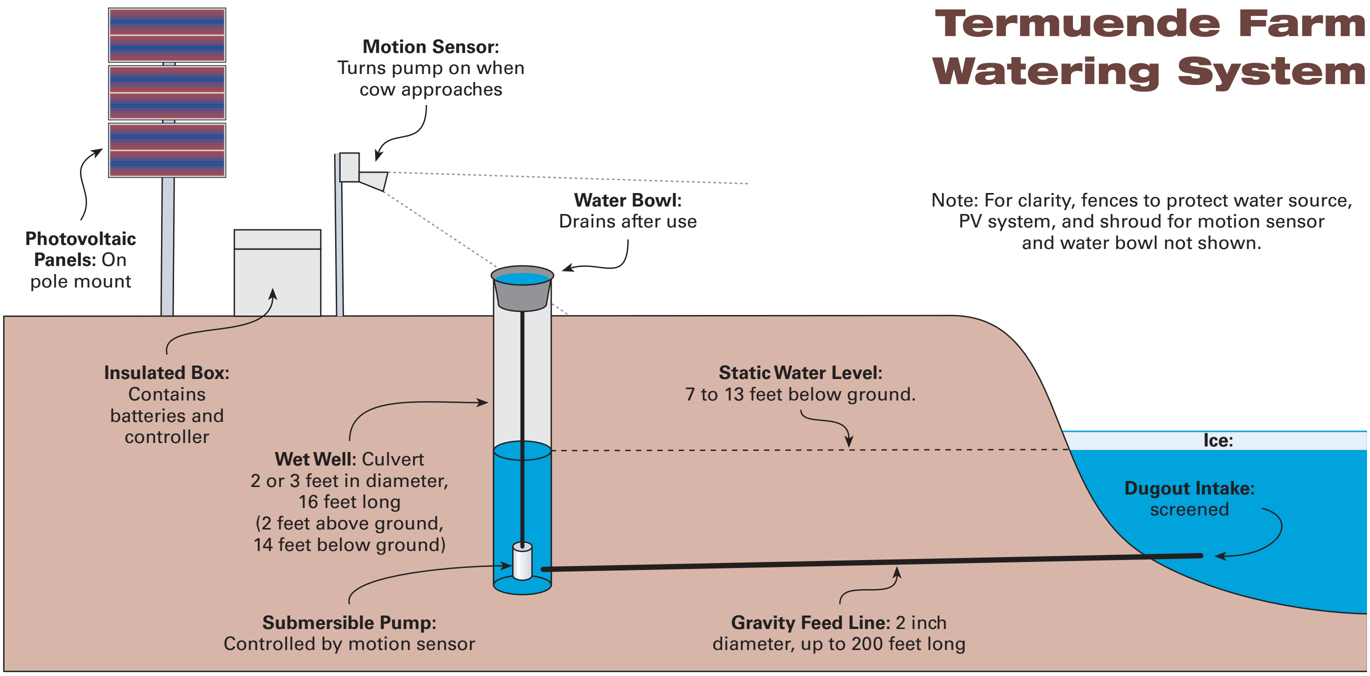
Pros & Cons

Advantages

- No freezing: all water drains back to the casing, eliminating the possibility of freezing.
- Few repairs: burnout or repairs are little concern because this system is designed without heating elements or adjustable controls.
- Little servicing: this is a very basic system with few moving parts. The water bowl is easily removed, allowing access to the pump.
- Natural heating: because the temperature below the frost line is 40°F (4°C), the culvert acts as a heat tube, allowing warm air to rise, reducing ice build-up in the casing.
- Utility connection not necessary: self-powered via PV.
- Minimal operating costs: once installed, there are few operating costs and no electricity bills.

Disadvantages

- The solar-electric winter watering system is more expensive than AC operated water bowls (where there is ready access to AC electricity).
- System installation is more time consuming than a standard trough system.
- These systems are best installed before freeze-up in the fall; during the cold part of the winter (-30°F; -34°C), the system would be difficult to install.



The system is surrounded by a plywood enclosure, limiting animal access to one direction. As a result, the motion detector is engaged only when animals actually pass in front of the water source. Another important function of the enclosure is to protect from the prevailing northwest wind, which tends to ice up some water bowls. Many of these systems have been installed without wind protection and with steel casings, however, and none have frozen up despite weeks of -40°F (-40°C) weather.

Initially, we had to feed the cattle close to the bowl so they would find the water. But they seem to know about water and adapted quickly to the watering system. The Prairie Farm Rehabilitation Administration's (PFRA) Water Quality Unit and the Western Beef Development Centre (WBDC) collaborated to build this demonstration site for innovative winter or season-long watering options for livestock producers. The Saskatchewan government's Agri-Food Innovation Fund (AFIF) provided funding for this study.

Water quality studies at Termuende Research Farm are ongoing. There is not enough data yet to completely confirm the benefits of pumping water for livestock. But evidence in one year of the study shows weight gains as high as 27 percent from using pumped water compared to allowing cattle to drink directly from surface water.

A plywood shroud protects the motion sensor from cows and the water bowl from prevailing winds.

System Adaptability

These watering systems can be adapted to suit any size herd. Larger systems have worked equally well with 400 to 500 animals on two bowls. Pumps can be operated from conventional electricity sources where available. For solar-electric applications, such as in remote areas, a typical system is simple and straightforward, consisting of three 64 watt solar-electric panels, a regulator, and two or more 6 volt golf cart batteries.

In addition to using a pond or dugout, this system can be applied to other water sources, such as seepage wells. When a seepage well is used, it typically involves an additional well with a 5 inch casing. A second pump delivers water to the sealed, 24 inch "wet" well, which becomes a holding tank. Water lines must run below the frost line.

Water levels can be controlled by a float switch located in the casing. Or if adequate water is available, a gravity feed can be run from the well to the casing below the frost line to prevent freezing. The water flow can be controlled with a float valve.

Of course, this winter watering system works equally well in all seasons; in warmer months, the system is effective in conserving water and electricity.

Recommended Practices

Our experience, and research conducted by Agriculture and Agri-Food Canada and other research agencies has resulted in several recommended practices associated with this system.

- The solar-electric system should be properly sized for the number of animals you intend to water, so you do not run out of electricity. Generally speaking, one 64 watt panel and two 6 volt batteries are required for a herd of fifty animals.
- To conserve energy, the water bowl should be set up in a wide open area without shelter, so animals will drink and leave the site.

Technical Specifications

Photovoltaics

Panel manufacturer and model: Uni-Solar US64
Module STC wattage rating: 64 W
Nominal array voltage: 12 V

Batteries

Battery manufacturer and model: Trojan T-105
Battery type: flooded lead-acid
Individual battery specs: 6 VDC nominal, 225 AH
Total number of batteries: 4
Battery pack specs: 12 VDC nominal, 450 AH

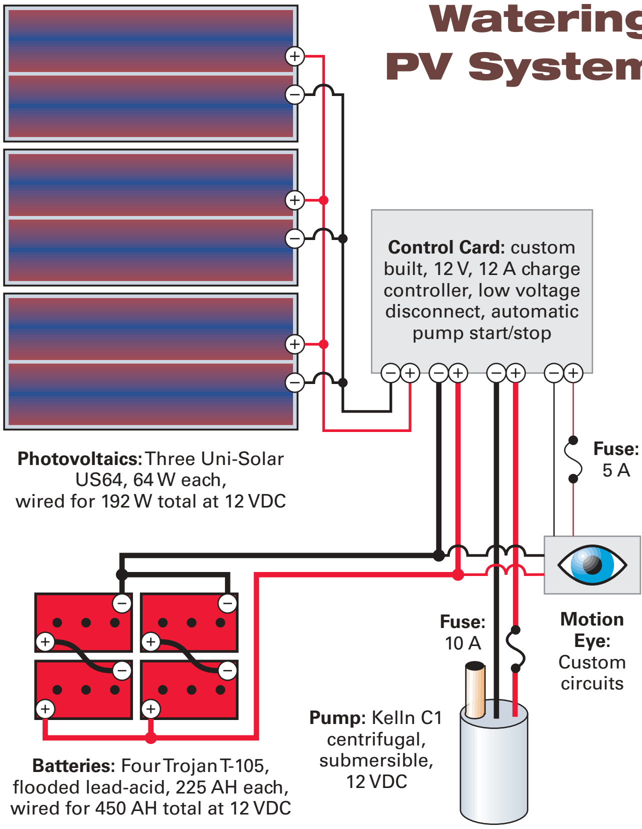
Motion Sensor & Controller

Manufacturer and model: Specialty Concepts, 12 V, 12 A, custom circuit motion eye

Pump

Manufacturer and model: Kelln C1 low-lift centrifugal, 7 (Imperial) gpm

Watering PV System



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

- Animals should be fed as far from the watering bowl as possible, so that extra debris is not deposited in the water bowl and casing. The live well should be flushed every year.
- Water should not be drained back into any well source, to eliminate the possibility of ground water contamination.
- An elevated mound should be created around the live well to assist with surface drainage and to help prevent the penetration of frost. During thaws, an elevated watering location ensures a drier, cleaner, and safer watering site.

Herd Health Improvements

Research indicates that these automated watering systems improve animal health and growth, resulting in higher profits. Direct access winter watering usually means poor quality water. Manure buildup is common in and around water sources, and this problem is more evident in winter. As the ice melts in the spring, animal excrement introduces disease-causing organisms such as bacteria, viruses, and parasites into the water.

Excrement also introduces nutrients, which can cause excess algae and plant growth during the summer months. Some cyanobacteria, often mistakenly referred to as "blue-green algae," produce toxins that can be fatal to livestock when ingested in large quantities.

An additional problem is trampling and browsing by the animals, resulting in the destruction of vegetation along the

Watering System Costs

Item	Cost (CN$)
3 US-64 solar-electric panels	$2,085
4 Trojan T-105 batteries, 6 V	520
Fiberglass casing, 24 inch x 16 feet	400
Water bowl, 24 inch	269
Charge controller, 12 V, 12 A, with low voltage disconnect & pump controller	249
Pump & filters	218
Motion sensor	159
Solar-electric panel mount	100
Insulated battery box	100
Wire	40
Poly pipe, 15 feet at 1 inch, & fittings	40
Total Cost	$4,180

transition zones near water. Animal traffic can also cause serious damage to the side slopes of dugouts and stream banks, destroying riparian areas and resulting in increased sediment in the water.

Providing cattle with higher quality water through the use of remote watering systems will cause them to drink more, eat more, and ultimately gain weight more quickly. Improved water quality leads to decreased occurrence of disease and other health problems in animals.

Solar powered winter watering systems provide an economical way to deliver the best water possible to animals, leading to improved animal health and profitability.

Access

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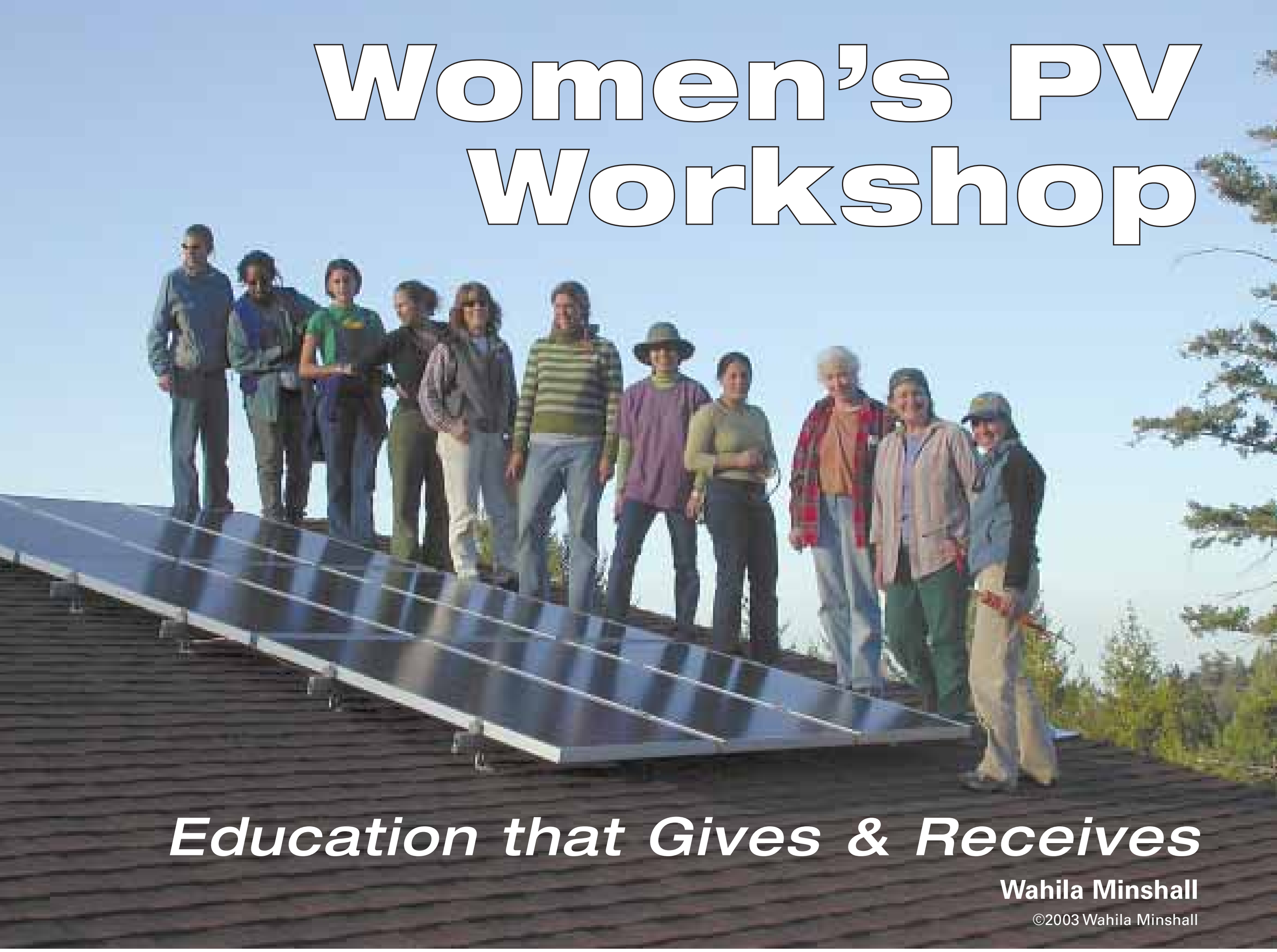
Termuende Research Farm, Western Beef Development Centre (WBDC), 203-105 North Rd., University of Saskatchewan, Saskatoon, SK, Canada S7N 4L5 • 306-657-5801 • Fax: 306-966-2614 • blardner@agr.gov.sk.ca • www.wbdc.sk.ca

Prairie Farm Rehabilitation Administration (PFRA), 408-1800 Hamilton St., Regina, SK, Canada S4P 4L2 • 306-780-7012 • Fax: 306-780-5018 • pfraweb@em.agr.ca • www.agr.gc.ca/pfra • Sustainable management of prairie farm and rangeland

Effect of Water Quality on Cattle Weight Gain 1999 to 2001, by the Western Beef Development Centre and the Prairie Farm Rehabilitation Administration. Available online free of charge at www.wbdc.sk.ca.

Alternatives To Direct Access Livestock Watering, by the Prairie Farm Rehabilitation Administration (see above). Available free online at www.agr.gc.ca/pfra/water/directac_e.htm

Women's PV Workshop



Education that Gives & Receives

Wahila Minshall

Instructor Justine Sanchez, bottom right, and the array installation crew line up behind the finished array as the sun sets.

On a clear, sunny day in March 2003, a group of women were outside a California environmental science school talking shop—and that isn't short for shopping. Discussing everything from conduit bending to system voltage, these 25 women were at Walden West Center in Saratoga, California, installing a 1.5 KW solar-electric system.

Walden West is an outdoor environmental science school in the Saratoga hills that hosts week-long science programs for 5,000 to 7,000 students each year. The women, who came from all across the U.S., had just finished four days of classroom sessions in Santa Cruz, California, as part of a women-only PV Design and Installation workshop offered by Solar Energy International (SEI).

Most SEI courses culminate in an actual installation, providing students with the hands-on training needed to truly understand PV system operation and installation. The PV system at Walden West began its life by educating future renewable energy workers and advocates. And since it is installed as part of an environmental education program, it will go on to teach tens of thousands of children about the benefits and practicality of solar electricity.

Collaborative Effort

The installation was accomplished through a collaborative effort between Walden West Center, Solar Energy International, Rahus Institute, and Akeena Solar. Walden West received a Flex Your Power grant from the state of California for the project, but that money didn't cover the full US$14,000 cost of the system and installation. Tor Allen, Director of Solar Schoolhouse, a program of the Rahus Institute, brought the funding situation to my attention.

Akeena Solar, which has two SEI graduates on staff, had already agreed to guarantee a local installation for the hands-on portion of the March 2003 SEI workshop. Akeena Solar's president, Barry Cinnamon, then offered to donate the remaining equipment for the project. Everyone involved was thrilled with this solution.

"As a parent, I want to do everything I can to help break our country's dependence on fossil fuel energy sources, both foreign and domestic. My kids go to Walden West in the summer, and they have a terrific outdoor education program," said Cinnamon. "By helping fund

Installing the conduit run from the PVs to the inverter.

Instructor Carol Weis (in red baseball cap) oversees the construction of the complicated junction box, affectionately dubbed the "artificial heart."

Educating Women PV Installers

Colorado-based Solar Energy International (SEI) is one of the nation's foremost educators for renewable energy installers and green builders. They offer classroom and laboratory work, complemented by case studies, field tours, and professional installations with real equipment in real settings.

Six years ago, SEI began to offer some courses for women only, to encourage more women to enter this traditionally male-dominated field by providing a less intimidating atmosphere for learning. These courses have been extremely successful, greatly increasing the number of women attending SEI workshops and drawing in women of all ages from all walks of life. Some come because they are thinking of installing their own systems, some because they are looking to make a career in the field, and others to further their knowledge of the field in which they are already employed.

SEI's women-only workshops allow women to talk about this very technical subject in language that they are comfortable with. As a result, a lot more questions are asked, and an inspiring amount of networking goes on.

I was a workshop participant in the first SEI women-only course to be offered in Santa Cruz. I was pursuing a career in the solar-electric field and felt that the hands-on aspect of the SEI course and SEI's good reputation for training renewable energy workers would make me ultimately more employable. This proved to be true when I interviewed with Akeena Solar. The fact that I could work as an auxiliary installer when needed tipped the scales in my favor, and I was hired as their marketing manager.

the installation, we will be able to communicate the clean energy benefits of solar electricity to thousands of students, and promote the transition from fossil fuels to clean renewable energy. Akeena Solar's philosophy is simple: we believe that producing clean electricity directly from the sun is the right thing to do for our environment and economy."

The Walden West system was an ideal installation for the SEI students for a variety of reasons. The site offered plenty of space for this large group of women to work. The installation offered some unique challenges, but was small enough to be completed in the two days allotted. To top it off, Walden West offered to feed and house the SEI students during the workshop, helping to defray their expenses.

System

The system consists of an SMA 2500U-SBD, 208 volt Sunny Boy inverter with display, and nine Sharp NE-Q5E2U 165 watt modules. When more funds become available, this system can expand to sixteen modules.

Technical Specifications

System Overview

Type: Batteryless grid-intertied

Location: Saratoga, California

Production: 190 AC KWH per month average

Utility KWH cost: US$0.23 per KWH

Percentage offset by PV system: 3.3 percent

Photovoltaics

Manufacturer and model: Sharp NE-Q5E2U

Number of modules: 9

Module STC wattage: 165 W

Module nominal voltage: 24 V

Array STC wattage: 1,485 W

Array nominal voltage: 216 VDC

Array disconnect: 30 amp Square D general duty safety switch

Array installation: Roof-mounted using UniRac SMR-Solar Mount Rails; orientation, 164 degrees magnetic = 180 true south or dead on true south; 18 degree tilt angle

Inverter

Manufacturer and model: SMA Sunny Boy 2500

Maximum DC input voltage: 600 V

MPPT voltage window: 180 VDC min, 550 VDC max

Nominal AC output voltage: 208 V (three-phase service)

System Performance Metering

Equipment: Sunny Boy display & additional AC KWH meter

Kate Latham and Cecily Cahill mount a rooftop junction box.

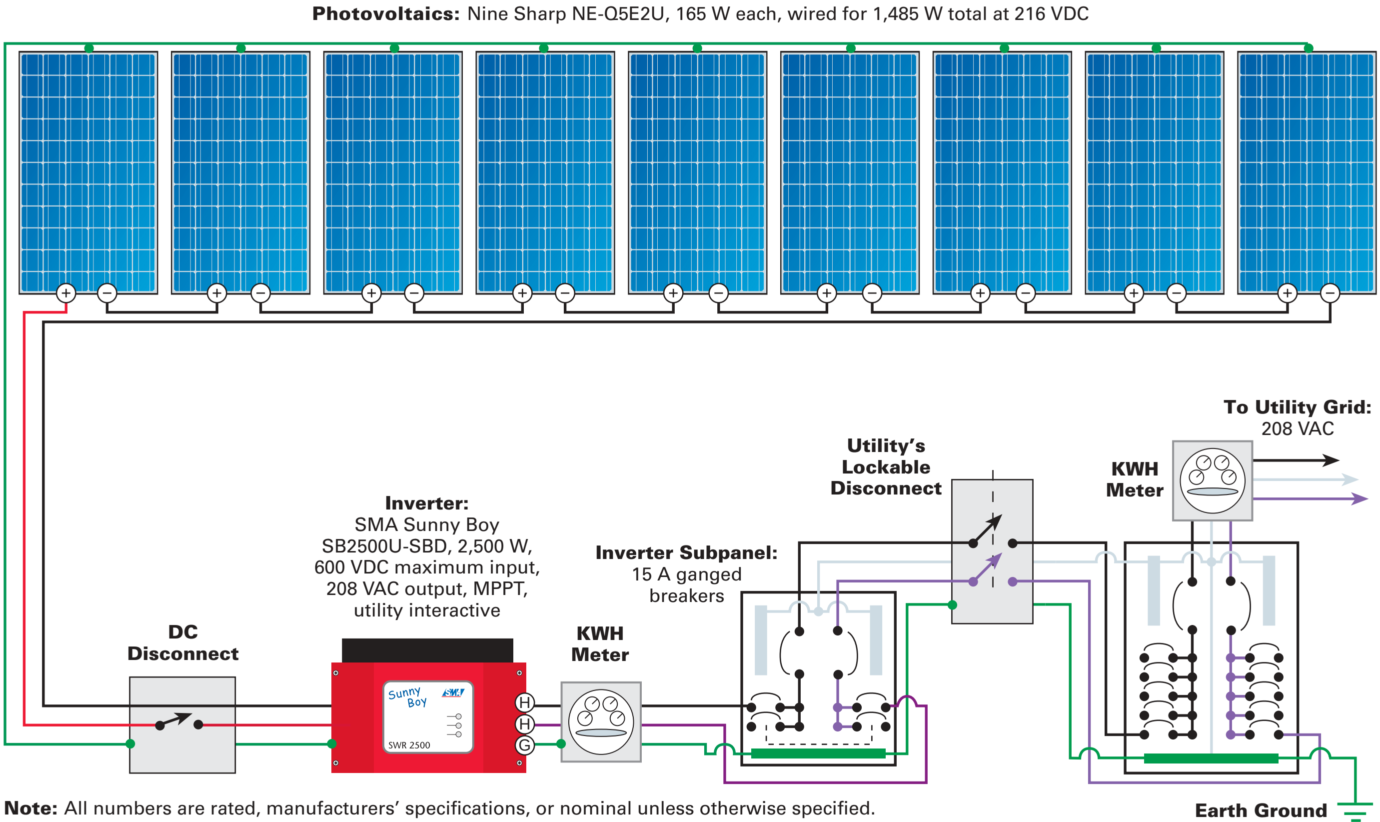
Because the building's commercial electrical service was 208 volts AC, we were not able to use the standard 240 volt model of the Sunny Boy. Note that the lower output voltage of the 208 V inverter means that the maximum AC output is 400 watts less than the standard 2,500 watts, and the maximum DC input it can handle is sixteen (instead of eighteen) modules at this location.

The system was installed in an accessible, outdoor classroom area, making the wiring a bit tricky to prevent vandalism and accidents. It was important to install the inverter and external AC display meter in a place that was visible to the students. It was also important to install the DC disconnect in a secure location inside a locked electrical closet.

The solution was to construct a custom junction box, so that conduit could securely pass through a concrete block wall. It was the most complicated part of the system, and was at the heart of the installation. We affectionately dubbed the junction box "the artificial heart" because of all the DC and AC lines going in and out. We clearly labeled the wiring inside this junction box to meet *National Electric Code (NEC)* requirements, since both AC and DC wiring runs through the box.

The DC line ran from the array to the junction box, through the wall to the array disconnect inside the electrical closet, and then back out through the wall via the junction box and into the inverter. The AC line went out of the inverter through the junction box and to the AC display meter, back through the junction box, and through the wall to the 208 volt AC service panel. The inverter was installed about 7 feet (2.1 m) above ground level to minimize the likelihood of tampering by students or others.

EMT conduit was used on all exposed wiring. A fairly long conduit run down the roof and across the face of the building under the eaves required some complicated bends. This gave plenty of opportunity for learning the art of conduit bending. A rooftop junction box was used for the transition from USE-2 wire from the modules to the THWN-2 wire used inside the conduit.



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

UniRac rails were secured to the composition shingle roof using aluminum L-brackets and lag bolts attached to the underlying rafters, which were 4 feet (1.2 m) on center. For ease of lifting, the women carried the modules up to the roof one at a time, instead of installing the modules on the rack on the ground. The modules were then mounted in a three by three panel array on the rails using top mount clips.

By 4:30 PM on the last day of the workshop, most of the pieces of the system were in place. But the sun was about to set beyond the western hills, so we had to pick up the pace. We worked madly to get all the modules aligned and finally secured, wiring completed, junction boxes closed, and final safety checks made.

Just before the sun went down, we began to commission the inverter. After about five minutes of system initialization, the system fired up with minutes to spare. A cheer went up as the AC meter started to spin backwards slowly and the inverter's display indicated that we were producing several hundred watts of solar electricity. The group was delighted to see that they had accurately applied the principles they had learned in the workshop.

Educating Consumers & Children

Walden West Center recognizes how critical it is to teach children about renewable energy. Spokesperson Richard Reid said, "Our children will experience a huge transition in how energy is produced in their lifetimes. An important goal of this school is to educate these students so that they will understand, embrace, and encourage this change."

Real-World Output

In terms of real-world system output and savings, Akeena Solar relies on a fairly conservative model of system performance. Total rated DC output of 1,485 watts (nine modules, each producing 165 watts DC) is reduced by 11 percent for PVUSA rating factors, 4 percent for low irradiance conditions, 7 percent for annualized panel soiling, 14 percent for inverter/MPPT efficiency and wire losses, and 3 percent for orientation/tilt factors.

After applying these factors in succession, the end result is that we expect the actual AC output to be about 66 percent of the PV's rated output. When we multiply this output by 5.5 hours of peak sun per day and 365 days per year, annual energy output for the Walden West system is about 2,000 KWH per year.

In reality, the vast majority of our customers see actual outputs that exceed our conservative initial estimates. In the 30 days that the system has been running at Walden West, it has already produced 190 KWH, which is about 15 percent ahead of what our modeled performance predicted for that time frame.

SEI's women-only PV workshop takes a break for a group picture.

Walden West Center System Costs

Item	Cost (US$)
9 Sharp NE-Q5E2U PV modules	$6,156
Balance of system components	3,744
SMA 2500U Sunny Boy inverter	2,569
Design & engineering	1,516
Total	$13,985
California buydown rebate	-4,921
Flex Your Power grant	-5,000
Akeena Solar contribution	-4,000
Walden West Bottom Line	$64

With this installation, the school will develop and implement a new curriculum unit on solar electricity to add to the solar thermal unit they already have. The students will conduct a weekly study on how much electricity is generated. They will then calculate the number of 100 watt bulbs that could be powered for an hour with this much electricity. Rahus' Solar Schoolhouse program has provided portable solar labs that allow the students to experiment with operating motors, lights, and water pumps with PVs. They will experiment with the effects of shading and orientation.

Rahus has conducted staff training workshops and complementary hands-on activities with the Walden West staff over the last six months. Lessons are being piloted this school year. "It is exciting because the kids will actually be able to see the electric meter spinning backwards. It is a great place for them to learn, and we'll save energy but also show them how we are saving energy for California," Anita Parsons, Walden West co-director said.

The school has upgraded all the lighting systems to reduce its electricity needs. They are using a combination of fluorescents with electronic T8 ballasts and high-pressure sodium lamps. In addition, they have a large solar thermal system for heating the swimming pool, and plan to install a solar domestic hot water system to supply the shower rooms.

The new PV system will provide Walden West with more than 2,000 kilowatt-hours of clean electricity per year. This will enable Walden West to eliminate the release of 60 tons of CO_2 over the 30-year life of the equipment and save US$600 annually on their utility bill.

Powering the Future

Walden West hopes to soon add the additional seven modules needed to fully power the Sunny Boy 2500. The school also has a new main building in the planning stage, and has included in the specs a PV system sized to provide all the electricity for this new structure.

Though these systems serve both to offset educational costs and to educate electricity consumers and future decision makers, due to the large upfront cost of photovoltaic systems, very few of them have been installed in schools. Many of the children who are educated about solar electricity here at Walden West will go on to educate their parents and others. This will help support a cultural switch to greater use of residentially produced renewable energy. In the words of one 6th grade student who was at Walden West during the installation, "You can make electricity from the sun? That is so cool!"

Access

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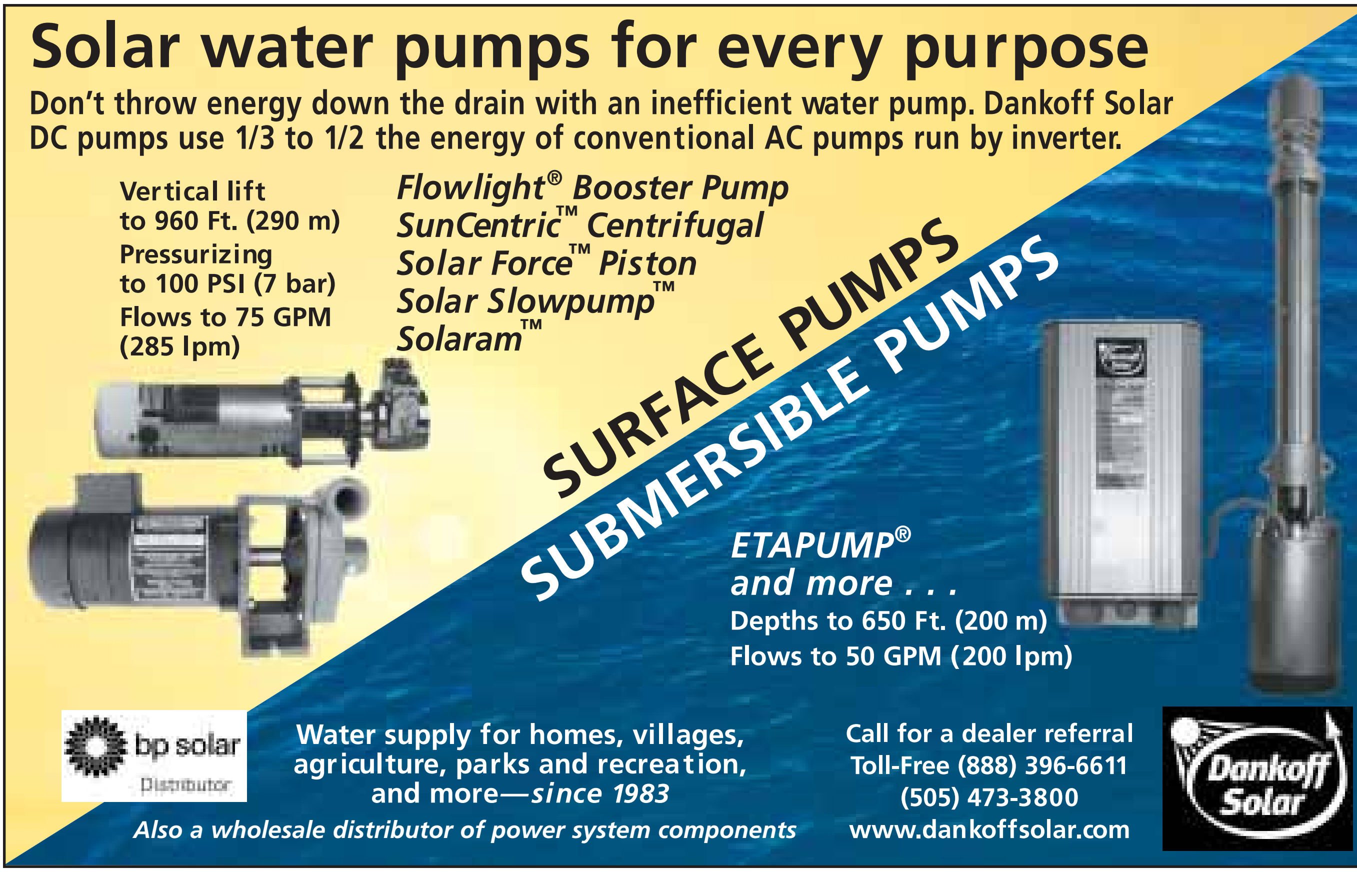
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Solar Hot Air System Design

Chuck Marken

Solar air collector systems are simpler and less expensive than solar water heating systems because air does not freeze or boil under any normal conditions on our planet. These systems don't require extraordinary chemical and control strategies associated with many liquid collector systems in harsh climates.

Jim Myers on the roof with the two solar hot air collectors that AAA Solar installed for heating his home.

Air collectors are primarily used for heating buildings. This makes sense, since buildings are usually filled with air. These systems are relatively new in the history of solar energy, first used around the 1950s. Air collector systems are also probably the most misunderstood of all solar energy applications, which led to the poor installation of thousands of systems (more on that later in this article series).

This is the first in a series of articles on the design, function, and installation of solar hot air systems. This article covers the collector and system design. The next article will cover installation, repair, and maintenance.

Roof-mounted solar hot air collectors require more installation infastructure than either thermosyphon or through-the-wall collectors.

Pros & Cons of Solar Air Systems

The properties of air make it a close to ideal medium for being heated in a solar collector, and it's free. The only thing that keeps it from being the first choice in most collector systems is its lightness and heat content. The heat content or specific heat of air is 0.24, about one-quarter that of water, which is 1. This means that you need four times as much weight of air to hold or carry the same amount of heat as the equivalent weight of water. This wouldn't be a problem if air weighed four times more than water, but in fact, it weighs only about a thousandth as much as water. (Water is 62 pounds per cubic foot. Dry air is about 0.075 pounds per cubic foot at sea level.)

This means that you need more than three thousand times as much air to hold or carry the same amount of heat as the same volume of water. This poses some problems. They are far from insurmountable, but the limitations keep air from being the best medium of heat transfer in solar collectors.

Air's lightness means that a large amount of it can be easily heated or cooled. But it tends to be much more unruly than water. Moving large amounts of air through ducts enhances the rebel in the air. It tends to want to stay in a straight path, and loses its velocity quickly when being pushed along. It is much more efficient to pull air than to push it if you want to keep the velocity as constant as possible.

Any turns in ducting tend to mix the air up a good deal, and also cause significant drops in movement. Piping systems and collectors for liquid systems need much less thought and design than ducting and collectors for air systems. Solar air collectors are about 10 percent less efficient than liquid collectors at any given temperature and solar intensity. Small solar air heating systems, without thermal storage, are typically used for daytime space heating. All of this is simply the result of the physics of heat content and mass.

Collector Design & Construction

Solar air collectors are simple devices—a piece of black metal mounted in an insulated box with a glass front. How to get the heat out of the collector where and when you need it is a bit more complicated. Good solar air collector design attempts to make the collector as efficient as possible at a reasonable cost.

Solar air collector construction is much like the makeup of solar flat plate liquid collectors, as explained in *HP85*. A well-made air collector and liquid collector are indistinguishable at a distance.

Air collectors typically have a metal enclosure (usually aluminum), high temperature insulation (fiberglass or isocyanurate), a low-iron tempered glass front, and an absorber plate. Absorber plate design is a big factor in how collectors are constructed.

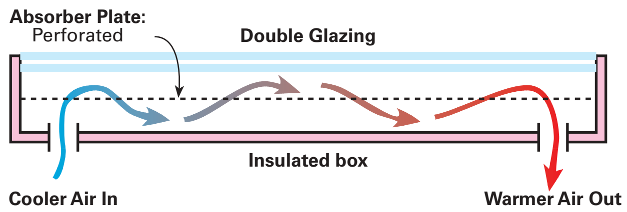
Absorber Plate Designs

Of the two predominant designs for solar air collector absorber plates, both have virtually unlimited variations. The first is called back-pass, and the second front-pass or full-flow. The back-pass design is used more today, since it requires only one pane of glass. Both designs require a dead air space to be efficient, much like a double pane window.

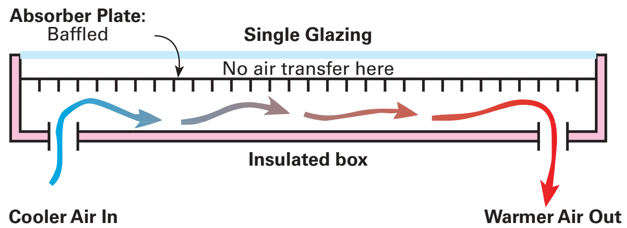
Front-pass. The front-pass or full-flow design is probably easier for a savvy do-it-yourselfer to construct, but it needs two panes of glass to be efficient. Collector absorber plates for this design can be made from a variety of materials. I've seen them made from the black metal lath that is used under plaster in home construction, and from recycled beer cans (make sure the beer cans are empty if you use this design). Both worked fine. You can use just about

Hot Air Collector Types

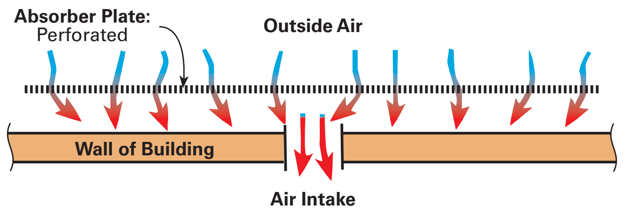
Front-Pass Air Collector



Back-Pass Air Collector



Transpired Air Collector



any type of absorber design that keeps two things in mind—make it black to absorb the sun's rays, and use a rough surface so the air becomes turbulent. This turbulence "washes" the heat off the absorber plate.

The air from the heated space is passed over the absorber and back to the heated space. This type of design can also have an aluminum absorber with louvers built into it. The drawback to this collector design is the extra weight and expense of the second pane of glass that is needed for the dead air space insulation, since the environmental air being heated is touching the inner glass.

Back-pass. The back-pass design saves a piece of glass (about US$100) and about 50 pounds (23 kg) for a typical collector. In the back-pass design, all the heated air passes behind the absorber. Since this air never touches the glass and there is an insulating dead air space between the top of the absorber and the glass, you need but a single pane. The absorber design of a back-pass collector is much less forgiving than the full-flow or front-pass. The air still needs to be well mixed behind the absorber, but it never touches the hottest surface—the black plate facing the sun.

Most back-pass designs, in addition to using dimpled or patterned aluminum, also attach extra surface areas on the back of the absorber. In addition to making the air turbulent, the added surfaces give more area of heat exchange from the absorber plate to the cooler air.

The full-flow or front-pass design was the most popular with manufacturers when plastic glazing was used in the early days of air collectors. When manufacturers became aware of the short lifetime of some plastics, low-iron tempered glass became the standard of the industry. The higher cost and greater weight of glass led to the back-pass design becoming the most popular.

Transpired Air Collectors. One other air collector design is fairly new—the transpired air collector. This design is very simple and can offer significant savings to commercial buildings that require fresh makeup air. Transpired air collectors have no enclosure, insulation or glazing, much like a swimming pool solar panel.

Aluminum sheets are perforated with thousands of small holes. These perforated sheets are placed on the south side of a building with good sun exposure (northern hemisphere), and the building's makeup air is drawn through the absorber. This can give a rise of 20°F (11°C) to the makeup air, and on large buildings, the savings can be significant. This design is not suitable for normal home or building heat—an additional 20°F just won't heat most places in the winter.

System Design

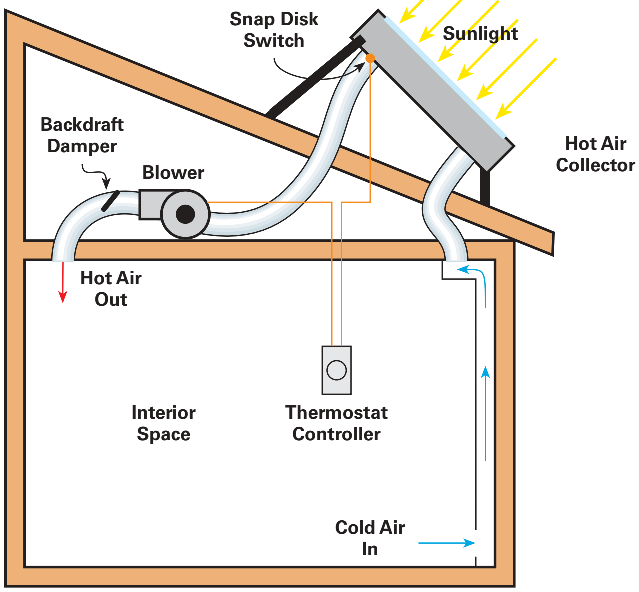
Three system designs are in use today, and these designs can either use back-pass or front-pass collectors. These three designs are thermosyphon, through-the-wall, and roof or ground mount.

Thermosyphon. Thermosyphoning is the tendency of heated liquids and gasses to rise. A hot air balloon is a good example of a gas being lighter when heated. A thermosyphoning air collector is perhaps the simplest of the simple. Take a collector and place it in a vertical orientation. Attach it to the side of a house or building and have an inlet at the bottom and an outlet at the top. When the sun shines on the collector, the heated air will move to the outlet at the top of the collector.

The outlet could be at the ceiling of a one-story home or perhaps on the second story of a two-story home. As the hot air naturally rises upon being heated, cooler air is drawn in from the inlet on the floor. Thermosyphon systems work best with large vertical distances.

With the absorber plate peeled up, the bafffles in the air chamber of a back-pass collector can be seen.

Roof-Mount System



Both liquids and gasses can also reverse thermosyphon, which explains why a backdraft damper is needed. In a thermosyphon hot air system, the hot air will enter the collector at night from the home and be cooled by the cold collector. Cool or downright cold air will spill into the lower inlet unless a closeable damper is incorporated into the system. Without a damper, a system can lose as much or more heat overnight as it gained during the sunny day.

Through-the-wall. Wall mounts are similar to thermosyphon systems, but they are not dependent on vertical height for performance. A small fan (1/100 hp or smaller) is used to pull the hot air into the room. This type of fan is called a propeller fan because of its resemblance to an airplane propeller. To automate the operation of the system, a small, inexpensive controller is used to turn the fan on and off depending on the temperature of the collector.

The small fan is more powerful than a natural thermosyphon current of air, and a weighted or spring-loaded back draft damper can be incorporated to automatically prevent reverse thermosyphoning at night. In well-installed wall-mount and thermosyphon systems, the only visible parts of the system from within the building are normal heating grilles and registers.

Roof and ground mount. The two big limitations to thermosyphon and wall-mount designs are shade and the home's orientation. Even if the home is oriented to the sun correctly, it will often have trees shading the southern wall. Most of the shading and orientation problems dissolve if you look to the roof or the ground for an unshaded spot to place the collectors. Roof mounts are the most popular location because this normally offers the most options. Wall-mount designs do not circulate the hot air to the northern parts of the home as well.

Roof and ground mounts require some ducting to and from the collector, and are therefore a bit more expensive and time consuming to install. Duct systems can add to the unruliness of air changing directions, but a squirrel cage blower can help tame this. Small propeller fans don't do the job when air ducts more than a couple of feet long are part of the system. The same type of controller and backdraft damper used on a wall-mount system are also used on roof-mounted designs.

Controls

Air collector systems for home heating don't need fancy differential controllers. A simple fan switch, also known as a snap disc, is usually all that's required. Fan switches have been in use in the heating, ventilation, and air conditioning (HVAC) industry for over half a century. They are made with two thin pieces of dissimilar metal "sandwiched" together.

Since the two metals have different coefficients of expansion and contraction, the "bimetal" will bend in one direction when heated and bend back when cooled. The bimetal is usually formed into a disc shape, and an electrical contact is placed on the disc. When it bends one direction, it turns the equipment on. When it bends back, it turns it off.

Snap or bimetal switches are inexpensive, very reliable, and seem to last forever. Typical temperature ranges for air collector snap disc controllers are 110°F (43°C) on and 90°F (32°C) off. This 20°F (11°C) temperature range prevents the system from short cycling (turning on and off rapidly). A 10°F (6°C) difference will turn on and off numerous times during a sun cycle, wasting energy. Having the system turn off at 90°F limits the cooling discomfort that some people feel with moving air at 70 to 80°F (21–27°C)—stemming from our normal 98°F (37°C) body temperature. Moving 80°F air can feel cool to many people in the winter due to evaporative cooling on the skin.

Residential and small commercial solar air collector systems are usually controlled with a simple line voltage thermostat and a bimetal switch called a "snap disc."

A 1/12 hp permanent split-capacitor blower (380 cfm) used in air collector systems (left). A backdraft damper (right) serves as a one-way air valve to prevent thermosyphoning at night.

Blowers & Fans

Solar air collector systems use very small air-moving equipment. In wall-mounted systems, a 1/100 hp motor or smaller is usually OK for a small, 3 by 6 foot (0.9 x 1.8 m) collector, and slightly larger for a 4 by 8 or 4 by 10 foot (1.2 x 2.4 or 1.2 x 3 m) collector. Just make sure the fan blades will fit the openings on the back of the collector.

Blowers for roof and ground-mounted systems are 1/12 hp for collectors from 32 to 40 square feet (3 to 3.7 m^2), and 1/10 hp for two of these size collectors ducted together. The squirrel cage blowers are of the permanent split-capacitor-type. Permanent split-capacitor motors deliver about 30 to 50 percent more airflow per watt-hour consumed than the older, shaded-pole motors. Blowers for larger systems can range up to 1/2 hp, depending on the type of collectors and the duct design.

Thermal Storage for Air Collectors

Washed river rock was once thought to be the ultimate storage material for air collectors. They are heavy and smooth, and theoretically should make an ideal union with heated air. The reality is that rock storage and air collectors don't mix well most of the time. Air is just too unpredictable. It is tough enough to try to predict the movement through smooth duct or fairly smooth collectors—try it with a bunch of rocks. If it works, you're lucky. Most of the rock storage systems ever built have been converted to simply heating the building while the sun shines, and their owners are much happier with the altered systems. The mass of the homes' interior construction and furniture become the storage for the heat.

A storage system that does work is an air radiant floor. A few centuries ago, rich Romans heated their homes with the smoke from fires beneath the floors. The floors of course needed to be noncombustible, and the same goes for storage for solar air collectors. Not that they'll catch fire—you just need the thermal mass.

Designs that have been successful are cinder blocks turned on their side to make a massive ducting system under a home. There was also a product called Airfloor that allowed you to pour concrete over metal forms that made a ducting system under the floor. Storage systems can be workable with air collectors, but need to be designed into the building from the start. They normally aren't a retrofit that's cost effective.

Other Applications

Most air collectors are used for home heating. They have also been used for heating other types of commercial buildings, including warehouses and offices. Air collectors can be found assisting natural composting in park restrooms, drying lumber, and for other industrial uses where hot air is needed.

The only difference in most of these applications is the controller. If the temperatures needed are for ranges other than human comfort, a differential controller will probably pay for itself many times over. Take the job of heating a warehouse storing paint that must be kept from freezing. A snap disc would be wasteful since the collectors could still be adding positive heat well below the 90°F (32°C) off temperature of a snap disc.

Payback

Solar air collectors depend on the thermal mass in the space being heated for the storage of the energy. They will give increased performance and comfort in more massive structures like block, brick, concrete, or adobe. These materials soak up the heat because of their weight (mass). Even in a conventional frame and sheetrock home, it is possible to have an air collector system take care of about half of the heating load.

The payback period for air collectors ranges from four to sixteen years depending on the cost of the energy being displaced, the local climate, and the type of building construction. Displacing electricity, propane, and fuel oil will usually bring the quickest payback, and natural gas the longest.

Air collectors are simple, reliable, and help heat buildings throughout the world. They are used much less in other applications—one reason is that the technology is much less known. The next article will address the nuts and bolts of air collector installation and maintenance.

Access

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Four previous articles with additional background on solar air collectors were published in *HP25, HP40, HP64*, & *HP72*.


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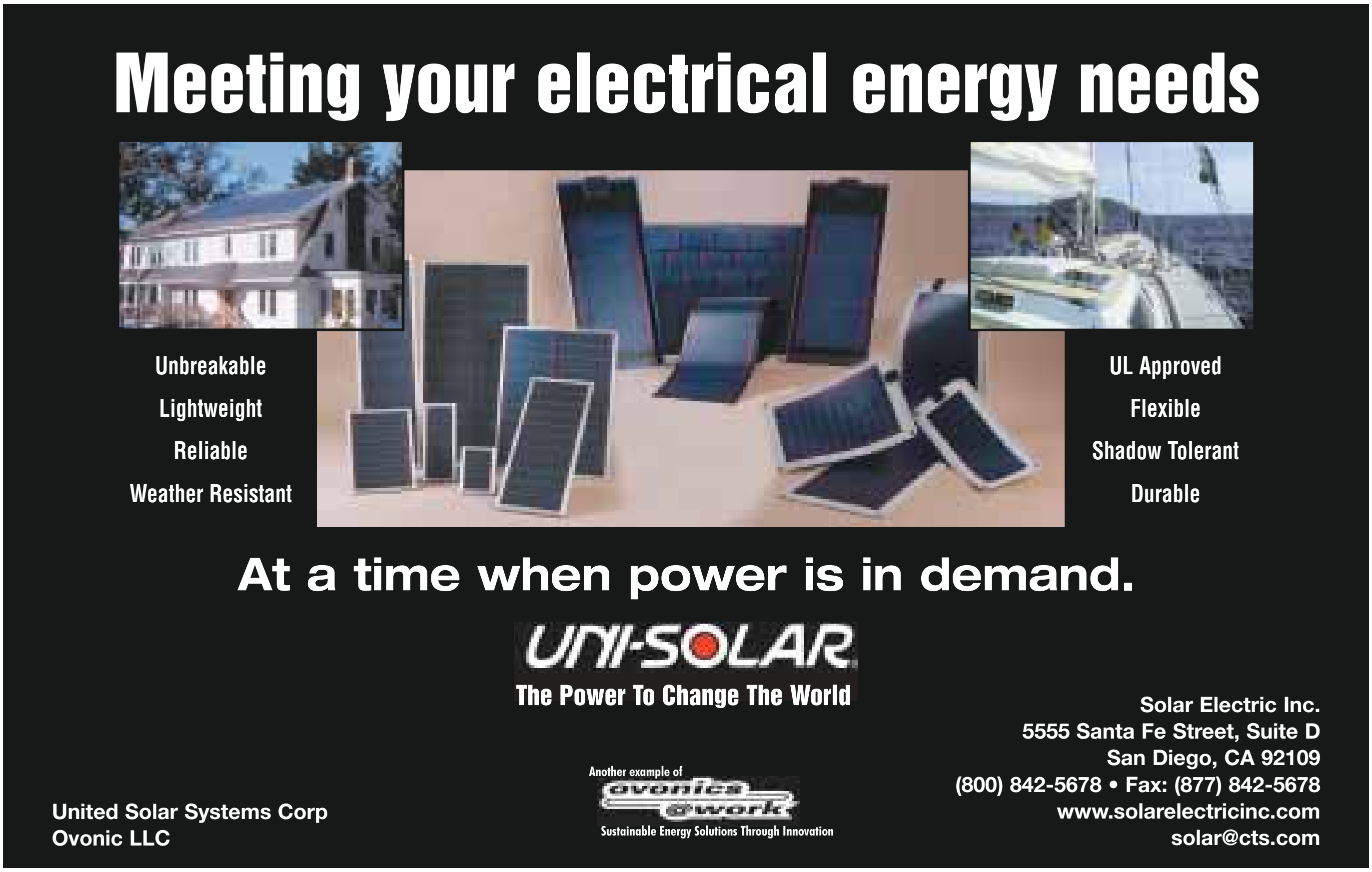
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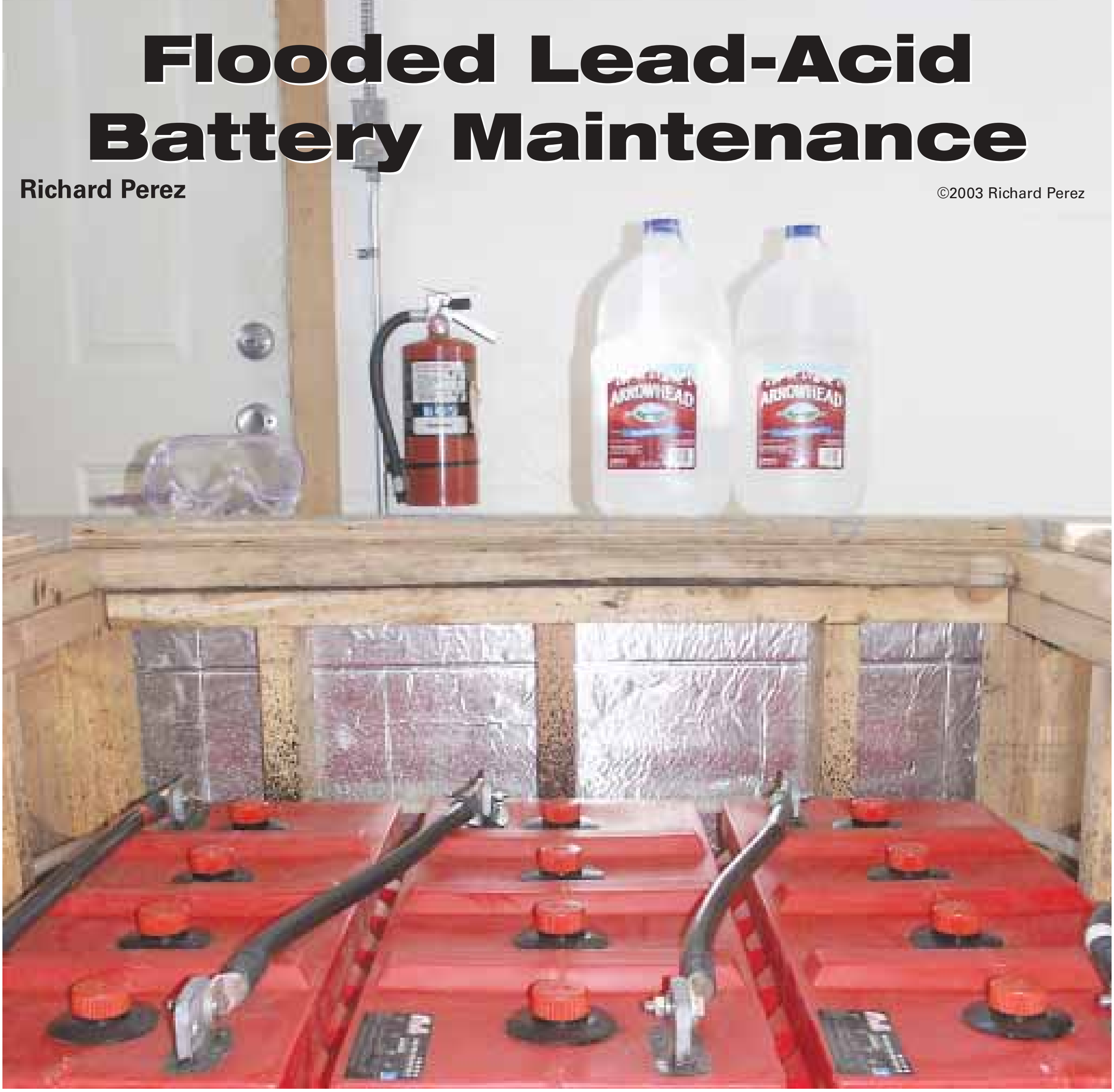
Flooded Lead-Acid Battery Maintenance

Richard Perez



For Richard and Karen Perez's Surrette battery bank, safety comes first—eye protection, fire extinguisher, smoke detector, and baking soda and rubber gloves (not shown) for neutralizing and cleaning up spilled electrolyte.

It's winter again, and time to make sure that your batteries are ready for this heavy-use season. After the long sunny days of summer, the typical PV system's battery has had it easy. It's during winter's heavy use that you often discover battery problems. Routine maintenance is the key to making sure that your battery is ready.

The information in this article applies to flooded lead-acid batteries—the type to which you can add water. It does not apply to sealed lead-acid batteries, or other battery technologies, such as alkaline types (NiCd or NiFe).

Living with Batteries

Batteries in an off-grid RE system are the most easily abused component in the system. How you treat them will make or break your renewable energy lifestyle, and your battery budget. Your battery bank allows your home to function normally when the sun isn't shining and the wind isn't blowing. But it only holds a limited amount of energy. You need to be aware of how deeply you are discharging your battery bank, and adjust your usage or start your back-up generator at the appropriate times.

Lead-acid batteries will last the longest if they are shallowly discharged rather than deep cycled. I personally consider it time to use the backup energy source once the battery gets down to a 50 percent state of charge. It's important that the battery be fully recharged several times a week. If this is not happening, you need to add more charging capacity to the system. In a well-designed system, the battery will receive an average nightly depth of discharge of less than 12 percent.

Safety Equipment

Winter is a good time to check all the safety equipment located near your battery bank. The following safety gear should be present and in good condition—rubber gloves, safety goggles, a smoke detector, a fire extinguisher, and a supply of baking soda for neutralizing spilled electrolyte.

The gloves should be the heavy-duty type sold by chemical supply houses, not the lightweight dishwashing models found in the supermarket. The goggles should be tight fitting and totally protect your eyes from any acid that may be splashed during watering. The smoke detector should have its battery replaced annually, and winter is a good time to do this.

The fire extinguisher should be of the ABC type that can handle wood, chemical, and electrical fires. Check it annually to make sure it still has its charge. Have lots of baking soda on hand—it takes two pounds of baking soda to neutralize one quart of battery electrolyte. Be prepared for an accident in which a battery disgorges all of its electrolyte.

Equalizing Charges

Over time, the individual cells that make up a battery will come to have unequal states of charge. The only way to bring each cell back to a fully recharged state is to overcharge the entire battery to ensure that each cell is fully recharged. If a battery is to perform well and efficiently, all cells must have the same state of charge.

An equalizing charge is a controlled overcharge of an already fully charged battery. The maximum charge rate for equalizing charges is C/20—which means that a fully discharged battery pack will be totally recharged in a 20 hour period. The charge rate in amperes is equal to the capacity of the battery in ampere hours (C) divided by 20 hours. Charging at a higher rate will cause the battery to overheat and will reduce its life. Equalizing charges can be done at slower rates, but they will take longer to achieve a state of cell equalization.

An equalizing charge should be done every five to seven deep cycles or every two months, whichever comes first. A deep cycle is when the battery has sustained a discharge cycle of 50 percent or more of its capacity. The beginning of winter is a great time to do one or more equalizing charges. This ensures that the battery is ready for the deep cycles it is sure to receive during the winter's sunless periods.

Equalizing: Step-by-Step

1. Make sure that the battery is fully charged. Your battery ampere-hour meter will supply this information.

2. Make sure that an adequate supply of distilled water is on hand.

3. If catalytic battery caps (such as Hydrocaps) are being used, remove them and replace them with the original factory-supplied caps. An equalizing charge will generate far too much hydrogen and oxygen gas for catalytic caps to convert back to water. The caps will overheat and in some cases even melt.

4. Apply a charge rate of C/20 to the battery and let it overcharge for between five and seven hours. During this period, the battery's voltage will get much higher than normal—up to 16.5 VDC in 12 VDC systems, and over 33 VDC in 24 VDC systems. If any voltage-sensitive DC appliances are on-line, switch them off before equalizing.

5. An hour before stopping the equalizing charge, add distilled water to each cell to bring the electrolyte up to the manufacturer's recommended "full" level. Equalization charges will electrolyze water from the cells. The electrolyte will have the appearance of a "rolling boil" as water is converted into hydrogen and oxygen gas. Four to five hours into the equalizing charge is the perfect time to add water to the cells. They will need to have their water replenished. And the agitated state of the electrolyte will thoroughly mix the added water with the existing electrolyte.

6. After the equalizing charge is finished, replace the battery's catalytic converter caps if they are being used.

If the battery has been abused by not performing equalizing charges, or by operating it without routinely bringing it to 100 percent state of charge, multiple equalizing charges may be necessary. Sulfation is a clogging of the plates with large sulfate crystals, which occurs when the cell is not fully recharged. Equalizing charges should be performed routinely during all seasons, but especially during the winter when the battery is more deeply discharged.

Water for the Battery

Only distilled water should be added to replace the water lost by the cells. Well water will probably contain

Tubing, clamp, and a flashlight help get the exact amount of distilled water where you want it.

These two Zephyr battery vents safely pull hydrogen gas from the battery boxes (inside) to the outside.

dissolved minerals and should not be used. Municipal water supplies usually contain not only dissolved minerals, but also chlorine, and should not be used. Though rainwater starts out pure from the clouds, it is often polluted by the time it can be collected on the ground. Batteries are electrochemical machines—they either fly or die on the purity of the reactants. Use only distilled water, and check the water levels at least every six to eight weeks.

Do not let the plates of the battery become exposed to air by letting the electrolyte level become too low. This will lead to oxidation of the cell's plates and permanent decrease in cell capacity.

Cleaning the Battery & Its Connections

Eventually, most lead-acid batteries develop a schmaze of acid electrolyte covering their tops. This smeared haze of acid will corrode the connectors attached to the battery. The acid schmaze is electrically conductive and can form discharge paths across the tops of the batteries. It should be carefully cleaned off the battery's tops. Quickly wiping the tops of your batteries with a paper towel each time you water them will keep them clean, and make the job easy.

While baking soda is an excellent neutralizing agent for acid electrolyte accidents, it should *never* be used on the top of a battery. If the acid can get out, then the baking soda can get inside the cells and neutralize the electrolyte. Use baking soda only on the sides of the battery, to neutralize the acid on connectors after removing them from the battery, and to clean up spilled acid. Once again—never use baking soda on the battery's top!

After corroded connectors are cleaned with a baking soda solution, they can be brightened with sandpaper or with a wire brush. Be sure to brighten the battery posts too. The general rule for all connections made to the battery is that they should be "tight and bright." Corroded connections will cause differing states of charge between the battery's cells, and lead to inefficient operation and early battery demise.

Temperature & Ventilation

The lead-acid chemical reaction employed in a battery is temperature sensitive. Temperatures below 50°F (10°C) will lead to temporary battery capacity loss, depressed voltage during discharge, and elevated voltage during recharge. The optimum temperature for the lead-acid reaction is 78°F (26°C). Keep the battery as close to this temperature as possible.

If the battery is in a conditioned space, keeping it warm is easy—just allow it access to heated air from inside the living space. But make sure that this air path is one way—into the battery containment and exhausted outside by a vent fan. It's important that the hydrogen gas, which is highly flammable, be exhausted outside of the battery containment and building. The air intake should be located low on one side of the containment. The outlet should be located high on the opposing side of the containment and vented outside. If the battery is in an unconditioned space, keeping it warm is more difficult. Use solar heat, super-insulation, or do whatever is necessary to keep the battery 50°F (10°C) or warmer.

This battery box is super-insulated, and heated with solar hot water circulated through hydronic tubing.

You should keep your batteries cool in the summer too. When a lead-acid battery is kept at over 95°F (35°C), its rate of self-discharge (energy lost inside of each cell) increases radically, and its effective lifetime will be far shorter. So when you plan for keeping the battery warm in the winter, don't forget to also allow for keeping it cool in the summer.

Be Prepared

Winter is a tough time for your batteries. The shorter days and longer nights mean that the battery has to work harder, with shorter recharge periods and longer discharge periods. While letting battery maintenance (especially equalizing charges) slide during the lazy, long summer days is not a huge disaster, slacking off on maintenance during the winter can kill a battery.

So now is the time. Run an equalizing charge. Check the battery's water. Clean the connections. In addition, double-check the safety equipment. A well-maintained battery is a happy battery, and will see you through the winter.

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OutBack Power Systems PSPV

PV Combiner Box

Joe Schwartz

Application: PV combiner boxes are commonly used to parallel either multiple PV modules or series strings of modules, and provide series overcurrent protection, as specified by the *National Electrical Code (NEC)*.

System: I've installed OutBack combiner boxes in multiple PV systems, both utility intertied and stand-alone, and at various operating voltages. I have one installed in my own off-grid system, and soon will be adding two more.

In the past, all sorts of connectors have been used to parallel PV modules or multiple series strings of PVs. Installers have used solder and electrical tape, split bolts, wire nuts, unfused combiner blocks—you name it.

One downside of all these approaches is that verifying PV array performance and troubleshooting the array becomes time consuming, since all the series strings are paralleled at a single location. These methods require unwiring parts of the PV array to test individual series strings of modules. More important, the combiner methods above do not contain the series fusing needed to meet *NEC* requirements, pass electrical inspection, and ensure safe array operation for years to come.

Series Fusing—Why It's Important

Consider the following scenario. A single PV module develops a direct electrical short. The other modules in the PV array could potentially backfeed the total array output to this short, exposing both the PVs and the PV interconnect wiring to current higher than the rating for the PVs and wiring. Overcurrent could cause both wires and PVs to overheat and possibly result in a fire. You obviously don't want a scene like this to be played out on your roof.

While the above scenario is somewhat unlikely, it can happen. Series fusing is an important safety feature in any PV system with multiple series strings or paralleled PV modules. Combiner boxes provide a series breaker or fuse for each string of PV modules in a given PV array. These breakers or fuses protect the PV and wiring.

All PV modules are rated by the manufacturer for the maximum backfed current a given module can be

The OutBack PSPV combiner box makes for code compliant and convenient PV array wiring.

exposed to without damaging the module or creating a fire hazard. Series fuse ratings vary depending on the electrical characteristics of a given PV model. To keep things simple, series fuse sizes are listed on the back of every UL listed PV module, typically between 6 and 16 amps.

The OutBack PSPV Combiner Box

OutBack's PSPV combiner box provides a PV wiring nexus that's both safe and convenient. Series strings are routed through a breaker or fuse, and paralleled in an orderly fashion. From there, larger wiring moves the combined array output along to a charge controller or inverter. The powder coated aluminum combiner box enclosure is rated for wet, outdoor locations (NEMA 3R). It can be mounted on vertical surfaces (a wall or a pole), or on sloped surfaces like a roof with a pitch of 14 degrees (3:12) or greater.

Inside the enclosure, a DIN rail mounting bracket will secure up to twelve OutBack DC-rated breakers for systems with open circuit voltages up to 125 VDC. The breakers have setscrew compression terminals, and accept up to #2 (34 mm^2) wire. The breakers have a ten-year warranty, and are load make/break rated for up to 125 VDC. ("Make/break rated" means that you can disconnect the circuit using the breaker in question while it's fully loaded, with no arcing danger.)

Features

High Points:

- Modular configuration
- Quick installation
- Simplified system troubleshooting
- Allows for two isolated output circuits

Low Points:

- Positive bus bars are a little lightweight, and will bend if too much pressure is applied during installation
- No factory drilled holes for convenient mounting on poles larger than 5 inches (13 cm) in diameter

List Price: PSPV enclosure, US$139; 6, 9, 10, 15, and 30 amp breakers, US$12 each; Touch-safe fuse holder, US$18; 15 amp 600 VDC busman fuses, US$18

Warranty: 2 years on enclosure; 10 years on breakers

Tech Specs

Rating: Outdoor, rainproof (NEMA 3) enclosure

Breakers & Fuses: Holds up to twelve OutBack 125 VDC breakers, or eight 600 VDC touch-safe fuses

Wire Sizes: Accepts up to #1/0 (53 mm^2) power output and equipment ground wiring

Physical Size: 9.2 by 3.5 by 13.1 inches (23.3 x 8.9 x 33.3 cm)

Shipping Weight: 6 pounds (2.7 kg), plus options

In high voltage systems, up to eight touch-safe fuse holders can be installed in the enclosure, rather than the lower voltage breakers. This allows system voltages up to 600 VDC. The insulated fuse holders also have setscrew compression terminals, and accept up to #8 (8 mm^2) wire. These fuse holders are not rated for load make/break usage, since high voltage DC circuits create greater electrical arcs than lower voltage systems. OutBack also provides a ground lug that accepts up to #1/0 (53 mm^2) wire. It can be positioned in different locations inside the enclosure for your wiring convenience.

The PSPV combiner was designed to be very flexible in its configuration. If the total rated amperage of your PV array requires two separate charge controllers that aren't designed to operate in parallel, the PSPV can be configured with two, electrically isolated output circuits, each feeding a separate controller.

In this configuration, the two positive bus bars provided with the enclosure are installed so they are not electrically bonded together. A second negative bus bar (purchased separately from OutBack) is then added to the enclosure to create two separate output circuits. OutBack's PV combiner box can also be configured for either negative or positive ground PV systems.

The PSPV enclosure provides plenty of knockouts for routing PV array wiring into the enclosure, and for home runs going out. Eight, 1/2 inch knockouts are provided at the bottom of the box. Four, 3/4 to 1 inch knockouts are also provided, one each on the bottom, back, and each side of the enclosure. The knockouts on the sides of the enclosure can be punched out to accept up to 1 1/4 inch conduit fittings. The bottom of the box can be punched out to accept up to 2 inch fittings. Knocking the bottom of the box out to 2 inches doesn't leave much extra room for a fitting's nut, so make sure to properly align your punch, and check that you have appropriate clearance inside the box.

Modular & Clean

Combiner boxes and series fusing are important components that will keep your PV array and wiring safe and easy to troubleshoot for years to come. The OutBack PSPV combiner box is very modular, and easy to configure to meet the specifics of your PV array wiring. I'm looking forward to installing a couple more up at my place, as soon as I'm through with this trenching and cement work.

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TREE HUGGER

SUN WORSHIPPER

Jane Oldale

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June 2003—Jane on the deck next to the solar array. Only Bruce's stump and branches remain.

Fall 2002—Fatal alignment. Solar array from behind with Bruce to the south.

The winter solstice marks the first full day of winter, a day to celebrate the return of the light. For the next half of the year, each day will be longer and the sun will be stronger. To those of us living in solar powered houses, it is truly a significant day. So I chose a special way to mark the occasion. I killed a tree.

Twenty-six years ago I planted the tree. At the time, it was a little baby white spruce about a foot tall, transplanted from a nearby field. I remember choosing the spot carefully on the front lawn of our under-construction house. We christened it "Bruce."

The following year, I recall warning the man with the backhoe installing the septic field to be careful not to harm Bruce while doing his work. At that time, solar electricity for my house was just a little niggle of an idea in the back of my head. Little did I realize at the time that the chosen spot to the south of the house would some day require the sacrifice of the spruce tree.

Well, Bruce thrived in the wide-open space of the front yard, nourished to some extent by the nutrients from the septic field. I fondly recall one occasion about nineteen years ago, when it was still easy to

Jane's RE System

I live in an off-grid rural home 20 miles (32 km) southwest of Thunder Bay, Ontario, Canada. The electrical system has evolved gradually over the years, and includes both 12 VDC and 120 VAC circuits.

PVs: Two, 120 watt Kyocera modules (pole mount with manual tracking) plus one 75 watt Siemens module (mounted on the deck)

Wind generator: Whisper 600, 12 volt, 3-blade wind generator on a 72 foot, tilt-up tower

Batteries: 12 V, sealed AGMs, 1,100 AH

BOS: Trace SW2512 sine wave inverter, Whisper EZ-Wire centre with meter, all appropriate disconnects

Generator: Honda, seldom used (approx 12 hours total last year)

Loads: Small Sun Frost fridge/freezer, energy efficient lights, shallow well pump (1/3 hp, 120 AC jet pump), small appliances, stereo, TV, laptop computer and ink jet printer, vacuum cleaner, occasional power tools, etc.

My energy requirement is less than 2 KWH per day. Approximately two-thirds is met by the PVs and one-third by the wind generator. The primary heat source is a Pioneer Maid, airtight, wood-burning cookstove, and my annual wood consumption is approximately 4 to 5 cords.

Christmas 2002—Bruce the Spruce in a sunbeam. Note how the sun's rays reach all the way into the house at this time of year—passive solar heating!

reach the top of the tree, and three children (a niece and two nephews) decorated Bruce for Christmas. The following year, I was still removing bits of tinsel from the branches!

In the past few years, I gradually became aware that Bruce's shadow was starting to create a problem. On those short winter days around the solstice when the sun climbs above the horizon for only a few hours each day, the shadow darkened the lowest solar panel of my array for that most important midday hour. At my location, 48 degrees north latitude, on the winter solstice, sunrise is at 8:44 AM, sunset is at 5:06 PM, and the sun is only 19 degrees above the horizon at solar noon.

I chose to ignore the problem for a while. But in May 2002, I made my decision—Bruce would have to go. I started by trimming off several of the tree's lower branches in a lame attempt to make it look ugly so it wouldn't be so difficult to cut it down. It didn't work. It was still a beautiful tree. I decided to enjoy it for one last season. It wasn't shading the solar panels in the summer when the sun was high in the sky.

In the fall, I asked a friend who was doing some work at my house to cut it down for me. He looked at me as if I had taken leave of my senses. "You want me to *cut it down*?!?" I knew he was right. I couldn't expect anyone else to do my dirty work for me.

"Why don't you raise the solar panels?" he asked. Yes, perhaps, but that would just put off the inevitable by giving me a few years grace. Besides, two new solar hot water panels would be going up on the roof that winter, and there's only one place on the roof for them. The shadow would affect them too, even though they are not as sensitive to shading as the solar-electric panels.

One sunny day in early December, I made up my mind. At midday I was watching the ammeter and saw the numbers drop sharply, even though the sun was shining in a clear blue sky. I checked outside and sure enough, Bruce's shadow was cast upon all three panels in the solar-electric array. The tree grew quite a bit last summer despite the dry season—must be that septic field! So there was no more denying it.

I chose the winter solstice as the appropriate time for the task. I cleaned up the chain saw, donned the steel toes and hardhat, and headed out to the front yard. I paused to give the tree a good hug and say a prayer of thanks for its life. I selected the mark on the trunk for the notch, choked the saw and pulled the cord. After a few splutters and stalls, I thought I had once again found a way to delay the task, but with one more yank of the cord, the saw roared into action.

As I started the notch, I realized that I had never before felled a tree with such a large girth. Most of my chain saw experience has been cutting small firewood, limited to trees of 10 inches (25 cm) or less in diameter. It took a while to make the notch. The felling cut took even longer. I gave the tree a good push to help it along, but it took its own time, eventually falling with a gentle swoosh, landing exactly where I wanted it.

It took much longer to limb it; it was a thick, bushy specimen. There's enough wood in the branches alone to make a good pile of firewood after it has a year to dry. I'll consider having the main log milled into boards, and I'll haul the smaller branches back into the bush where they will provide shelter for little critters, and eventually decompose and feed the forest floor. The full length of the tree from ground to tip was 35 feet (10.7 m). The stump measures 16 inches (41 cm) in diameter.

I cut off the top 8 feet (2.4 m) of the tree and dragged it up to the house, set it up in a bucket full of stones, and hauled it into the living room. What a way to get a Christmas tree! Now the house was filled with the beautiful fragrance of spruce boughs. The tree was loaded with little brown cones that made my decorating job easier. I found a bird's nest in one of the lower branches of the big tree, retrieved it, and used it as a decoration to remind me of the life the tree once sheltered. I decorated the tree and turned on the solar powered lights to shine on it.

At the base of the stump, there are ten, tiny white spruce seedlings—Bruce's babies. None are more than 6 inches (15 cm) tall, and all are thin and spindly from their shaded existence under the spruce boughs. Next spring, I will try to carefully transplant them all to new homes where I can care for them until they can make it on their own. And I will make sure not to plant them where they will someday shade a solar array.

Sharing my story with you is a form of therapy to alleviate my guilt. At this special time of year, may we all pause to celebrate the coming of the Sun or the coming of the Son, however we choose. May we learn from each other's mistakes. May we make our plans carefully and thoughtfully. May we plant more trees than we cut. May we put solar panels on our south-facing roofs and spruce trees in our north side yards.

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Using DC in Your Off-Grid Home

Steve Willey

An off-grid electrical system can support more luxury gadgets and at the same time cost less and save electricity when both AC from an inverter and DC from the batteries are used. This is especially true of small, 12 VDC systems. In higher voltage systems, battery equalizers and DC-to-DC converters make it possible to run select DC appliances at lower voltages. Knowing which appliances should be considered for DC can improve the performance of a smaller independent electrical system. It can allow you to add many luxuries not otherwise possible without planning a larger (and more expensive) system.

Using DC is a particularly helpful strategy for a small system, and especially any system where the budget is really tight or resource conservation is important. Of course, this strategy of adding DC circuits is not for everyone. With new construction or a system remodel, if you aren't an owner-builder or handy do-it-yourselfer, just adding a couple more PVs and keeping the system voltage standardized and simple could be more cost effective than paying for the additional labor and materials required for running DC circuits.

The Modern Inverter

Today's inverters are appropriate for most conventional appliances. But the inverter itself consumes some of your energy when it produces AC voltage, even if no AC appliances are running. Just to remain "on" when no electricity is being used in the home, most inverters will burn at least 10 watts internally, and some sine wave inverters draw as much as 60 watts.

Many inverters have a feature to minimize this waste by switching to an energy saving "sleep" or "search mode" when no AC appliances are on. After the last AC light or appliance is switched off, the inverter stops production of AC electricity and uses almost zero energy from the battery. It begins operating at full voltage when an AC light or appliance is turned on.

This 24 volt off-grid PV system uses a converter to run 12 volt RAB motion lights, among other loads.

Wasteful Loads

Some otherwise very low power appliances can sabotage the inverter's energy-saving idle feature by making the inverter stay on full-time to consume potentially large amounts of your precious renewable energy. If you plug in a telephone message machine, alarm system, or other device with an AC wall cube (wall wart), your battery voltage is first converted up to 120 volts AC in the inverter, losing some of it on the way. The electricity is then converted back down to low voltage DC in the wall cube transformer, losing more energy.

The wall cube is also a phantom load that keeps the inverter running continuously day and night, consuming another 10 to 60 watts (depending on which inverter) in addition to the 2 or 3 watts that the inactive message machine or alarm system really needs. Since both these items need to do their job 24 hours a day, turning those appliances off to save electricity at night or when the house is vacant just defeats their purpose. They need a tiny trickle of electricity over many hours.

Other appliances need electricity only a few minutes a day, but cannot restart a sleeping inverter. These include motion sensing outdoor light controls, remote control garage door openers, the start circuit on whole-house vacuum cleaner systems, and doorbells.

A simple solution might be to leave the inverter locked on full-time, producing AC 24/7 just like the utility. If you have a substantial solar-electric system, this may be the

Low Voltage DC Appliances

These low voltage DC products can use significantly less energy than their AC counterparts:

- Circulating pump for solar and hydronic loops
- DC electric bed warmer; 50 to 60 watts rather than 200 watts for an AC electric blanket
- Evaporative house cooler; under 100 watts instead of 800+
- Rechargeable shaver
- Cell phone recharger
- Flashlight battery recharger
- Electric fence charger
- Electric gate opener; a solar module can trickle charge the battery
- Water pump for most applications; 12 to 48 volt
- DC ceiling fans
- 12/24 volt DC refrigerators & chest freezers
- Muffin fans; 12 or 24 volt computer style fans for use as personal fans or to improve heat circulation
- Notebook computers; can be just as functional as a desktop model with the addition of an external keyboard, mouse, and optionally a display
- Consumer audio equipment with wall wart, common on cordless phones, message machines, and boom box stereos
- DC lighting; especially useful in battery rooms and for single lights used for long hours
- White LED bulbs, 1/2 to 1 watt can be left on all the time
- Positive displacement pumps; but have higher maintenance
- Newer centrifugal DC well pumps; no starting surge

most convenient approach, although not the most efficient. Running the inverter ten extra hours at night will consume between 120 and 600 watt-hours of energy, depending on the idle draw of the inverter you purchase. On the high end, that could be enough to power a small freezer. And when battery charging by generator is needed in winter, that half a kilowatt-hour wasted means an extra half to one hour of generator charging each day.

With a little extra work, many small appliances can be adapted to use 12 volt DC electricity directly from the solar-electric home's battery. These items use very little DC energy, making DC a more appropriate choice for systems on a tight budget. Even higher powered DC appliances like water pumps use only 20 to 50 percent as much energy per gallon pumped as most AC pumps.

Two Strategies

In a 12 volt system, you'll just need to add a breaker box or use those that may already be included in your DC power center. If your system voltage is 24 or 48, there are two basic strategies once you've decided to use DC for some of your loads.

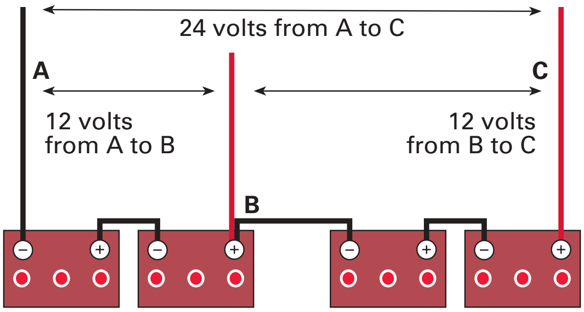
Strategy #1. You can tap the battery bank to get 12 volts DC, and then use a "battery equalizer" to balance the charge in your battery bank. These devices sense an imbalance between the two halves of a tapped battery bank, and shift energy from one side to the other to balance the bank.

Strategy #2. You can use a voltage converter to step down from your battery voltage to 12 volts DC. These devices are simple, reasonably priced, and some are up to 95 percent efficient. The most common voltage converter gets you 12 volts from a 24 volt battery bank, or gives 12 or 24 volts from a 48 volt battery bank.

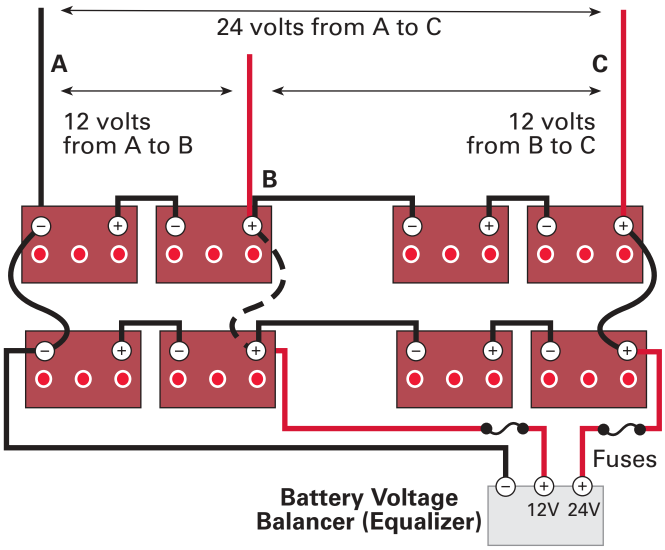
Tapping the Battery Bank

Remember that each battery cell in a lead-acid battery produces a nominal 2 volts. So a 12 volt battery bank is made up of six, 2 volt cells connected in series (positive of one to negative of the next) to add voltages and make 12 volts. A 24 volt battery bank has twelve 2 volt cells in series; a 48 volt battery bank has 24 cells in series. A 24 volt battery tapped at the midpoint will produce 12 volts between the wires connected at A and B (see diagram below) because there are six, 2 volt cells between A and B.

One point that generates many questions is whether to make the tap connection for point B at the positive terminal of the second battery, or at negative terminal of the third battery. Observe that these two possible connecting points are directly connected together by a heavy battery cable, so electrically they are the same point in the battery circuit, with the same voltage. Either can be used.



A 24 volt battery bank (made of four, 6 volt batteries in series) can also be thought of as two, 12 volt batteries in series.



Any battery made up of two or more series strings of batteries, such as the two-string 24 volt battery shown here, must have the tapped point cross connected (dotted line) to include all the strings in the voltage tap. A 12/24 voltage converter is connected to the battery.

In larger battery banks with more than one string of batteries connected in parallel, be sure the voltage tapping point is also connected across to each string of batteries. This point seems to generate a lot of questions and confusion. The heavy dotted line at point B connects across all the battery strings, just like the cables at the positive and negative ends of the battery bank connect all the strings together. These battery cables are added at point B (dotted line in the diagram at left) so the left half of all battery strings, not just of the top string, will supply the 12 volt electricity and will be rebalanced by the equalizer.

Equalizers

Connecting wires to "tap" half the 24 volt battery as shown (left) takes 12 volt electricity only from one half of the battery bank. Since normal charging of the battery recharges all the cells equally, a progressive imbalance between the tapped portion and the rest of the battery bank results in shortened life for those batteries, and lower voltage in the tapped portion of the battery.

A simple battery voltage-balancing device is added to automatically redistribute charge between tapped and

Dealing with Devices Requiring Continuous Power

Many electronic devices need to be on all the time if they are to be effective. Instead of keeping the inverter awake all the time to power them with AC, the following products can be powered directly by DC. Here are some strategies for adding these conveniences to your life without overburdening your system's capacity.

Telephones. Cordless phone and phone message machines powered by DC save energy and can operate 24/7. Selected models are available commercially, or those using a wall wart (wall cube) can be modified.

Motion sensing light controls. Operating on 12 volts DC, motion sensing light controls can be on-duty full-time. They use only 1 watt when idle, and can operate 12 volt yard lighting directly. With the addition of a relay, they can turn on larger AC lights that start up the inverter as needed.

Doorbell. Doorbells are usually powered by 24 volts AC through a transformer. These devices constantly waste a small trickle of energy, and are inoperative when the inverter is in a sleep state. But standard electro-mechanical doorbells can operate on 12 volts DC, and they use electricity only while the button is actually being pressed.

Alarm systems. Alarm systems available at Radio Shack and elsewhere usually have a 12 volt backup connection so that they will operate during power failures. Connected to your 12 volt DC supply, these will operate continuously with little energy used.

Appliance timers. Seven-day programmable appliance timers can control either DC or AC appliances to make your stereo into a wake-up clock-radio, disconnect the phone during sleeping hours, or operate a water pump unattended. These timers are available for 12 or 24 volts, use minuscule current, and reliably keep their time setting and program memory.

Garage door openers. Garage door openers use electricity 24 hours a day to keep their remote control receiver awake. A neat trick for these energy wasters is to install a 12 volt motion detector light control with a timer outside the garage. When it senses a person or car, it activates a 12 volt relay that connects AC power to the garage door opener and to an outside light. This starts the sleeping inverter and allows the door operator to work normally. Inside the garage, a windup light timer switch can be used to manually power up the door opener for departure.

Fish tank bubbler. One of the most difficult problems for saving energy in a solar home has been a fish tank aerator. Since an AC aquarium bubbler should run nearly all the time, the inverter needs to be on all the time too. A 12 volt DC powered bubbler called Power Bubbles, suitable for aerating small garden ponds, is available from Cabelas (www.cabelas.com) for US$34. Running only 0.2 amps, it can be excessive for a fish tank, where its vigor may be reduced by a voltage converter to operate it on 6 volts, 0.1 ampere. A voltage converter producing 3, 4.5, 6, or 7.5 volts is available from Radio Shack for US$8 to $16.

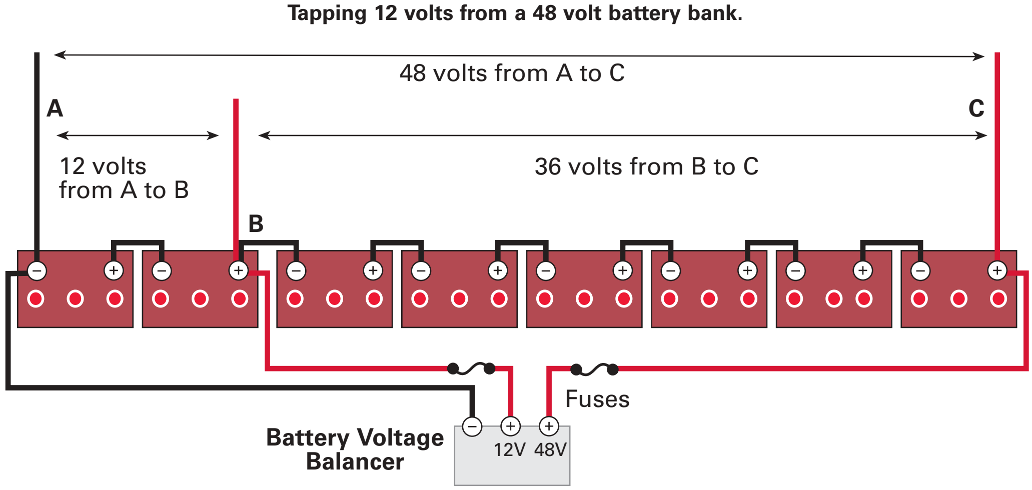
The Vanner Voltmaster (left) and Solar Converters EQ 12/24 (right) battery voltage equalizers.

untapped portions of the battery to produce an equal charge balance. No user attention is required other than occasionally checking the voltage of each half to assure that the equalizer is still working.

The Vanner Voltmaster is a high quality battery voltage equalizer. It maintains precise voltage balance between the two halves by transferring energy from the untapped portion to the tapped portion until both voltages are precisely balanced. (The word "equalize" here refers to maintaining this balance of battery halves, a different usage from the more familiar extra high voltage charge to equalize random weak battery cells). When 12 volts DC is consumed from the connection at A and B, the equalizer senses a drop in voltage in that half and transfers energy there from the other half until voltages of each half are exactly equal again.

Solar Converters makes lower priced voltage converters that balance batteries the same way. Their units can also be used in several other ways, which are described later.

Tapping 12 volts from a 48 volt battery bank.



Advantages of 12 Volt Tap

Tapping a higher voltage battery to get 12 volts offers a great advantage when many 12 volt circuits are in the house, and where some 12 volt loads require higher current for short periods, like DC motor starting. Since the 12 volt current is supplied directly from the battery rather than passing through a conversion device, huge surge current is available, and power quality and stability is as good as your battery.

Voltmaster, the most common equalizer, is rated at a maximum of 20 amps transfer current, but models are available for up to 100 amps. But the battery is able to supply much higher currents for a limited period of time, and the equalizer will work around the clock at its 20 amp rate until it catches up. The battery will be completely rebalanced.

No electronic noise is introduced to the 12 volt lines since the battery (itself a great passive noise filter) is supplying the 12 volt electricity. And best of all, if the equalizer fails, and tries to generate the wrong voltage, it will blow its own fuse or stop working. The only result is a charge imbalance that you will soon discover during your monthly battery check. In no case can it pass higher voltage to your 12 volt appliances and damage them.

Series Voltage Conversion

The other major option is converting voltage, without tapping the battery. The Solar Converters EQ voltage conversion products can be used simply as in-line voltage converters. They can be installed in the battery room or out at the end of a DC circuit to change voltage from a 24 or 48 volt battery down to 12 volts for specific appliances. This makes an easier retrofit to existing homes because the converter can just be added near the appliances it serves.

Since current is lower when voltage is higher, the 24 or 48 volt DC circuit can be wired at much greater distances on smaller wires. Then the series in-line converter is connected at the end of the line, near the 12 volt appliances. This is practical for an office in a 24 or 48 volt home, where 12 volt telephone message machines, wireless phones, alarms, and intercom systems are all together in the office. This gives these appliances full-time, energy efficient electricity with no inverter involved. This application limits the 12 volt current to the maximum rating of the converter, and no surge power above that limit is possible.

Advantages of Series Converter

The chief advantage of using a series converter is that DC wiring in the power center and to outlets is all one voltage. If just a few appliances need a different voltage, or if the house never had any DC outlets provided, a series converter at point of need, even a distant point, is a quick way to gain the advantages of DC.

How DC Circuits Are Set Up

Many DC appliances used around the house need very low current, so conventional #12 or #10 Romex house wiring normally suffices, except for long runs to a refrigerator or large pump. The rumor that DC requires stranded wire is false. A given gauge of wire, whether solid or stranded, will carry the same current and have the same voltage drop.

I advise placing one DC outlet in each room in most new construction along with the standard number of AC outlets. In existing off-grid homes with a power center that takes DC

Eliminate Throw-Away Flashlight Batteries

Flashlights and portable gadgets like radios and tape recorders can switch to nickel-cadmium or nickel metal hydride batteries that can be recharged overnight for reuse hundreds of times. Recharging with a 12 volt DC powered charger avoids the inverter, which loses even more energy than the small amount stored in the flashlight batteries.

If the appliance powered by flashlight batteries is not portable, but used in a permanent location, it can be powered from the solar-electric house battery, avoiding the hassles of changing portable batteries. Any portable battery device uses only a tiny amount of energy, a barely noticeable load on a typical home battery system.

Voltage converters for this purpose are made in lower current ranges, from 1/4 to 2 ampere capacity, and convert 12 and 24 volts DC from the house battery to match various throwaway battery pack voltages. Most radios, tape recorders, baby monitors, and intercoms use two to eight AA, C, or D batteries, which add up to 3, 6, 9, or 12 volts. A few devices will convert up from a 12 volt outlet to 16 volts for notebook computers. You need only match the original voltage of the battery pack, and make sure that the converter used is rated for at least as high a current as the device requires.

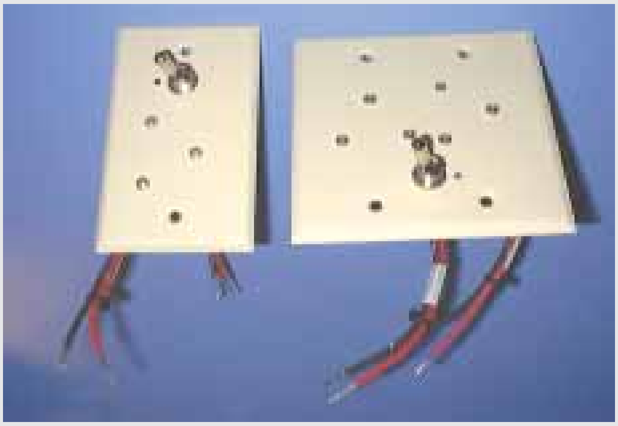
If there is no external power jack on the appliance, wires can be soldered to the contacts in the disposable battery compartment. As with all electronics, it is essential to get the positive and negative wires connected correctly the first time without reversing them, or the equipment can be ruined instantly. For overcurrent protection, use an in-line fuse appropriately sized for these appliances.

Consumer electronics stores like Radio Shack offer voltage converters to replace small batteries. These are intended for use in vehicles, so most are built in a plastic case in the form of a large cigarette lighter plug for automotive use. Another drawback is that most divide rather than regulate the 12 volts. For example, a 12 to 6 volt converter divides the input voltage in half, and it will produce 7 volts if your battery is at 14 volts. Current ratings vary from 1/4 to 1 amp or more. If these should overheat and fail, they may pass the full 12 volts through to the appliance, probably ruining it.

Zane International makes small, 2 amp and higher converters for 12 or 24 volt batteries that the user can adjust to produce most any voltage. Output is regulated to hold that voltage even if input voltage varies. Most are down converters only, and would not hold a given output if the house battery should drop close to or below 10 volts. However, Zane model 13700 will hold a steady voltage above or below your input battery voltage. Once it is set to 12.8, it holds stable 12.8 output to the cell phone even as input from house batteries varies from 11.5 to 15 during charge and heavy discharge cycles.

A typical cord supplied by Lind Electronics to power a notebook computer directly from 12 to 14 volts DC.

Small Zane converters are mounted on standard switch-plate covers to fit single and double-gang wall switch boxes.



DC Converter Test Data

Product / Circumstance	Idle Watts	Input Amps	Input Volts	Output Amps	Output Volts	Efficiency	Voltage Balance
Vanner Voltmaster 60-20A / equalizing	0.3	1.22	25.0	1.95	12.5	79.9%	12.43 / 12.44
Solar Converters EQ12/24-20 / converting 24 to 12	1.5	1.04	25.0	1.95	12.5	93.8%	12.45 / 12.46 after adjusting
Zane Solar-Down / mid to high power	0.3	1.34	12.0	1.34	6.0	50.0%	
Zane Solar-Down / low power	0.3	0.42	12.7	0.40	9.0	66.6%	
LIND 12–16 V computer power adapter cord	1.3	4.18	12.0	1.99	24.0	95.2%	

breakers, each DC circuit can be added as need arises. If just one or two circuits are needed, your existing DC power center usually has enough extra positions to install DC load circuit breakers. If a large number of low voltage circuits will be used, a separate breaker box for DC is best, like the Square D brand breaker box with "QO" series AC/DC rated breakers. Remember that circuit breakers or fuses on each wire are just as important for low voltage DC as for AC circuits.

DC outlets should be distinctly different from your AC outlets to meet building code as well as to prevent damage to equipment accidentally plugged into the wrong outlet. A good choice is the 240 volt AC duplex outlet, either 15 or 20 amp, which fits conventional AC outlet boxes and cover plates. They look like the standard 120 volt outlets except one or both prongs are turned 90 degrees, so AC appliances cannot be plugged into DC by mistake, or vice versa.

For easier identification, select a different color for the DC outlet and its cover plate. The 240 volt AC outlets are legal to use for DC circuits if you have no actual 240 volt outlet circuits in the house. Don't use the junky cigarette lighter plugs and sockets, which are poor quality and do not meet building codes.

AC/DC—Making Smart Decisions

In the end, I defend the modern inverter as the easiest way to run nearly any AC appliance. No longer would I change the motor on a washing machine to a DC substitute, as we did 30 years ago when good inverters did not exist. Nor would I want to see several and various DC voltage circuits running throughout the whole house for a mix of random appliances of various voltages.

But when confronted with operating an important electronic device that should be on duty full-time, DC connection has the advantage if the device needs very little electricity, and actually uses low voltage DC internally, with an easy way to input the DC.

Notebook Computers

A notebook computer usually kept at the desk doesn't need to constantly cycle or overcharge its internal battery. Notebook computers come with a cord containing an external converter to power them from 120 volts AC. You can order a DC power supply from most computer makers to operate the notebook computer from a 12 volt battery or a car's lighter outlet, even with the computer's rechargeable battery removed to avoid shortening its life. These cost US$70 to US$100, because notebooks usually require a boost to 16 volts to charge the internal battery (this may vary with brand).

Beware of computer catalogs that sell a cheap AC inverter to connect a 12 volt source to the notebook's 120 volt AC power supply cord. This cheap fix uses much more energy, because it converts 12 volt DC to 120 volts AC, and then the computer AC cord converts it back to 16 volts DC. The give-away is that these "12 volt computer power cords" connect to the computer's AC power cord. A real DC-to-DC converter cord uses far less energy by converting 12 volts directly to the computer's required voltage. It is identified by having the exact plug to match the DC connector on your notebook, never connecting to the computer's AC adapter cord.

A 240 VAC outlet (left) for DC circuits meets code and prevents damaging appliances with the wrong voltage and current.

For alarms, message machines, doorbells, cell phone chargers, and other applications discussed here, it is easy to wire a DC circuit. This offers simplicity and efficiency rather than sending your prized solar electricity on a roller coaster ride, converting up to 120 volts AC, and then taking it right back down to DC again for those appliances. Low voltage DC is always waiting right there in your battery bank, ready to use in the right application.

Access

Steve Willey, Backwoods Solar Electric Systems, 1395 Rolling Thunder Ridge Rd., Sandpoint, ID 83864 • 208-263-4290 • Fax: 208-265-4788 • info@backwoodssolar.com • www.backwoodssolar.com

Solar Converters Inc., C1-199 Victoria Road S., Guelph, Ontario N1E 6T9, Canada • 519-824-5272 • Fax: 519-823-0325 • info@solarconverters.com • www.solarconverters.com • DC voltage converters and motor speed controls.

Vanner, Incorporated, 4282 Reynolds Dr., Hilliard, OH 43026 • 800-AC POWER or 614-771-2718 • Fax: 614-771-4904 • info@vanner.com • www.vanner.com • Battery equalizers

Zane, Inc., 510 Fruitvale Ct #B, Grand Junction, CO 81504 • 970-523-5170 • Fax: 970-523-5170 • zaneinc@attglobal.net • www.zaneinc.com • Small DC-DC converters

Lind Electronics, 6414 Cambridge St., Minneapolis, MN 55426 • 800-697-3702 or 952-927-6303 • Fax: 952-927-7740 • lrlind@lindelectronics.com • www.lindelectronics.com • Custom and computer power supplies; Ask for unit with wider low voltage input tolerance, so it will not shut off due to low voltage line drop as if it were protecting a car's battery from discharge.

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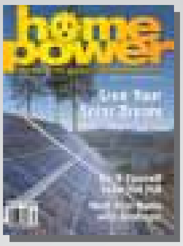

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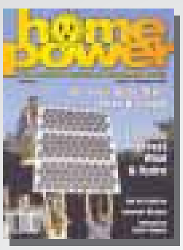

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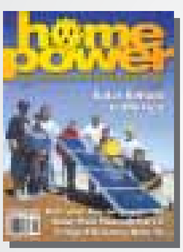

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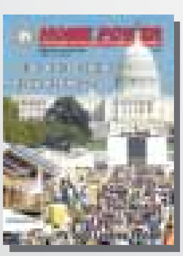

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Charging My Electric Vehicle

The Evolution of a Charge Profile Monitor

Joe Miller

Since getting "White Rabbit," our Voltsrabbit electric vehicle running (*HP92*), the care and feeding of the vehicle's battery pack has become a big issue. Everything I read warned me that the average newbie (like me) would likely churn through the first battery pack within a year.

Unlike leaving a flashlight on, where a pair of AA batteries will cost a couple of dollars, the battery pack of an electric vehicle represents a substantial portion of the cost of ownership. My car is fairly typical, with twenty, 6 volt, flooded, lead-acid batteries. They are model #US-125, made by U.S. Battery, and rated at 235 amp-hours. The twenty batteries, with shipping, cost nearly US$1,400, and I want to make them last as long as possible.

Once the batteries were in the car, and the Russco SC 18-120 battery charger was properly connected, I was able to check the voltage on the twenty batteries–about 120 volts. Fully charged, I thought…but *wrong!* At rest (no charge or discharge for six hours minimum) a fully charged 6 volt battery will have a voltage of 6.37 volts at 80°F (27°C). When it reads 6 volts at rest, it is 50 percent discharged.

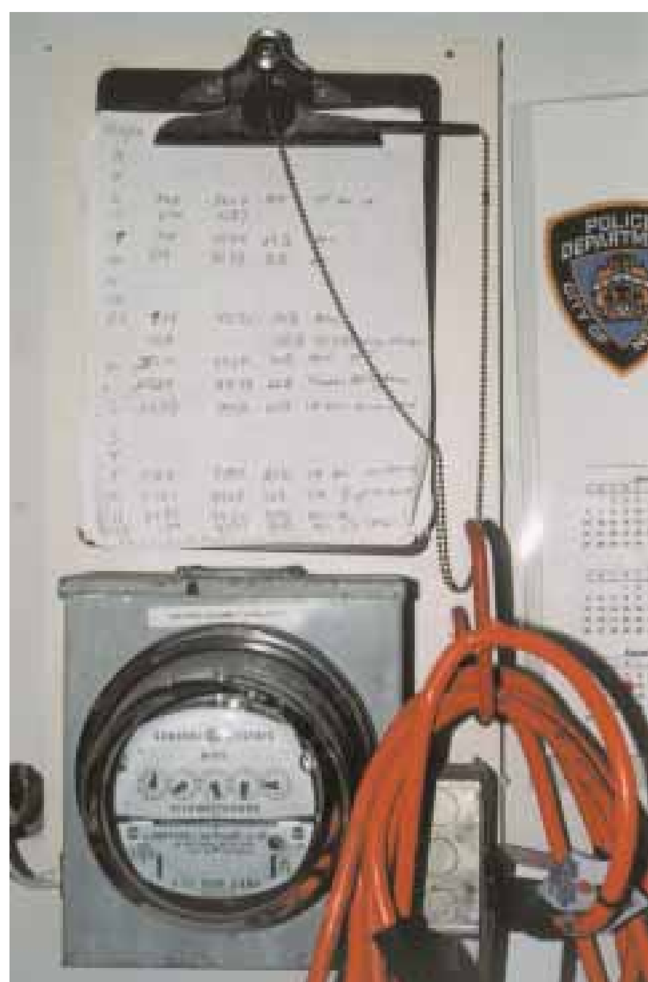
This was news to me. It also quickly became clear that knowing the voltage across the battery bank only tells part of the story. Assuming that each battery in the string is at a similar voltage is a recipe for disaster.

The Ins & Outs of Battery Usage

Battery capacity is rated in amp-hours. The more amp-hours, the more work the battery can do before it becomes discharged to a point where it can no longer do its job (getting me home at the end of the day). A battery charger is labeled in two ways: the nominal voltage (a characteristic of the battery it is intended to charge, determined by the number and type of cells within the battery) and the number of amps it can deliver

The charge profile monitor is normally installed in the electric vehicle, but can be removed to monitor the charging of an individual battery.

A KWH meter and clipboard for recording data.



(determined by how robust the charger is internally, and the outlet it is plugged into).

The amount of energy a battery can hold is determined by the battery voltage and its amp-hour capacity. Electricity is purchased in units of watt-hours (WH) or kilowatt-hours (KWH). Leaving a 100 watt light bulb on all day (24 hours) will consume 2,400 watt-hours, or 2.4 kilowatt-hours—about 25 cents worth of electricity where I live.

So if I wanted to keep track of how efficiently my car was running, I needed to monitor the kilowatt-hours going into the battery pack. The simplest way of doing this was to monitor the 120 volt AC going into the battery charger.

Charge Profile Monitor

The charge profile monitor is ready to go. To the left is the Fujitsu IBM compatible computer, keyboard not attached. The yellow cable connects the computer to each of the Radio Shack digital multimeters (DMMs). One DMM records the total voltage across the battery pack during charging. The other records the charge current (by recording the voltage drop across a small shunt resistor). The Plexiglas cover protects the equipment from accidental damage, with two holes to allow access to the DMMs.

Utility Meter on the Wall

Before I started driving the car, I purchased a KWH meter from the local electrical supply house for around US$30. I also went to a salvage yard and purchased the meter housing for around US$10. I added a big extension cord, and I was in business.

By using the KWH meter, I thought I could keep track of how much energy (KWH) was going into the battery pack. At the end of each day, before plugging in the charger, I recorded the odometer reading, the KWH reading, the state of charge, and any notes as to how the trip went. My hope was that this log would tell me how well I was charging the car.

In the first few weeks of using the car, it appeared that I was using about 0.6 KWH per mile driven—a figure about twice what I expected. But I discovered that what is often reported as the number of KWH consumed per mile is measured in the car while driving. There are conversion losses in the charger, and in the batteries themselves. Additional losses are associated with bringing the batteries up to a finish charge voltage.

Installing the KWH meter proved to be useful, for it forced me at the end of each day to think about the state of the batteries and the car. A sense of “feel” started to develop about how the car was doing at the end of a drive. By seeing how many miles were traveled, I became aware of problems as they developed.

Two Problems

Two problems in particular became apparent by comparing the miles driven to how the car “felt” upon return. One battery post failed early, apparently due to a hairline crack that developed. When 400 amps are being drawn from a battery pack, small resistances can result in a great deal of heat! Fortunately, the problem was quickly resolved, first by jumping past the battery, and then by replacing it.

The second problem became apparent a few days after checking the water level in the batteries. When reinstalling the “speedcaps,” a nice feature of these batteries, I did not seat one of the cells’ caps properly, and the fluid level in the cell dropped very quickly. As soon as I noticed the problem, I added water, pulled the battery, and placed it on an extended charge, frequently adding water. After reinstalling the battery, it seemed that performance was back to normal, and I was hopeful that no serious damage had been done.

However, about a month later (after driving about six months total), I noticed a very sudden drop in range to a level about half of what I expected. Every day is different in terms of how many miles I drive, but I nearly always spend about four hours a day at my office. I had obtained permission from my employer to charge the car at work, which prevented me from excessively draining the batteries, and provided needed flexibility for stops on the way home.

For the month prior to this sudden drop in range, the outlet at work was not available due to construction. Instead of being able to charge the batteries for four hours before driving home, the car was sitting partially discharged, and I limped home on a low battery bank.

A few weeks of this and the range started to fall, until suddenly I was having difficulty driving 20 miles (32 km) between charges, where I had been able to go 50 miles (80

Battery Diagnostic Info

Charge	SG*	6 V	12 V	24 V	36 V	48 V
100%	1.277	6.37	12.73	25.46	38.20	50.93
90%	1.258	6.31	12.62	25.24	37.85	50.47
80%	1.238	6.25	12.50	25.00	37.49	49.99
70%	1.217	6.19	12.37	24.74	37.12	49.49
60%	1.195	6.12	12.24	24.48	36.72	48.96
50%	1.172	6.05	12.10	24.20	36.31	48.41
40%	1.148	5.98	11.96	23.92	35.87	47.83
30%	1.124	5.91	11.81	23.63	35.44	47.26
20%	1.098	5.83	11.66	23.32	34.97	46.63
10%	1.073	5.75	11.51	23.02	34.52	46.03

*Note: Specific gravity corrected to 80°F (26.7°C).
All voltages are "at rest"—no recent charge or discharge.
Table data courtesy of Trojan Battery Company.

km) on a single charge, and 60 or more (96+ km) with some charging at work. Where previously I hadn't thought much about where I was going during the day, planning the day's travel became an obsession, for fear of getting stranded somewhere.

The Great Equalizer

Apparently, I had allowed my battery pack to get out of balance. Each battery is slightly different in how it behaves as it is charged and discharged, despite the fact that all the batteries are in series with each other, and the same load is applied to each.

How these differences evolve over time may be influenced by various things. Variation in temperature is one factor. At the edge of a pack, batteries are more influenced by ambient temperature, while in the middle of a pack, the temperature is more influenced by the neighboring batteries. Another factor is the cleanliness of the batteries. Spilled acid allows some batteries to discharge spontaneously from one battery terminal to the other. Finally, the care with which the battery water level has been maintained can vary.

As the battery cells develop differences in their internal resistance to taking a charge, some batteries are fully charged before others. The total voltage across the pack is limited by the battery charger. As a result, an imbalance can develop where some of the batteries are overcharged habitually (resulting in gas formation and excessive water consumption), while other batteries are left undercharged (resulting in a buildup of sulfate on the cells, making charging even more difficult). A little investigation revealed that the most likely problem with my battery pack was a need for an equalization charge, also known as "controlled overcharging."

Diagnosis

There are at least three ways to diagnose a pack that is out of balance. The first way is to measure the specific gravity of the electrolyte within each cell following the completion of a charge. This is measured with a hydrometer. As a battery gains charge, the density (specific gravity) of the electrolyte solution increases, as more sulfate ions go into solution from the battery plate. The density of the electrolyte can increase by as much as 25 percent. An equalization charge produces a high enough voltage across all the batteries to allow each battery to become fully charged, with all battery cells having the maximum amount of sulfate ions moved into solution in the battery acid.

The second method to detect an out-of-balance pack is to measure the voltage across each battery while a load is applied. Practically speaking, this is difficult in the extreme without special wiring, since it is necessary to perform the battery measurements while driving the car.

The final method, similar to the second method, measures the voltage across the pack while the battery pack is being charged (rather than discharged). It is much easier to get under the hood of the car and measure voltages while the car is parked and plugged in, rather than running. Here, the voltage of the out-of-balance battery with its higher internal resistance will increase more slowly than its neighboring batteries, and will not complete its charge cycle as quickly. Frequently the pack as a whole will achieve a high enough total voltage to cause the battery charger to prematurely shut down, resulting in the one weak battery being prevented from achieving a full charge.

The Charge Profile

As a battery is charged, the current accepted by the battery varies over both time and voltage between the terminals. To be fully informed about the charge cycle, it is necessary to measure three quantities: the pack voltage, the charge current, and time. This requires more information than my KWH meter alone could provide.

Although it is possible to use a special instrument called a clamp meter to measure the amperage through a wire, it is more customary to measure the voltage drop across a shunt, a calibrated very low resistance conductor that is inserted in series in the circuit.

While several excellent lower-current shunts (developing 50 mV drop at 50 amps) are commercially available, I chose to construct my own shunt for both reasons of cost and sensitivity. After some experimentation, I found that a copper pipe hanger provided about 1.66 mV drop per amp. I mounted the shunt in an aluminum box along with a pair of Anderson connectors, so it could be inserted when needed between the charger and the battery pack.

I also included a current limiting resistor for the battery voltage test point. Use of this resistor limits the current to a few milliamps in the event of a short circuit. Though I have a fuse in the circuit, a lot can happen before the fuse blows! The resistor will affect the accuracy of analog meters, but digital multimeters (DMM) typically have input impedances measured in mega-ohms, and are minimally affected by the introduction of this safety measure.

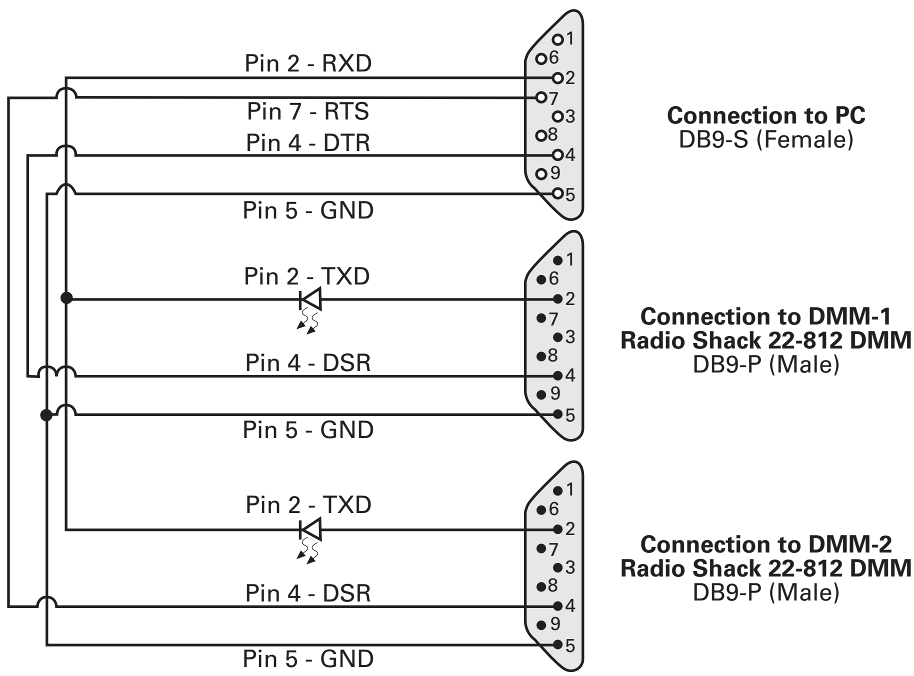
This setup allowed me to monitor the charge profile by first measuring the voltage across the pack, and then moving the meter to measure the voltage across the shunt. My family began to question my devotion to them relative to the car after getting up and going out to the garage every ten minutes or so to record the charge profile. And the most inconvenient issue was that the interesting portion to me was the end of the charge cycle, rather than the beginning or the middle. Getting up in the middle of the night to check the batteries was not an option!

Automation to the Rescue

I considered several options, including getting a second DMM and using our family camcorder to videotape the meter displays. Then I saw that Radio Shack was having a sale on their DMM that provides serial output to a computer. It comes with software that will run on a Windows computer, allowing an automated record of time and voltage to be generated at user selectable sampling intervals. I purchased one and was pleased to be able to record one channel of data. However, there was no way to use the program with two DMMs (to record both volts and amps), and I did not have two laptop computers to use.

After some experimentation, I found that the Radio Shack DMM would transmit its data only after one of the input lines was connected to a plus voltage. This meant that it would be possible to connect two DMMs to a single computer, and switch between them by selecting one of the two using computer controls. The serial port on IBM PC computers has two output lines (DTR, pin 4 and RTS, pin 7) that can be controlled, and with a little programming, I was in business. The Radio Shack Web site documented the encoding used to transmit the reading from the DMM.

Digital Multimeters (DMM) to Computer Connections



A custom cable connects the two digital multimeters to the tablet computer.

Some Construction Required

A special cable was constructed that allowed the laptop to connect to two DMMs (see above schematic). I purchased an RJ-45 "patch cable" and cut off both ends for the wire (it has eight conductors; four are required). LEDs mounted on the DMM DB-9 connector serve two functions. They allow each DMM output to not interfere with the other, and provide a visible indication that data is being transmitted.

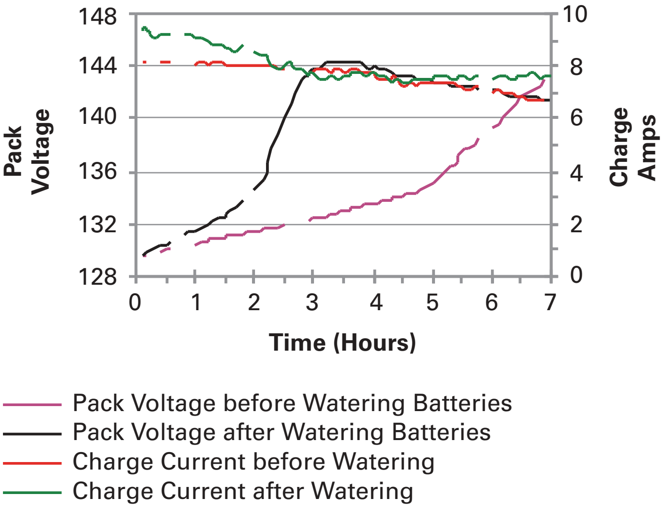
My program "DualDMM" was written in Visual Basic Version 6.0 and is available for download from the *Home Power* Web site in the Promised Files section. If you choose to do it in another programming language, the instructions for decoding the output from the RS 22-812 are available on the Radio Shack Web site, or can be hacked from my Basic program.

The program flow is quite simple: DMM1 is selected by enabling the DTR line. A delay of about 15 seconds passes to allow the output to stabilize, and DMM1 is sampled. The DTR line is then set low, the RTS line is asserted, another 15 seconds passes, and the second DMM is sampled. The results are written to the display, as well as to an output file.

It is important to realize that the DMMs must be "floating" with respect to the shunt and battery. This means that the DMMs must either be battery powered, or powered by independent power supplies that provide DC isolation. Radio Shack wall warts work just fine, and cost about as much as two 9 volt batteries.

I chose to mount the finished assembly so that it could remain in the vehicle, and record charge cycles that occur at work as well as at home. Since we had recently installed a WiFi network at home, I splurged and bought a wireless card for the tablet computer, an old touchscreen portable

Pack Voltage & Charge Current vs. Time



with (just) enough horsepower to run Windows 95. This solved the interface and cabling problem completely! Now I can check the charge status from my desk, since the tablet computer appears as a shared hard drive on my main computer.

Using the Data

I am still learning how to interpret the data from the charge profile monitor, but the value of some information regarding the charger performance at the end of the charge cycle is already apparent. Viewing the charge profile graphs, a much more abrupt and uniform "end of cycle" is seen after watering the batteries as compared to before watering.

The two sets of charge cycles illustrate that the end-of-charge condition changes with pack internal resistance. The graphs both start at the same pack voltage; the charger had been running for an unknown period of time to reach the same voltage. The data demonstrated the need to add water to the battery pack. (Of course, the fact that it was hotter than hell in Tucson should have been a clue.)

Before adding water to the pack, there is charge going in but it is converted to heat (excessive boiling, gassing). Because the battery charger is current limited, only so much charge is available to those batteries still able to accept charge. The pack voltage is slow to rise, with a poorly defined end point. After adding water to the battery pack, there is less gassing early in the charge. All the batteries are able to take charge more readily, and the end-of-charge rise in voltage is more abrupt and uniform. More of the charger output current is available to charge the battery, and less is wasted in gassing.

The current profile tells a different part of the story. Both before and after the battery pack is watered, the current fails to drop, since the maximum pack voltage of around 150 volts is never achieved. My battery charger is unable to fully charge the battery pack during the limited time that the car is charging at night. The data supports the use of a higher-capacity charger that would fully charge the batteries and promote the overall health of the battery pack.

It is a logical step to think about integrating control of the battery charger with a computer controller. However, before I proceed in that direction, and run the risk of either seriously over or undercharging the battery pack, some reliability issues will need to be addressed.

Note the gaps in the graphs: those gaps occurred because of glitches in the DMM sampling software. I would recommend that before any "mission critical" applications are assigned to software of this type, as many failure modes be contemplated and protected against as possible.

The current software may prove to be a useful starting point to others in controlling custom chargers. Be careful, and be sure to build enough mechanical and clockwork fail-safes into your charger that if a glitch does occur, it doesn't trash your expensive battery pack!

While the Radio Shack DMM can report data far more frequently, I usually configure the software to sample one time every six minutes, or ten times an hour. This allows easy calculation of amp-hours and kilowatt-hours.

The program allows me to verify that I have the charger voltage and current settings properly adjusted, and to predict how long a charge will be required. Most important is that it has provided me with more information to help preserve the life of the battery pack, and to watch for wasteful overcharging.

Access

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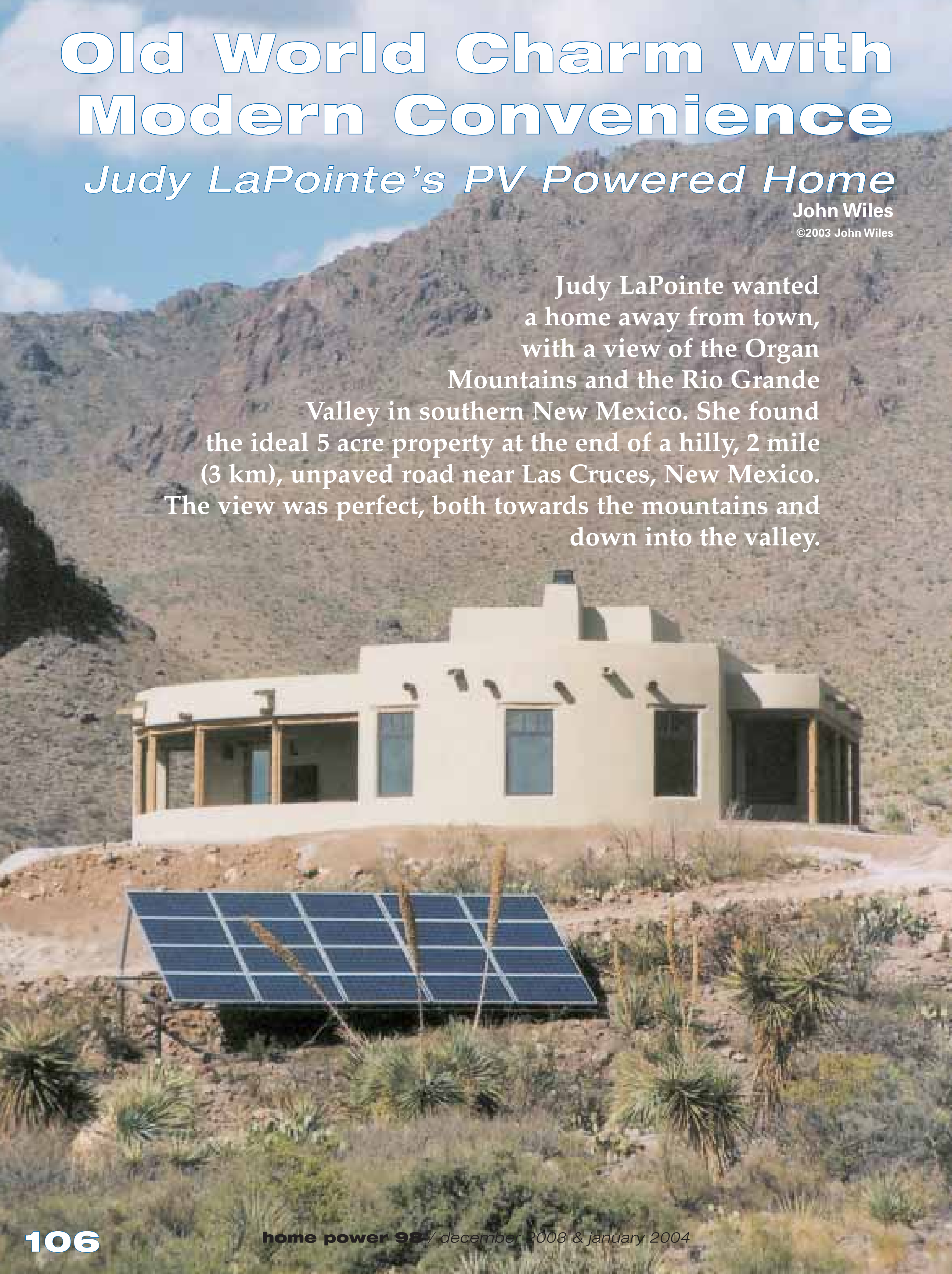
Halted Specialties, 3500 Ryder St., Santa Clara, CA 95051 • 800-442-5833 or 408-732-1573 • Fax: 408-732-6428 • sales@halted.com • www.halted.com • Fujitsu Stylistic 1000 tablet computer • DMMs

Microsoft, One Microsoft Way, Redmond, WA 98052 • 800-426-9400 or 425-882-8080 • Fax: 425-936-7329 • www.microsoft.com • Microsoft Visual Basic compiler

Old World Charm with Modern Convenience

Judy LaPointe's PV Powered Home

John Wiles



Judy LaPointe wanted a home away from town, with a view of the Organ Mountains and the Rio Grande Valley in southern New Mexico. She found the ideal 5 acre property at the end of a hilly, 2 mile (3 km), unpaved road near Las Cruces, New Mexico. The view was perfect, both towards the mountains and down into the valley.

Judy LaPointe in front of the PV power panel.

Judy's pueblo-style home is about 1,800 square feet (167 m^2), plus a two-car garage, and is made with Perform Wall. Perform Wall is made of 85 percent recycled Styrofoam and 15 percent Portland cement. It looks and stacks like long cinder blocks (10 feet long by 10 inches wide by 15 inches high; 3 m x 25 cm x 38 cm), and has cores filled with rebar and concrete. The 10 inch Perform Wall has a laboratory tested (real) R-value of about 11. The high thermal mass due to the concrete mixture and concrete core may yield a higher effective or dynamic R-value that may be as high as 30 in some climates.

The inside walls of the home are plastered and the outside walls are covered with stucco. This construction is quite solid, has a four-hour fire rating, is very quiet inside, and is insect and rodent proof.

Traditional & Contemporary

The house, designed and built by architect and builder Colleen Boyd, has traditional and contemporary features. A recycled basketball court floor was laid over the concrete slab in portions of the house for a beautiful and durable hardwood floor. Southwest-style ceramic tiles cover the rest of the floor. A *kiva* (Native American) fireplace, and high *vigas* (wooden beams) supporting an exposed wooden ceiling, coupled with restored antique doors, complete the great room. An enclosed porch has tiles, with a rustic ceiling of *latijas* (small sticks).

A modern kitchen (with a tin plate ceiling), two bathrooms, and a radiant floor heating system ensure comfort and convenience. The propane range is a Pro 30G by Premiere-Peerless, and uses a low-power electronic spark system to light the oven and burners. Most of the electrical appliances are Energy Star rated. Manual switches are installed on the satellite receiver, VCR, and other devices that represent significant phantom loads.

The radiant floor system uses DC circulating pumps rather than AC zone valves, and uses very little energy from the PV system. Potable hot water is heated by a Heliodyne GOBI solar hot water collector with a separate PV module for the circulating pump. The boiler used for the radiant floor heating system provides backup. A special controller provides low-energy AC and DC control to the boiler and circulating system. High quality, low-E windows are used throughout the house. The cooling system is set up for either an evaporative cooler (swamp cooler) or central air conditioning.

The potable water and radiant floor system components live in the garage.

Electricity & Water

When Judy bought the site, there was no electricity or water on the property. Utility lines were 0.5 miles (0.8 km) away, and the local utility wanted more than US$35,000 to provide electricity to the property on overhead lines. These poles and lines would spoil the magnificent view of the mountains. The utility was hesitant about even quoting the cost of underground service, which would involve trenching, blasting, and encasing the lines in concrete. Judy LaPointe opted to have a photovoltaic (PV) system installed to provide for her electrical needs. She asked me to design the system and supervise the installation.

Wells in the area are 800 feet (244 m) deep, with the water rising to about 700 feet (213 m). A well and 1.5 hp centrifugal pump would cost about US$20,000 or more. Judy elected to install a 1,700 gallon (6,435 l) storage tank and have her water hauled in by truck from a source about 3 miles (5 km) away. A Dankoff positive displacement pump, operating at 24 volts DC, was selected to pressurize the system and serve as a transfer pump to fill the storage tank.

PV System Design

The 3,300 watt PV system and the basic design and system schematic for this project were presented in *Code Corner* in *HP94*. The detailed code-required electrical calculations were described in *Code Corner* in *HP95*.

Twenty, Sharp NE-Q5E2U, 165 watt PV modules are connected at 48 volts in two sets of ten modules on a fixed ground mount, tilted at about 30 degrees from the horizon. The local latitude is 32 degrees north. Each set of ten modules is combined to a single source circuit in a Xantrex TCB-10 combiner box mounted on the array supports. The two source circuits from the PV array are connected to two RV Power Products Solar Boost 6024H maximum power point tracking charge controllers.

Sixteen, Trojan L-16HC batteries with Hydrocap recombiner caps are used for 24 volt storage, and are installed in sets of four in heavy-duty polyethylene toolboxes connected by conduit. A Xantrex SW4024 inverter is used for AC electricity for most of the house. An Onan Marquis Platinum 6.5 KW generator runs on propane and supplies backup as needed. The 24 volt battery bank is tapped at 12 volts to start the generator. DC electricity at 24 volts is used for the pressure pump and the radiant floor circulating pumps.

The original system design started with 1,800 watts of PV modules, but recent module cost reductions allowed the PV array to be increased to 3,300 watts without significantly exceeding the overall budget. The added output from the array makes it possible to consider putting in conventional air conditioning and a well with a submersible pump at a later date. Adding refrigerated (traditional, compressor driven) air conditioning may be desirable to cope with the windy, spring months when pollen and dust may pose allergy problems.

With the automated features built into the charge controllers and the inverter, the only routine maintenance will be adding water to the batteries every month or so. The Hydrocaps will minimize that watering need, since they return water to the batteries via the catalytic action of recombining the escaping hydrogen and oxygen gas produced when the battery is charged. Oil and filter changes will be required on the generator, but use is expected to be less than 100 hours per year, so this maintenance will be infrequent.

Grounding & Lightning Protection

Code-required grounding is accomplished by a main grounding electrode consisting of a 120 foot (37 m), bare, #4 (21 mm^2) copper conductor embedded in the concrete footing beneath the slab. Only a 20 foot (6 m) length is required to meet *National Electrical Code* (*NEC*) requirements. The additional length was used to provide a better ground for lightning protection in this very dry, rocky area.

Two, supplementary, 8 foot (2.4 m) ground rods were to be driven at the array location and tied to the equipment-grounding conductors that ground the module frames and the array mounting structure. The rocky terrain prevented driving them in vertically or at a 45 degree angle, so they were installed horizontally in trenches 30 inches (76 cm) deep. These ground rods, along with the concrete encased mounting poles for the array rack, make up a

La Pointe System Costs

Item	Cost (US$)
20 Sharp NE-Q5E2U Modules, 165 W	$13,200
Onan Marquis Platinum generator	4,170
Xantrex SW4024 inverter	3,200
16 Trojan L16HC batteries, w/ boxes, cables, & terminals	3,115
5 Power Fab module racks	1,250
2 RV Power Products SB6024HDL controllers & display	1,050
Conduit	650
Rack support structure	500
Electricity & data cables	500
Misc. hardware & supplies	500
2 Xantrex TCB-10 PV combiner boxes	440
Generator controls	341
Xantrex SWRC/50 remote display	290
Xantrex DC-250 battery disconnect	280
6 Delta LA302 surge arrestors	270
Grounding rods & cables	250
Xantrex TM500 battery monitor w/ shunt	225
2 RV Power Products SB50RD25 remote displays	190
Heinemann 175 amp PV main breaker	175
2 House interface enclosures, 20 x 20 x 8 inches	150
System labels	125
Xantrex SWBC conduit box	80
30 ILSCO grounding lugs & screws	75
2 Heinemann 75 amp CD PV input breakers	70
200 Module USE-2 interconnect cables	56
3 NSI PL4-4 connectors	51
2 RV Power Products 930-0022-20 battery temp sensors	50
Xantrex DCBB ground block	45
Xantrex battery temp sensor	35
Plywood back panel	32
20 Cable clamps, rubber/stainless	30
White enamel paint	30
Square D QO612L100S inverter bypass enclosure	25
Square D QO270 bypass breaker	25
Square D QO170 bypass breaker	25
20 Littelfuse TCF10 fuses, 10 amp	24
12 Heat shrink tubing	15
Square D QO2DTI interlock bar	15
Square D P7GTA ground bar	6
Total	$31,560

Technical Specifications

System Overview

System type: Off-grid PV

Location: Las Cruces, New Mexico

Production: 350 AC KWH per month average

Photovoltaics

Manufacturer and model: Sharp NE-Q5E2U

Number of modules: 20

Module STC wattage: 165 W

Module nominal voltage: 24 VDC

Array STC wattage: 3,300 W

Array nominal voltage: 48 VDC

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

Array disconnect: Xantrex DC250 enclosure with one 75 A breaker for each subarray, and one 175 A main PV breaker

Array installation: Power Fab DP-RGM4-SH165 ground-mount, facing due south, tilted at latitude

Charge Controller

Manufacturer and model: Two RV Power Products SB6024 HDL

Features/Description: MPPT, step-down

Inverter

Manufacturer and model: Xantrex SW4024

Nominal DC input voltage: 24 VDC

Nominal AC output voltage: 120 VAC

Battery

Manufacturer and model: Trojan L-16HC

Battery type: Flooded lead-acid

Individual battery specifications: 6 VDC nominal, 390 AH at the 20-hour rate

Number of batteries: 16

Battery pack specifications: 24 VDC nominal, 1,560 AH

System Performance Metering

RV Power Products digital meters on two charge controllers; two remotes in house

Xantrex SWRC remote control for inverter in house

Xantrex TM500 battery monitor in house

Engine Generator

Manufacturer and model: Onan Marquis Platinum

KW rating: 6.5 at sea level; 6.0 as installed

AC output voltage: 120 volts AC

Average annual run time: 100 hours, estimated

Battery row—sixteen L16HCs in four polyethylene tool boxes.

supplementary grounding system for added safety and lightning protection.

A #6 (13 mm^2), bare conductor was attached to each module frame with outdoor-rated, direct burial connectors, and then routed without splicing to the nearest ground rod and to the combiner box for that subarray. A ground rod is also driven at the generator and connected to the generator frame.

In addition to the heavy-duty grounding, each PV source circuit has a lightning arrestor installed at the array end in the combiner box, and at the charge controller end of the circuits between the array and the charge controllers. The AC line from the generator also has a surge suppressor, as does the inverter AC output

Unspoiled View

Judy LaPointe has moved into her new home and is enjoying the view of the mountains and the valley, unspoiled by utility lines. The PV system has supplied all of her electricity this summer, and she expects only minimal use of the very quiet generator this winter. The solar hot water system is working well, and she is anticipating the comfort of radiant heated floors when it gets cold. Great views unmarred by utility lines, with no worries about rate increases, brownouts, or blackouts—what more could a person want?

Access

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Colleen Boyd, Boyd Design & Construction, Las Cruces, NM • 505-522-2464 • cb@boyddesign.com • Architect/Builder

Bristol Stickney Consulting, PO Box 533, Tesuque, NM 87574 • 505-989-7029 • bristol@cybermesa.com • Radiant floor heating and solar hot water

A Little History

Don Loweburg

Most *Home Power* readers know that the National Renewable Energy Laboratory (NREL) carries on basic research in renewable energy. Many solar designers are also familiar with the "Red Book," NREL's listing of solar data for many locations in the United States, titled *Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors*. You may not know that NREL is but a remnant of a much grander vision initiated by the Carter administration following the energy crisis of the 1970s.

I discovered this bit of history while reading a short article by Denis Hayes in the November/December 2002 issue of *Solar Today*. In "SERI: The Highs, the Lows, the Legacy," Denis reminisces about his leadership role at the Solar Energy Research Institute (SERI), which later became NREL.

Denis writes, "My dream—largely realized before the Reagan administration came to power—was to build a team that approximated a Manhattan Project for solar energy. We had an incredibly talented group of physicists, chemists, biologists, engineers, architects, economists, legal scholars, anthropologists, meteorologists, statisticians, and others, all engaged in a common effort to build a renewable energy future." Three of these people went on to win Nobel prizes in their respective fields.

At its peak, SERI was spending more money and achieving more than all the other labs in the world combined. Then the Reagan administration made a US$100 million cut in SERI funding, reducing the staff by 50 percent. The Reagan axe job on SERI was followed by the removal of the solar hot water panels from the White House. Hayes remarks, "The Reagan Administration's conscious decision to abandon that leadership role (in renewable energy) may eventually come to be viewed as its stupidest single act."

Cost of a Failed Energy Policy

Today the leadership role belongs to Europe and Japan. And the United States government is still not addressing the root issue of its energy challenges—such as the euro out-valuing the dollar, the United States becoming a debtor nation in the mid-1970s, and the fact that dollars and lives are lost occupying oil fields in Iraq. All of these issues are related to the United States' unsustainable energy policy. And our government continues to devote meager resources to renewables.

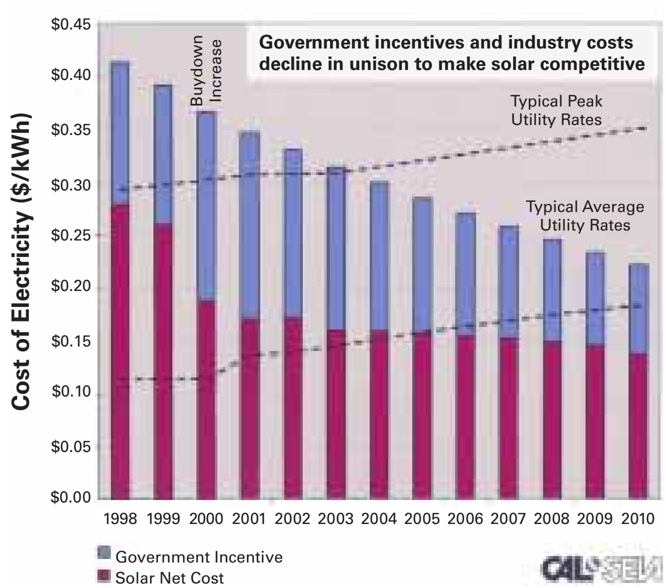
The recent blackout on the East Coast is another symptom of the country's energy problems. It was interesting to hear various experts call for more transmission capacity, debating how much it would cost and who would pay. Almost no one asked whether distributed generation (DG) and renewables offer a solution. Though the United States Department of Energy is doing great work on DG, their message fails to make it to the policy level. Inaction will not make the problems go away!

Now more than ever, we need a Manhattan-scale effort for renewables, coupled with a national upgrade of the grid, tailored to maximize the benefits of distributed generation. The old guard mentality still rules, favoring an increase in bulk transmission capacity and more central station generation. This approach is doomed to fail. It rewards the perpetrators of the current problems.

Capitalizing the Future

Subsidies might be called investments in the future. Reflecting on technologies that have revolutionized modern life, such as cell phones, transistors, integrated circuits, jet engines, recombinant genetic technologies, and AIDS research (just a few examples), we can see that all have been subsidized. Few people would begrudge these subsidies. Each of the technologies mentioned has realized huge returns on the initial investment.

Projected Solar Incentives & Utility Rates



Historical Utility rates: CEC, CPUC. Future utility rates assume 3% per year increase. Government incentives reduced 10% per year beginning 2004. Levelized solar cost based on a blend of large and small scale systems financed over 30 years, declining at a historical rate of 5% per year

Assuming that subsidies are investments in the future, the question is not whether subsidies are good or bad, but rather, why some technologies are subsidized and others are not. In the case of energy, it is very clear that through the political process, the existing large energy corporations are creating barriers to the adoption of renewables.

States Take the Lead

Many state governments have taken the lead in renewable energy deployment, implementing state-level incentive plans. Among the states listed on the national listing of incentives at www.dsireusa.org are New York, California, New Jersey, Montana, Delaware, Wyoming, Oregon, Wisconsin, Washington, Illinois, Massachusetts, and Arizona. All these states have some sort of incentive for grid-connected PV, and a couple for off-grid. The energy leadership in these states should be applauded. However, these programs fall far short of the Manhattan-scale effort that will be required to establish renewables as a significant energy resource in the United States.

California's incentive programs, coupled with high utility rates, have resulted in the state leading the nation in installed, on-grid PV. It is estimated that about 60 MW of PV will be grid connected by the end of 2003. This total includes all programs—CEC rebate, CPUC rebate for large systems, and the incentive programs operated by the municipal utilities. This 60 MW is generated by more than 6,000 installed systems. As grand as these results are, some alarming facts emerge when examining the most recent rebate data from the CEC rebate program.

Trouble on the Horizon

Last March (2003) marked the restart of the rebate program after several months of inactivity. Whether it was pent-up demand due to the interruption itself or the resolution of the "solar tax" assault that resulted in renewed interest in PV, new applications for the rebate soared. Since the restart of the program in March '03, the California Energy Commission has received more than 5,000 rebate reservations.

The resources needed to review these applications are thinly stretched, with more than 1,500 applications backed up awaiting review. A quick scratch pad estimate of the funding required to fulfill these reservations received since March '03, predicts that sometime in early 2004, the funding for this program will again be depleted. Funding that was intended to last four years will be gone in less than one year.

Good News—Bad News

The good news part of this story is that there is a tremendous demand for PV in California. As mentioned before, this can be attributed to the availability of the rebates, high utility rates, and a very high level of support for renewables and especially PV among the citizens of California. The bad news is that the on-again, off-again nature of the rebates is creating problems for the installing companies and suppliers.

This also creates uncertainty in the buying public and to some extent distorts purchasing decisions. Either customers believe the rebates are not available and do not purchase PV, or they believe they must make a rushed decision to get a rebate before the money is gone.

Such are the "problems" of success. Certainly there are no bad guys in this picture. In fact, the California Energy Commission has been very supportive, and has supplemented the available funds by US$40 million this year. But the buydown account may still be out of money by early to mid-2004.

Momentum Must Be Maintained

State government, manufacturers, installers, dealers, and customers—no one wants a stop-and-go market caused by interruptions of funding. It is clear that there is strong demand for solar electricity in California. It is imperative that the momentum be maintained. Members of the solar industry in California are working on a long-term vision for sustainable incentives. As a key element of this vision, incentives, declining at a rate coupled to the decline of the cost of PV modules, would be in place till 2010. With the average cost of utility electricity rising and the cost of installed PV declining, the two would converge.

In fact, in California, the cost of PV is already comparable to the peak cost of utility electricity! It's been a mistake to assume that PV must compete with *average* utility prices. PV starts becoming cost effective as soon as it can compete with *peak* utility prices (see graph). This is the situation in California today, and explains the growth of PV there.

The next phase of funding must sustain the PV trajectory until PV is competitive with the average cost of utility electricity. In California, this very important vision needs the support of state government, the citizens of California, the PV industry, and media. All these forces acted together before in the defense of solar energy (see "A Cliff Hanger" in *HP95*), and will need to act in concert again to anchor PV into the energy mix for a California RE future.

Of course this is still no Manhattan-scale project. However, numerous mini-Manhattan projects on the state level could accomplish what the federal government refuses to do—affirmatively establish renewables and PV as preferred energy sources for the nation.

Access

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Database of state incentives for renewable energy • www.dsireusa.org

National Renewable Energy Laboratory (NREL), 1617 Cole Blvd., Golden, CO, 80401 • 303-275-3000 • public_affairs@nrel.gov • www.nrel.gov

Solar Sebastopol

Community Energy Project

Michael Welch

I have become an energy fair groupie. If one is within range, you can count on me showing up. Last August when I was visiting a friend in Santa Rosa, California, there was an energy fair in nearby Sebastopol. I was prepared for the normal hobnobbing with the public and the usual RE suspects. What I didn't expect to see was the incredible relationship that the city of Sebastopol is building with renewable energy.

The fair itself was excellent. RE product sales were not high, but the exposure was also mostly to folks new to RE, rather than the folks already into it and living with it. There were lots of booths, as many RE dealers as I have seen at any fair, and the usual food, music, and workshops, too. About 1,500 people attended the fair. That is not a big fair, but the people were more interested than usual in becoming new RE system owners.

The uniqueness was that with a few exceptions, the fair was aimed at the urban grid-intertie market. It was also different that a government agency was primarily responsible for the event's ultimate goal of one megawatt of PV to be installed on the rooftops of this small town by 2005.

Inspiration

The project got started when a class at nearby Sonoma State University (SSU) researched and published a study showing that 1,000 to 1,500 KW of PV could be installed on Sebastopol rooftops, financed by issuing municipal bonds. The May 2002 study concluded that the city could significantly reduce the costs of these installations and make them more attractive to homeowners by becoming a "facilitator," taking care of financing and transaction costs, and getting the public and businesses interested.

Sebastopol's city council was ready to find ways to provide RE for the community. They had grand visions of creating financial incentives for solar and wind, but did not have the resources to hire the consultants needed to get those kinds of programs going. So without permanently abandoning their old idea, the SSU report gave them a focus, and the council endorsed the study's conclusions.

Sebastopol is proud of its progressive politics, and Mayor Craig Litwin clearly relishes the fact that Sebastopol is the first city to enact this type of program. "I am thrilled with this. I want to see as many solar roofs as possible and... we can make it happen. This will help Sebastopol become a more sustainable place."

Enter CCEnergy

The city then put out an RFP (request for proposals) for bids on the project. Many companies, large and small, were interested in getting this contract. But the successful bid was by Cooperative Community Energy (CCEnergy), a northern California, member-owned co-op, with a very interesting mission statement:

Cooperative Community Energy provides access to reasonably priced renewable energy solutions for homes and businesses. It will work with its members to provide and use energy solutions that are environmentally and economically sensible. The fees earned from the primary business of reselling renewable energy equipment will be used to engage the public, the energy markets, and the political leaders in the building of safe and lasting renewable energy solutions.

Sebastopol's leaders loved the fact that they had a bid from a company that was as much into education and advocacy as it was sales and profits—it was a perfect fit.

As with most co-ops, CCEnergy is a business, but they are not in business to make a net profit. Instead of making a profit, their goal is to get as much RE into use as possible. Yes, they have to meet expenses and make payroll just like any other business. But with co-ops, the theory is that all net profits are given back to the members, usually in the form of dividends. In practice, CCEnergy's profits go into education and advocacy for more RE. Of course, member-owned co-ops are steered by the member/owners. In this case, the members agree that they want to see the funds go into furthering RE.

Die-hard capitalists may cry, "No fair! We have to compete directly with a company that does not need to make a profit." But really, most small businesses operate this way, too. The owner is a worker, and needs to get paid for the work done, but any extra money is usually plowed back into the business to keep it viable. CCEnergy's viability is

The thickening crowd, early on fair day.

CCEnergy's booth at the fair.

Photos by Sonoma West Publishers

directly connected to getting more RE. What CCEnergy is doing to fulfill their mission is providing services to communities that might not otherwise have access to those services, and providing services to individuals who might not otherwise be able to find or afford those services.

According to Dan Pellegrini, co-founder and president of CCEnergy, municipalities are good at setting public policy and accessing capital. Private organizations are more efficient at coordinating relationships between individual citizens and businesses, like manufacturers and local contractors. "That's where we come in.... It's a great public sector/private sector partnership."

In working with the city to implement the Solar Sebastopol initiative, CCEnergy is taking care of everything necessary to make solar energy easy, affordable, and accessible to the citizens and businesses of Sebastopol by:

- Raising awareness and interest
- Educating people about solar technology and rebate incentives
- Visiting homes, businesses, and municipal sites to assess energy needs and solar feasibility
- Helping clients conserve energy and increase energy efficiency in their homes
- Providing design services and solar installer referrals
- Arranging low-interest financing
- Ordering equipment (at up to 35% below retail cost)
- Handling all building permits, California Energy Commission rebates, and utility paperwork

Part of the project's goal is to demonstrate this model to other communities. Several cities and counties, including San Francisco, have expressed interest in the Solar Sebastopol model. If you would like to see something like this happen in your own area, get in touch with your like-minded community leaders, and then give the folks at CCEnergy a call. CCEnergy is working the bugs out of their program in Sebastopol, and once they have done so, they will be ready to go to work in your community.

Access

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Cooperative Community Energy (CCEnergy), 534 Fourth St. Suite C, San Rafael, CA 94901 • 877-228-8700 or 415-457-0215 • Fax: 415-457-0216 • info@ccenergy.com • www.ccenergy.com


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Capacitance

Opposition to Change in Voltage

Ian Woofenden

Derivation: From Latin capere, *to hold, contain.*

Alternating current (AC) electricity can be pictured as a wave, rising and falling many times a second. We even call its form a "waveform." Perhaps you've seen diagrams of a sine wave, a modified square wave, or a square wave. These diagrams represent the fluctuations of the basic parts of what we call electricity—voltage and amperage.

Voltage is the electrical "pressure"—the push that makes electrons move. Amperage is the rate of electron flow—we call this flow rate "current." If these two values fluctuate in step with each other, we can graph their waveforms as parallel, undulating lines. When a circuit has only resistance in it, voltage and amperage peak at the same time and go to zero at the same time. They are said to be "in phase." But two other electrical effects can shove the voltage and the charge flow rate out of sync.

In my last column, I talked about inductance, an electrical effect that opposes a change in electron flow (current). Inductors are simply coils of wire, and the way their magnetic fields affect the charge flow is called inductance. It's like a flywheel in an electrical circuit, grabbing some of the energy and tossing it back toward the source in a delayed reaction. In this case, the voltage "leads" or peaks before the amperage—the charge flow rate is reduced by the inductor.

Capacitance has a similar effect on a circuit, but the timing and focus are different. The voltage "lags," peaking after the amperage. This can effectively cancel out inductance in a circuit, so capacitance and inductance are considered opposites. Inductors store energy in a magnetic field. Capacitors store energy in an electric field.

A capacitor is two metal plates that are separated by an air space or another insulating material. When the circuit is energized, electrons are pushed into one plate, and the voltage there increases. The fields from these extra electrons reach across the gap between the plates, forcing an equal number of electrons to flow out of the other plate and back toward the source.

It's as if you have a loop of hose with a pump (analogous to a generator, PV, or battery) circulating water through the loop. But the loop is cut at one point, and a balloon is put on each of the cut hose ends, with the balloons forced next to each other inside a rigid housing. Water flows into one balloon, pressurizing it, but at the same time pushing on the other balloon. There's no direct transfer of water, but some of the energy is transferred.

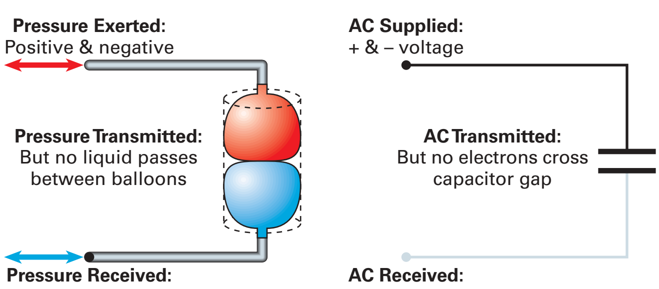
In a DC circuit, with the charges flowing all one way, a capacitor will be "charged" very quickly and that's the end of it. The balloon gets pressurized with water and the flow stops. If you connect (short) both sides of the capacitor, it will discharge its energy, just as when you release the pressure in the balloon, it will empty itself.

But in AC circuits, the charge flow direction changes constantly, so the two sides of the capacitor are alternately being charged and discharged. The net effect is that the capacitor, like an inductor, stores a bit of energy in each cycle and bounces it back toward the source. But the voltage (pressure, in the balloon analogy) builds up first on one side and then the other, "lagging" the charge flow (current). When the potential of one side changes, strong electric fields affect the other side. A dose of charge is needed to force the change in voltage between the two plates, and the net effect is that capacitors resist a change in voltage.

Capacitors are used widely in electronic circuits, acting as filters, timers, frequency tuners, and for other functions. They are often used to smooth a waveform and absorb spikes or "noise" in a circuit. They can filter out high or low frequencies. Timing applications rely on the finite time interval required to charge and discharge a capacitor. Capacitors and inductors have opposite effects on electrical circuits, so capacitors are used to offset inductance in industrial machinery to help AC motors start more easily.

In my next column, I'll look at how inductance and capacitance relate to "power factor."

Balloon Model & Circuit



Access

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

Post Impressions

Kathleen Jarschke-Schultze

We moved a lot when I was a kid. By the time I graduated from high school, I had lived at fifteen different addresses. Some I remember; some I don't. We used to collect misspellings of our name (Jarschke). "Parselike" was our favorite. Mail happened, but I took it for granted.

Mail to Male

I met Bob-O through the mail. I moved far away from my family and friends to be with him. For the first couple of years, we had no phone. That is when mail took on a whole new importance in my life. First, it introduced me to my husband. Second, it kept me in touch with my family. I wrote many letters home. I took to writing very long letters. Then I would photocopy them down at the Forks school and do a multiple mailing. It is very hard to write ten separate newsy little letters.

I met Glady, the Forks of Salmon postmaster, when I first came to the river to meet Bob-O. She had been posting our letters to each other and felt that she had a hand in our romance. We thought so too.

Forks Postmaster

Glady was born in Sawyers Bar on the North Fork of the Salmon. Her father owned the hotel there. Esther Schwartz, who lived in a beautiful river rock home at the Forks, once told me this story about how she and her husband had decided to move to the area.

One fine day, Esther and her husband Phil had gone for a long trip in their Model A, to see the backcountry. They pulled into the Sawyers Bar Hotel and a five-year-old Glady was sitting on the front steps. They stopped and talked to her. She was such a sweet and charming little girl that the Schwartzes decided then and there to move to the Salmon River.

Glady had been postmaster since 1953. She presided over her rugged postal territory from the smallest post office in the U.S. The Posty at 96031 was teeny; it was a remodeled goat shed. It had a cramped foyer with 30, small-windowed, brass mailboxes in the wall. To one side was a small window for the clerk, where transactions were made. If more than two good friends were getting their mail at the same time, it was crowded. In the wintertime, Glady always had the woodstove going in the back. In good weather, after the official business had been completed, she would come out from the Posty and stand in the sunshine with patrons to trade jokes.

A Penchant for Jokes

Glady liked nothing better that a bawdy joke. She and I would always try to have a new one when we saw each other. One joke drove us crazy for weeks because we only knew the first part of it.

In the dark hours of the night, Bob-O and I were awakened by our CB radio. We always left it on in case of emergency. This night though, it was two log truck drivers trying to keep each other awake by chatting. They were headed up to Callahan Summit. The higher they got, the louder and clearer the transmission became.

One driver started telling a joke, but just before he delivered the punch line, the radio went silent. They had crested the mountain pass and were going down the other side. This was dark territory for our radio.

The next time I saw Glady, I told her what I knew of the joke. Neither of us could guess the last part. For absolutely weeks, we both asked everyone we saw if they knew the answer. No one did.

Finally, I was up at Cecilville one day, talking to one of the old-timers there. I told him the joke as far as I knew it. "Do you know the answer?" I asked, not really thinking he would. He finished the joke, and I couldn't wait to tell Glady. I can't tell that off-color joke here, but if you send me an e-mail or letter, I'll pass it along.

Service with a Smile

If you live off-grid, you will likely have a rural mail service. Rural postal service differs greatly from the bureaucracy and impersonal service in urban areas. When you get your mail from a rural post office, you get a higher standard of service because the postmaster knows you personally—which can create some interesting trade-offs.

Shortstop. Back on the river, Bob-O used to subscribe to *Playboy* magazine. He came to realize that he received his issue a couple days later than his friends. A well-timed trip to the Posty found Glady, with her feet propped up by the woodstove, reading that month's tardy issue. "I read it for the jokes," she explained. After that, the magazine was still always a day or two late, but Bob-O didn't mind.

Fish mail. My sister Mary sent me a letter mailed inside a plastic fish. It was fluorescent pink with my address and the postage stuck right on the outside. It tickled Glady to have it come through the Posty. "We should be mailing those from here," she commented. She talked about the fish mail for quite a while.

Kathleen with fresh mail.

Postal mysteries. Misspellings and bad addresses do not flummox the rural postmaster. The occasional postal mystery is merely a challenge—not a dead-end letter. Bob-O actually received letters at the Forks mailed to "Bob-O, 96031."

Once I sent some film away for developing. It came back with the negatives, two pictures, and a slit in the envelope at one end. Glady meanwhile got a small package from the postmaster in Castella, California. It was a handful of pictures he had found in the bottom of his mailbag. One of the snapshots was of the old Forks Store, so he sent them to Glady. She looked through the snaps and saw Bob-O and me. I received the pictures in the next day's post.

Mail watch. One birthday after moving to Hornbrook, my sister bought me a Swiss Army watch. I'm wearing it as I write this. She ordered it through the mail and had the watch drop shipped. The label had been printed with my last name first, and my first name last. Then in transit, the label was torn. All that was left on the label was:

een
eek Rd.
96044

Because there was still a zip code on the label, it was sent to Elden, our postmaster here in Hornbrook. We had lived here less than a year by then. I got the package in the next day's mail run. You see, Elden knew that I was the only "een" on "eek Rd." in Hornbrook. You just cannot beat service like that.

Access

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

adopt a library!

When Karen and I were living with kerosene lamps, we went to our local public library looking for a better way to light up our nights. We found nothing about small-scale renewable energy. As a result, one of the first things we did when we started publishing *Home Power* sixteen years ago was to give a subscription to our local public library.

If you'd like to do the same for your public library, we'll split the cost of the subscription with you. Inside the U.S., you pay $11.25 and we'll pay the rest. Outside the U.S., the same offer stands, so call us for rates.

— Richard Perez, Publisher

Check with your local library before signing them up. Eligible libraries must be open to the general public.
PO Box 520, Ashland OR 97520 • 800-707-6585 • 541-512-0201 subscription@homepower.com • www.homepower.com

RE happenings

INTERNATIONAL

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

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

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

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

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

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

GERMANY

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

NEW ZEALAND

Jan. 31–Feb. 1, '04; Sustainability Expo 2004; Christchurch, NZ. Energy efficient building design; PV, SDHW, & wind systems; composting toilets, waste water systems, & grey water; efficient insulation, glazing & appliances; alternative transportation; permaculture; speakers; demonstrations; & working displays. Info: John Veix, PO Box 6302, Christchurch, New Zealand • 64 274 576 527 • john@gosolar.co.nz • www.ecoeng.co.nz/Sust_Cante.htm

NICARAGUA

Jan. 4–16, '04 (again Jul. 18–29); Solar/Cultural Course. Managua. Lectures, field experience, & eco-tourism. Taught in English by Richard Komp & Susan Kinne. Also, Micro-Irrigation Course: Feb. 22–29, & RE Fair: Apr. 1. Info: Barbara Atkinson • 215-942-0184 • lightstream@igc.org • www.grupofenix-solar.org

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

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

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

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

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

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

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

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

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

COLORADO

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

IOWA

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

KENTUCKY

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

MASSACHUSETTS

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

MICHIGAN

Urban Enviro 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

NEVADA

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

NEW YORK

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

NORTH CAROLINA

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

OREGON

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

TEXAS

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

Houston RE Group: email for meeting times: HREG • hreg@txses.org • www.txses.org/hreg/

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, & a 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

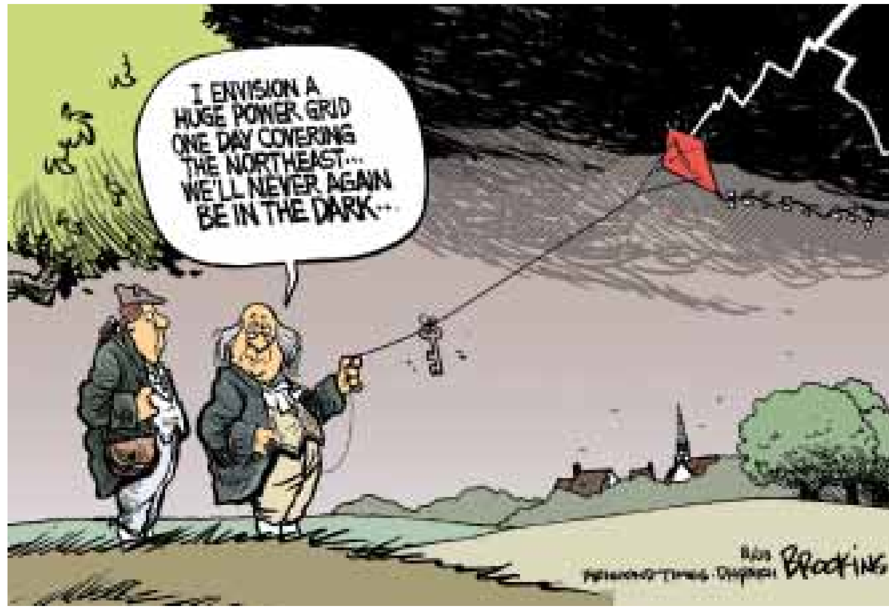
Apr. 18, '04; Intro to Renewable Energy workshop, Guemes Island, WA. Solar, wind, & microhydro for homeowners. Info: see SEI in COLORADO listings. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

WISCONSIN

MREA workshops. Solar Water & Space Heating; Wind System Install, PV Install, Straw Bale, Sustainable Living, & others. Info: MREA, 7558 Deer Rd., Custer, WI 54423 • 715-592-6595 • mreainfo@wi-net.com • www.the-mrea.org

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

Taking the Grid for Granted



Gary Brookins, 2003, *Richmond Times-Dispatch*

As the electricity failed throughout the northeastern United States and eastern Canada on August 14, I was just leaving the office for my 45 mile commute to my apartment north of Baltimore. I skipped out a few minutes early, so traffic was light on the curvy country roads I prefer to the gridlocked interstates. We had electricity at work and home, but as I listened to the news, I imagined myself a few years from now, in a home with its own sources of renewable energy and immune (or at least resistant) to such outages.

As I drove past a rolling field with freshly shorn sheep, I extended that small daydream to wind farms off Long Island, or arrays of PV mounted on the skyscrapers of Manhattan and on rooftops throughout the urban environs of northern New Jersey, and then the rest of the country.

The radio anchorwoman was talking about hotels asking their guests to sleep elsewhere because the electronic keys required electricity to open doors to rooms. Tens of thousands of people walked to ferries and waited for hours to get rides out of Manhattan. The stars would soon be visible.

The infrastructure of the grid is being blamed for being out of date and not able to cope with certain fluctuations in demand and supply. How and where the problem started is still not understood. Newspeople and even the president are quick to point out that it was not caused by a terrorist plot. They neglect to mention that it was caused by the general public taking for granted basic amenities like electricity and water.

Just because something works does not mean it cannot be improved. Let us not be complacent. We are making fantastic advances in all forms of technology, but most of the industrial giants are not taking advantage of anything that does not immediately improve their profitability. If electricity generation were based in thousands or millions of different locations rather than at a few hundred plants, perhaps the blackout would not have been so widespread.

Just as I avoid the gridlock on the interstate by choosing back roads, I can do my best to create my own energy to power my needs and maybe some extra for others. As I neared my home, a slow-moving, soot-spewing dump truck turned off and left the road ahead of me clear. Joshua Roberts • joshman291@aol.com

Blackout Biz

Richard, I'm looking at a photo of the blackout in the Northeast last summer. From a power kind of guy's view, this is what is *not* supposed to happen. The other day I was thinking about how we got here. The electricity industry has become like the banking industry, making deposits and withdrawals, always looking at the bottom line. The generator guys hand the energy to the transmission guys, much like a central bank (like the federal government) passes money to the banks. The transmission guys pass it off to the distribution guys, much like a bank passes money to small businesses and consumers (like most people are). The bank is the transmission guys, making a profit on the flow of electronic money. Since the market is only marginally profitable compared to either end, and there is competition, costs have to be kept in check. This means that they lower maintenance costs, slash expansion plans, and play the margin. This applies to the entire process, from the provider getting the best price, through to the middleman who sells cheap, to the entrepreneur, who offers all sorts of selection (communications, gas, cable TV, etc.) to the general public. Michael Perez • mperez70@satx.rr.com

RE for All

I greatly appreciate that you serve as a strong informational support of RE-related topics of such a broad variety as electricity generation, hot water, transportation, and business application. I am also appreciative of the networking services that you are able to offer as a hub of the RE community. It is especially of note that you aim to reach and serve *all* those who have an interest in RE, from the second home owner with a 4 KW plug-and-play system, to the guerrilla tinkerer with her garage full of toys, to the backwoods survivalist awaiting Armageddon with a mixture of nonchalance and glee. We can all learn from each other. Thanks for bringing us all together. smallfrog@peoplepc.com

There is perhaps no greater compliment than to hear you acknowledge that we're succeeding in exactly the way we'd hoped. Coincidentally, your observations echo the sentiments of last issue's "From Us To You," HP97*, page 10. We seek to energize our readership, but often find that in reality, it's a two-way street. Positive feedback goes a long way toward re-energizing the* HP *crew. Thanks so very much for taking the time to put fingers to keys and keep our batteries charged. Scott Russell • scott.russell@homepower.com*

Wind System Output

I was puzzled by the apparently low power output of the Bergey Excel wind turbine installed at the Nichols ranch in Washington State as described in the *HP96* article. The 7,222 KWH of production for the first eleven months seemed low to me, so I talked to several experts, one of whom was an experienced wind turbine and PV installer, the other a Bergey representative. Neither had seen the article. The Bergey representative said he would have expected much higher output for a class 3 or 4 site. The installer also agreed with me that this was low output. He commented on the photo of the Nichols ranch as seen from 100 feet up. Noticing that the ranch appeared to be located at the base of a ridge, he thought the turbine appeared to be poorly located. He also mentioned the possibility of an inaccurate meter. Please comment. Thank you. Rick Rodriguez • rrickrod@charter.net

Rick, Others have also commented on the apparent low output. We should have included in the article that the average wind speed recorded over the measurement period turned out to be 8.4 mph. Considering the lower than predicted wind speed, the turbine output is at or slightly higher than projected by Bergey. I feel this is very acceptable considering the long wire run—924 feet from the tower to the inverter, plus another 100 feet for the tower. We used the XTRW30 tower wiring kit with #6 wire, and #2 copper from the tower to the inverter, per Bergey's recommendation. We calculated that this wire size would suffice at mid-range turbine output, but we'd suffer some line loss at higher wind speeds. Overall, the Nichols and I are happy with the turbine's performance. Randy Brooks, Brooks Solar, Inc. • Randy@BrooksSolar.com • www.BrooksSolar.com

Hi Rick, I'll attest to the fact that this turbine is very well sited. I took the photo from the tower top, and the turbine has excellent exposure to local winds. Our apologies for not including complete information about the wind speed. Ian Woofenden • ian.woofenden@homepower.com

My Peerless Burners Won't Light.

I've had a Peerless/Premier Pro 30 gas range operating on natural gas with sealed burners for about a year. The rear burners light only about 10 percent of the time. The front burners and oven work well, as do the rear burners once they are lit. The factory has no idea what is wrong and I have replaced all pieces in the rear circuits from igniter to burners. If you have similar problems, please call or send me e-mail so we can get this unsafe condition rectified. John Wiles • 505-646-6105 • jwiles@nmsu.edu

Wind Generator Testing

Dear *Home Power*, I'd like to address the issue of wind generators and their testing. I feel that if manufacturers are going to make products, they need to be able to make something that's going to stand up to their claims. And that's what the consumer needs to be given as a product. Wind generator manufacturers should not be boasting "maintenance free" equipment. There's no such thing. Instead they should claim "minimal maintenance" and deliver it in their product.

As a dealer for nearly all the small wind generators available in the U.S., it's hard enough to sell the idea of small wind to most consumers simply because of the up-front price. Let alone if one of them were to actually spend the money to install a machine and then within a year or less the thing is already broken down, not performing properly, or has had to undergo major repairs; it just leaves a terrible taste in their mouth for RE.

My folks own a 10 KW wind generator (new last September). Due to some pending circumstances with the manufacturer, the output of the machine has been extremely low for the site's wind speed. The machine it replaced, a 1.5 KW Enertech, was producing about the same on a tower that was 40 feet shorter. The local utility noticed the low output of the new wind genny and started telling anyone who came to them for information on wind to forget the idea. "It doesn't work," they'd say. They even went as far as to publish an article in their monthly newsletter about the poor reliability and low output of small-scale wind. If that doesn't shoot local sales in the foot!

The first machine that I installed as a new business was a Jacobs 31-20. The machine ran for a day. Luck would have it that the alternator was not quite up to par and it burnt out after seven hours of operation. The machine was down for several weeks awaiting parts. During that time, there were quite a few who stopped in to ask the owner why it wasn't turning. And at the same time the owner was starting to wonder if he had made a mistake by investing in wind.

Word travels fast, and I believe that the manufacturers need to think twice before sending out their latest "new design" that promises greater output and higher reliability. We need to quit putting band-aids on problems that need stitches. New products should be tested long before they reach the market. And I'm not talking about wind tunnel testing either. Products need to be tested in the manner they are going to be used—real life, in-the-field testing.

When I was working as a service technician for a major utility-scale wind turbine manufacturer (see *HP78*), one of their company policies was that any new model or design had to undergo five years of in-the-field testing before it would be released on the market. I feel that the small wind market could benefit from a similar testing strategy. This would lead to a lower number of warranty claims and a wider acceptance from the general public. It makes me wonder how much the small wind manufacturers have to pay to keep up with their warranty claims. And of course this also plays into the overall cost of their equipment for the next guy.

The consumer also has his or her duties to fulfill. The wind system owner needs to perform the necessary maintenance, even if it is minimal. The purpose of this letter is not to bash the manufacturers—that's been done enough already by many others. But I'd like to encourage them to improve and lower costs of some great products through in-depth testing. Corey Babcock, Midwest Wind Electric • midwestwindelectric@yahoo.com • www.geocities.com /midwestwindelectric

Distributed Generation Can Help

I have been planning a new home with a BIPV system as the roof. To my surprise and disappointment, Ohio does not offer much in the way of incentives to people who are willing to install such renewable energy sources. I recently sent e-mail to my state representatives expressing my disappointment with Ohio's indifference to residential renewable energy systems.

On August 14th, the grid shut down in my area and across the northeastern United States. One article that I read said the there just aren't enough transmission lines to deliver the energy to the places where it is needed. I hope that this blackout will increase the interest of Ohio citizens and our government to take a closer look at residential renewable energy. If we had some energy producers within our own community, we wouldn't have to transport as much through those lines. I would rather see money spent building smaller renewable energy systems than larger transmission systems to bring us electricity from nonrenewable sources. Mike Powers, Akron, Ohio

Solar Pumping

I set up a little homebrew remote pump setup to supply water at my "hermit pad," as my son calls it. The system consists of two, 60 watt UniSolar PV modules on a UniRac, 4 inch pole mount. A custom toolbox houses the instrumentation, and a beverage cooler acts as a battery box. The pump is operated by a 1/5 hp gear motor in a 300 foot well. It pumps from about 90 feet at 1.5 gallons per minute. The pump is powered through a 12 V time clock and a continuous duty relay because of the amp draw. Two, 220 AH, 6 V batteries are charged via a BZ Products MPPT200LVD. I'm in shakedown mode right now, but everything seems to be working fine. The project has been great fun and saved mucho $$$ compared to extending utility lines. Skip Dye, Jamul, California • skipdye@flash.net

Eyes Opened

We are taking the first steps toward being off the grid. Our second home (retirement home) will rely 100 percent on solar and wind electricity, and a well for water. We went to the newsstand, bought about ten magazines on self-sufficiency, solar and wind energy, green environment, etc. From that we identified Web sites, articles, and the beginning foundation for our research. Our project will take approximately two years to complete because the endeavor will be 100 percent debt free. Your magazine, *Home Power*, offers information in lay language, with facts and figures to match. I've just ordered the Quick Start package for a subscription and six back issues. You are opening our eyes to a whole new way of thinking, and we thank you for the resources provided in your publication. ccbakeraz@msn.com

Green Manufacturing

Dear friends and fellow enthusiasts, I have come to realize that renewable energy is certainly the direction we must head as a world devoted to preservation of our environment, ecology, and human health. I have been working in the industry for almost three years now and feel that RE businesses do make a significant difference in these matters as well as in how people do business. Each one of us can make a positive impact through our conscious connection to this world and its people.

However, I have come to realize that we need to keep moving forward and progressing towards our goals, hopes, and dreams. My biggest concern is the nature of production of these solar products. Which of these large corporations and smaller companies are actually producing their products with renewables? Are the office lights, computers, air conditioners, etc. powered with solar energy? Do they take responsibility for recycling? Are we actually gaining any ground in our efforts if we use products that use as much energy and create as much pollution behind the corporate curtain so to speak?

Skip Dye's water pumping system.

I realize that this industry has had its ups and downs. And I know that we have only just begun to work towards improvements in technology, cost effectiveness, and efficiency. But as we see the real growth of this industry here in this millennium, let us consider our initial intentions and do what we can to keep improving. The industry depends on this. The world depends on this. Thanks for your efforts, Jeremy Taylor, RMS Electric • souljah4truth@yahoo.com

Hands-On Users

Dear *Home Power*, As I write this, I'm getting ready for my third winter with my small stand-alone office solar-electric system described in my *HP97* article "Recipe for a Solar Office: 1 Part Solar, 5 Parts Load Reduction." So far, there have only been a few unexpected experiences during the two-plus years with my system. But I think they are interesting enough to share with *HP* readers.

First, I came in the office one winter morning and, as usual, checked the state of my batteries. It was supposed to be mostly sunny after several cloudy days. It was about 5°F and mostly cloudy outside, snowing a little, but the sky was getting brighter as the clouds were beginning to thin. I knew my PVs should be producing about 10 to 20 percent of their rated full output (about 0.6 to 1.2 amps or 8 to 20 watts) in this kind of daylight. But I was only getting about 0.14 amps! So for the third time that winter after ice or snowfall, I went outside and cleaned off my PVs, just as anyone would clean off their car windshield. I came back in—it was still only about 9 AM—and saw that I was getting about 1.15 amps! By 9:30 AM, the output was double this and rising!

This made me think about big systems on somebody's house roof or a company's flat roof. Does anyone believe that typical rooftop PV systems get promptly cleaned of snow and ice like this? Does anybody believe that any utility or company would have employees out cleaning off snow and ice in winter or bird droppings in summer to help their PVs function optimally as I have learned to do? This is why I continue to prefer the most user-accessible systems and educated users who commit to periodically tending to these kinds of simple tasks long after installation. I don't believe utility-scale PV systems or consumer systems in hard-to-access places are being so maintained when it's icy or snowy and cold in winter or blazing hot in summer. Accessible systems and committed users produce not only better economics, but also better outcomes. At least in my case, this means not running out of energy...

Second, since there's twice as much sun at my site during summer than winter, and since I designed my system to make it through winter without backup generation, I have surplus solar energy during summer. I have more work in summer, but I've also been learning to use surplus energy in other ways. With disposable batteries providing the most expensive electricity (often US$50–$200 per KWH in common AA, AAA, D sizes), I've steadily converted devices around our house and my business to rechargeable batteries. So now during at least three-fourths of the year, I'm charging small batteries on the surplus solar electricity from my office system. My business is regularly using 28 small rechargeable batteries and the house another 16. I'm finding most of my clients using lots of small batteries, mostly disposables, unfortunately. I was recently surprised even to hear from an off-grid Indiana household that they were spending over US$100 per year in disposable small batteries!

Third, since I bought most of my office equipment described in the article during 2000–01, some of it is being replaced or getting ready to be replaced by now, especially computers, accessories, and lamps. I've found it relatively tough but not impossible to get accurate energy data from manufacturers before purchase, but so far I've had decent luck finding a replacement low-energy printer and scanner. My first replacement laptop, again a pre-owned model, fortunately used just about the same power as the one it replaced. But its swappable CD also was a phantom load when not being used, just as the prior model, so I've continued my preference for leaving CD drives either external or swappable.

My wife's new laptop with 15 inch screen and two internal CDs (one R/W) typically uses more than double the power of my 12 inch models, so I'm trying to avoid that trap. I recently heard the U.S. secretary of energy say after the NE grid failure that U.S. electricity demand has increased 35 percent from 1992 to 2002. This kind of trend is the enemy of standalone solar energy folks like me. My goal is to maintain my energy consumption at or below current levels *ad infinitum*, not to experience significant ramp-ups over time, which would force me to increase the size of my small system. Imagine if our energy secretary and most utilities thought more like this!

Fourth, it's not uncommon to encounter noise problems in electric systems, so I'm not surprised to have had some myself. First it was a new table lamp that buzzed when turned on and connected to my inverter output. It didn't buzz when connected to the utility's AC. Then I metered it and found a phantom load (!), and the lamp also made a very small hum when plugged in but turned off. I tested a second lamp of the same brand and it acted the same way. (They were called "happy lamps," so I mused that they must need energy to stay happy...) I then discovered that my phone answering machine connected directly to my DC instead of its intended AC-DC converter recorded annoying background noise when answering calls. This noise wasn't heard by the caller or by me when I recorded my own message, but it was quite noticeable in all callers' messages.

The noise also seemed to reduce the signal-to-noise ratio enough to cause occasional premature cut-offs, especially for callers using cordless and cell phones. So I tried powering my machine directly with a 12 volt battery not connected to my grounded system. This eliminated all the hum and premature cut-offs. Since then, I've been using a couple of portable, sealed, 12 volt, 7 AH batteries, rotating them each day for recharging while disconnected from the phone machine. Having had past problems with ground loops between electric musical equipment, I can report that the noise sounds like a ground loop, but I've not spent time yet confirming this or working on a permanent solution. I'd appreciate hearing if anyone has solved a similar phone noise problem like this. John F. Robbins • jrobbins@queencity.com

A Better Purpose

I just read the article in *HP97* by Windy Dankoff about the Sagasers' solar water pumping. I used to work for the second largest American manufacturer of this type of pump (they have now been purchased by the largest manufacturer). These are called progressing cavity pumps. They are very robust, though they require a large startup torque, due to the rotor initially sticking to the stator.

I think you'll enjoy the irony here: Though the pump started out and is still widely used in industrial settings (frequently referred to as the "pump of last resort," due to its robust nature and tolerance of solids in the fluid), the major usage recently has been to pump oil out of the ground. Virtually every electronic control system used on the pump in the article was originally developed for an oil pumping application. It's good to see the technology being turned around and used to foster independence instead of dependence. David Brandt, P.E. • ev_dave13@yahoo.com

Dear David, You are right; the helical rotor in the ETAPUMP is also called "progressing cavity pump." It was originally developed in the 1940s. It's used for oil wells and concrete pumps! Water Well Journal *recently reported on one that served a residential water well since 1952, and was only pulled last year because lightning destroyed the motor. In the 1980s, solar pumps using rod-driven helical rotors (motor above ground) were successful in the U.S. and Africa, but were expensive and hard to install. In the 1990s, several companies tried to make them submersible, but the starting difficulty and the cost and reliability of motor controls were big obstacles. These have been overcome by advances in electronics and precision manufacturing. We can turn oil pumps into solar pumps. Now, if we can we just beat swords into plowshares... Windy Dankoff, Dankoff Solar Products, Inc. • windy@dankoffsolar.com*

Passive Solar Plans

Dear *Home Power*, I am interested in constructing a new home. I am researching environmental designs and would like to know of any resources that may help me in this process. Do you know if any of the companies that produce factory manufactured homes have passive solar blueprints? Additionally, do you know of any companies that produce environmental kit homes? I am interested in constructing a futuristic, comfortable, and efficient home for under US$60,000. I would greatly appreciate any help or resources that your staff could provide me. Ray Simpson, 61 Hoover Rd., #6, Murphysboro, IL 62966 • www.lattucaelectronics.com

Ray, At the American Solar Energy Society's annual meeting (ASES 2004) in Austin, Texas, I met Debra Rucker Coleman. She is an architect in Alabama and has developed Sunplans, Inc. She has published Sun Plans: Passive Solar House Plans for the 21st Century, *which is a nice little workbook containing solar house plans. With each plan, there are projected annual energy performance sheets and energy cost examples (see HP90).*

Although some of the houses are too big (in my opinion), she is giving people a good starting point, a benchmark, and the analysis of so many different plans can give people great ideas. She was good to talk to, admitting that some plans have fundamental problems, and she was very willing to address these issues. I would check her Web site out for more information: www.sunplans.com.

I don't have any information about environmentally friendly factory manufactured homes. If you do find something of that sort, I recommend that you visit the factory where the homes are assembled. Find out how environmentally friendly the manufacturing process is. Often the energy spent manufacturing the end-product will never be recovered in the energy saved in operating the home. And often these homes use very toxic adhesives and materials to save in costs, while creating large amounts of waste. Things to think about. I hope this helps, Rachel Ware, Solar Energy International • rachel@solarenergy.org • www.solarenergy.org

Too Much Hot Water?

Hello friends, The article in *HP96* about a solar heated greenhouse by Richard Lane and Chuck Marken does not say anything about what they intend to do with all that hot water during the summertime. The drawing does not show any shunt load capability. Running the hot water through the floor would make it unbearably hot to be in the greenhouse during the summer, and it will be a pain to drain the liquid or cover up the collectors. The drawing does not show this to be a drainback system, so what's the plan? Thank you and all the best. Roy Tonnessen • randa@iowatelecom.net

Hello Roy, There are no provisions for dealing with any over-temperature issues since they don't exist in this system. In the article it mentions that the collector is built with low cost absorbers supplied by AAA Solar, and they are painted, not a selective surface. Also as mentioned, they are great for low temperatures, but bad for high temperatures. They can't even deliver high temps if we wanted them to. The installation of the panel at a tilt of 55 degrees further limits any over-temperature concerns. Consequently, the system doesn't ever overheat.

The system was built and installed for economic efficiency, not technical proficiency. Additionally, most HP *readers do not live at latitudes like Green Bay (halfway to the north pole from the equator), so they may not know that the intensity of the sun is never a problem here. We are just able to make up for lack of intensity by length of day, which contributes to total BTUs, not instantaneous BTUs. Richard Lane • rlane@solarminingco.com*

System Update

Hello *Home Power* people, *HP83* contained an article on our energy system titled "RE Comes to the RR Farm," and I thought I would write to describe our experiences with the system to date and what has been changed. Our first couple years of experience almost put us back to living like we had in Portland, even to the point of forgetting to turn off lights when leaving the room. Fortunately, with the CF lamps, the energy consumption wasn't too excessive. The indicator lamp included by Backwoods Solar with our purchase of the

Trace SW2512 inverter plugged into a dining room outlet reminded us many times that there was a power draw somewhere. That simple device is really a great "extra" demonstrating the thoughtfulness of the Backwoods Solar folks.

We have experienced no difficulties in the operation of any electrical devices listed in the article. I was a little conservative with my consumption estimate, which gave us more capacity than anticipated. So naturally we added more equipment, including more lights, a chest freezer, and a satellite Internet connection. Even with these additions, our TriMetric usually indicates a fully charged battery in the morning before turning on the lights in the summer and seldom shows the battery under 75 percent in the winter.

Last June, we had a lightning-caused wildfire to the southeast of us. We were lucky it didn't get any closer. Unfortunately, we had a fire retardant drop on the house and outbuildings. Our PV arrays were painted red. I was worried about the effect of the retardant on the panels, but after I washed them off, there seemed to be no harm.

A couple weeks ago, I went to the chest refrigerator for a cold beer and smelled hot insulation. The refrigerator was running. I checked the inverter's meter and the voltage was down to 73 volts. When I turned off the refer, the voltage jumped to 123 and my next assumption was the compressor motor was shorting. I called Steve Willey at Backwoods and he thought it was the inverter. He gave me two possible repair shops, one in southern California, and one near Vancouver, Washington. Not knowing if that was really the problem or how long it would take to repair it if it was, I ordered a 600 W inverter from Steve to get by with.

The regional Xantrex repair facility told me that the problem was the DC FET board—about half the transistors were burned. They explained that the failure is usually caused by overloads or load spikes. Lightning could also have caused the failure. The only possible overload or spike I could think of was the refer starting at the same time Norma started the vacuum or the microwave. Seemed unlikely, but it could happen I guess.

We are back in operation on all fronts now and though it was not near as long a duration without electricity as the recent failure in the NE U.S., we sure appreciated the lights. I still am not sure what caused the problem and would be grateful for any input. Thanks, Will Greenslate • 541-490-1094 • willnormagtf@direcway.com

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

Power Lines

Richard Perez

Do we need more high voltage transmission lines? Inadequate maintenance of these high voltage power lines resulted in the 1,800 acre Grizzly Peak wildfire near Ashland, Oregon in 2002.

The recent blackout of August 14th in the northeastern U.S. left more than 50 million people powerless, and has focused attention on the condition of America's electricity grid. Even though the exact cause of the blackout remains unknown as I write this, the politicians in Washington are crying for "modernization" of the grid. Do we really need more generating plants and more transmission lines? Perhaps instead, we need to rethink the way that electricity is used, generated, and transmitted.

The State of the Grid

The U.S. electrical grid is huge. It serves 270 million consumers inside the U.S., and another 31 million in Canada. More than 2,000 generating plants feed electricity into 157,000 miles of high voltage transmission lines. With a generating capacity of more than 914 megawatts, these plants produce more than 3,700 billion kilowatt-hours of electricity annually. The grid is a huge, complex, technological marvel. And last August's blackout demonstrated that this amazing grid can be stretched to its breaking point.

Modernization?

When politicians talk of "modernizing" the grid, what they are really talking about is more of the same—building more generating plants and running more miles of high voltage transmission lines. Many of the new plants they are considering would be nuclear-fueled, and this is in spite of the fact that no one has yet developed satisfactory methods of dealing with the radioactive waste generated by these plants. Current estimates are that we need to build at least 30,000 miles of new high voltage transmission lines to distribute our existing generating capacity and to render the grid reliable.

Building new nuclear power plants is going to cost hundreds of billions of dollars. And this doesn't include the more than US$4 billion we've already spent caching the waste from the existing 104 nuclear power plants, and the estimated US$50 billion plus that we will have to spend to deal with their already existing waste in the future.

A mile of new high voltage transmission line costs about US$1 million to build. This is about the same amount of money it costs to build a mile of new, four-lane, superhighway. So add another US$30 billion plus to construct new transmission lines (assuming that you can find people who want to have these new lines in their backyards). And this estimate doesn't include upgrading and maintaining our existing high voltage lines, the bulk of which were constructed over 40 years ago.

The bill for "modernizing" the grid is adding up and getting rather large. Experts estimate that the cost will be between US$100 and US$200 billion. Based on the cost overruns of past, large-scale, national infrastructure projects, I expect the cost to be much, much higher. Electricity consumption per capita is rising far faster than the population—each of us is using more energy. And U.S. electricity usage will only continue to rise as the population grows, so it isn't a "fix it once and be done with it" deal.

"Renewable energy technology renders obsolete the concept of centralized production of electricity. It relieves the burden on our overloaded transmission lines."

What's the Real Problem?

OK, it's time for the chickens to come home to roost. We are the real problem. More than 60 percent of the energy consumed from the grid goes to homes—our homes.

Our electricity consumption has doubled in the last twenty years. We are asking an ancient infrastructure to deliver twice what it was designed to deliver, and we don't want to pay more for the energy we use.

During this same twenty year period, the utilities cut their construction of new transmission lines by half. The reasons? Well, people don't want transmission lines in their backyards—the NIMBY factor is huge. We approved utility deregulation, and this is another reason—the major utility bucks to be made today are in trading electricity over longer distances (Enron-type activities), and not in building new generating capacity, or in building new transmission lines and maintaining existing lines. Out of the 3,170 utilities in the U.S., 74 percent are IOUs (investor owned utilities) and their primary directive is profit. Electricity is a big business—over US$240 billion per year. Deregulation has made investment in the infrastructure not as profitable as merely trading in electricity.

Transmission lines can only handle a finite amount of current. Feeding too much current causes them to overheat, expand, and sag (as in touch each other or the ground). The utilities are already running as much voltage through these lines as they can possibly handle without arcing. Voltage to the max, current to the max—is it any wonder that when a fault occurs, it cascades into a huge problem and the lights go out for more than 50 million people?

Let's take responsibility for the latest blackout, folks. We are the problem. We want more and we want to pay less. Solutions? Well, lots of people have ideas—here are mine.

Alternatives—Your Home

Instead of "modernizing" the grid, I suggest some more sensible alternatives. Use less. By adopting the energy saving techniques that many *Home Power* readers have been employing for more than a decade, you can reduce your home's electricity consumption by one-third to one-half of what it is now. Please understand that I'm not advocating doing without. I'm merely advocating doing what we do with electricity efficiently. Same bang, but for fewer bucks—fewer KWH of energy. These techniques will save you money on your electricity bill immediately. They will lessen the need to "modernize" the grid at a cost of hundreds of billions of dollars (which incidentally, you will pay for via your utility bills and taxes).

Get rid of those incandescent lights and replace them with compact fluorescents—you'll save about 65 percent on your lighting's energy consumption and still have the light you want. If your refrigerator is more than five years old, buy a new super-efficient refrigerator. This can cut your refrigerator's energy consumption by about 40 percent. Turn off unused appliances—lights burning in unoccupied rooms, TVs displaying information to no one—they are a dead waste of energy.

Pay attention to your home's thermal envelope—caulk windows that leak air, add insulation, and set thermostats intelligently. You will save energy while reducing your electricity bill. Use a clothesline instead of an electric clothes dryer when weather permits. Since home energy consumption accounts for most of the electrical energy

A computer-enhanced satellite photo of the August 14, 2003 blackout. Note that lights are still on in a very small percentage of this heavily populated area.

consumed in the U.S., we can make a huge difference by using energy efficiently in our homes.

Install a solar water heater. This will slash a major energy consumer in your home and pay for itself in less than five years. Install a grid-intertied solar or wind electric system for your home—this can make you energy independent (as in zero electricity bill) and with the addition of batteries, blackout proof at the same time. Payback time (10 to 18 years) is longer than solar hot water, but still well within the lifetime of the system (25 or more years). By relying on the sun or wind for your energy, you can tap into a free energy source and lessen your impact on an overloaded electricity grid.

Alternatives—The Big Picture

For the last century, utilities have been locked into a mindset of centralized electricity production—they make it and we buy it. This centralized system relies on a vast network of transmission lines to deliver the energy to the end users. We have outgrown this paradigm.

Technology has made it possible for each home to generate the energy it needs on site. Renewable energy technology renders obsolete the concept of centralized production of electricity. It relieves the burden on our overloaded transmission lines. It is no longer necessary to ship electricity hundreds of miles. The energy can be generated where it is used. What is left over can be shared with our neighbors.

The adoption of solar hot water systems and utility-intertied RE systems would be a real "modernization" of the grid. No need for more nukes, more pollution, or more transmission lines. If we are considering spending hundreds of billions of dollars on energy infrastructure, we should give a long, hard look at these alternatives.

Generating renewable energy in your home basically makes it "drop out" as a load on the grid. The energy this home needs no longer has to be generated in a centralized plant. It no longer needs to be shipped long distances on transmission lines. The people living in this home don't pay high monthly energy bills. They have an uninterruptible and sustainable energy source. And this home can show an energy surplus that can be shared with its neighbors. All in all, this scenario is far more attractive than throwing hundreds of billions at a grid that has given us blackouts, brownouts, pollution, proliferating transmission lines, and high monthly energy bills.

The Choice Is Ours

We are at a crossroads. We can pump megabucks into an antique infrastructure based on outdated concepts, or we can spend this money on energy systems with a future.

On a national scale, this decision will probably be made by the politicians and business moguls who gave us the problems we're faced with now. Their vested interest is in the status quo, business as usual—they make it and we buy it. While in my fondest dreams, I see Washington, D.C., and our utilities embracing renewable energy, my practical side sees this chance as slight. RE has one big problem—the energy is free.

The one bright and shining light is that we, as individuals, can make this decision for ourselves. We can drop out of the conventional energy morass. We can make ourselves part of the solution, not part of the problem. We can practice energy efficiency in our daily lives. We can use the free energy that nature offers us in our own homes. We can make a difference.

And if the politicians and fat cats choose the path of the past, at least the lights will always be on at our house...

Access

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All utility factual data was gathered from the U.S. federal government and the Electric Power Research Institute (EPRI).

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Questions & answers

PV Wiring Distances

Could you please tell me what distance is feasible to run between a PV array and the inverter? Thanks, Greg Sullivan • gsullivan1@cogeco.ca

Hello Greg, Having the PVs as close as possible to the batteries and inverter will always decrease the cost of installing a system. The wire and conduit size decreases, and so does the trenching required to protect the wire. The catch is that you want to install the PVs where they receive full sun whenever possible, and this isn't always close to the batteries or inverter.

The specific wire size and allowable distance between the PVs and batteries depends on the operating voltage of the PVs and the size of the PV array. Tracking, ground, and pole mounts for PVs are often sited a couple of hundred feet from the batteries.

If long distance transmission runs are required (100 to 500 feet), it always makes sense to design the system to run at high voltage. This reduces the wire size and decreases cost. The maximum power point tracking (MPPT) PV charge controllers that are commonly used these days are designed to use all available PV voltage to increase the array's output. Power lost in transmission wiring means lost PV output day after day, year after year.

The key to wire sizing as it relates to PVs is to keep the voltage drop as low as possible. Below 2 percent is good, and 1 percent is better. Here's an example: If you have a 1,000 watt PV array operating at 12 VDC nominal located 200 feet away from the batteries, 1,750 MCM copper wire is required to keep the voltage drop under 2 percent. The cost of the wire and connectors make this approach cost prohibitive. If the same system is operating at 48 VDC nominal, #1/0 copper wire will keep the voltage drop under 2 percent. The 12 volt wire run would need wire as big as your wrist. The 48 volt wire run would only need wire as big as your finger.

If you have a large array and long DC transmission distance, MPPT controllers manufactured by RV Power Products and OutBack Power Systems can be programmed to operate the PV array at a nominal voltage higher than the battery bank's. These controllers then step the high voltage array output down to the nominal battery voltage. The MX60 charge controller manufactured by OutBack Power is capable of operating as high as 120 VDC (PV open circuit voltage) and allows for wire runs of several hundred feet in many cases, without getting into huge wire. If your system is on-grid and batteryless, SMA-America manufactures high voltage Sunny Boy inverters that operate at PV voltages up to 600 VDC.

Finally, if you're off-grid, and the PVs need to be located far away from the home, another good option is simply to move the batteries and inverter closer to the PVs. A power shed built near the PVs can house the batteries, inverter, and the rest of the system components. The PVs' DC output is used to charge the batteries and run the inverter. Since the inverter output will typically be 120 or 120/240 VAC, long distance transmission is less of a problem. Take care, Joe Schwartz • joe.schwartz@homepower.com

Inverter Hum

Hi Richard, I have a question that I would be very grateful to get some help with. I have a 1,200 square foot off-grid home above White Salmon, Washington. I have just brought a landline phone to my house at great expense ($1,200!). Cell reception is nonexistent at my locale. Plus I wanted to get an Internet dialup connection and end my long drives to the library to get e-mail.

My system is extremely basic: two Siemens panels, two L-16s, and a tiny Xantrex UX612SB (w/ battery charger) modified square wave inverter, and a Honda EU2000i generator. The house is wired to local code using #10 wire. When the inverter is running, I get a hum in my phone line, and the modem in my Mac PowerBook won't let me get on-line. I assume that this is because the RF is a competing frequency that confuses my modem. As soon as I turn the inverter off, my problem ceases, but I also have no lights.

If I turn my main panel off but leave the inverter on, I don't have the noise. This tells me that it's the wires in the walls that are transmitting the RF throughout the house, and that the inverter installed in my mudroom is not broadcasting the signal. If I plug the phone or computer into the network interface device (NID) on the outside of the house with the inverter and main panel switched on, I don't have any problem with noise in the phone or Internet dial-up connection. Inside the house I have the problem, but outside I don't! Why would the exterior walls be any better at isolating the signal than the interior walls? The phone line is fully grounded with an 8 foot grounding rod. The DC battery-to-inverter cables are taped together to gain a field effect cancellation of signal. The inverter's chassis and the main panel itself are fully grounded. There is no electrical connection between the phone and house wiring.

Do you have any suggestions as to how to isolate my phone line from this inverter signal that's being broadcast by my house wiring? All I can think of is an isolation transformer. But why would this work if it's plugged into the wall? I'd rather avoid buying a sine wave inverter to add to my system. I want to believe that there's a simple answer to my problem. I'm at a loss and so is Xantrex tech support. Thank you very much for your time. Perhaps some past article in your publication addresses my problem. Any suggestions via e-mail would be appreciated. Sincerely, Charles Crosman

Hello Charles, You have correctly identified the problem—RFI from the modified square wave inverter. This RFI is being broadcast by the wiring in your home; the wires act as antennas. At some place in the home, the telephone wires are close (either very close or running parallel for some distance) to the electrical wiring. At this point, the RFI from the electrical wires are inducing noise in the telephone wiring. You have done a good job of troubleshooting this problem. The solution is really simple—replace the inverter. No transformer or filter will eliminate this problem. Get the RFI at its source—the inverter.

Inverter RF is directly related to the number of steps in the waveform. The Xantrex UX series uses a modified square wave and has four steps. The Xantrex SW series has 34 to 52 steps (varies with power output). Exeltech and Xantrex Prosine inverters use over 600 steps, which radically reduces RFI. Be advised that all inverters produce RFI at their DC cables, so these need to be as short a possible and twisted together if possible.

Look on the bright side here—the modified square wave inverter is really obsolete. We've had great sine wave models for years now. All the appliances you are powering with the inverter will run better, last longer, and be more efficient on sine wave electricity. I'd recommend considering either an Exeltech, OutBack, or one of Xantrex's Prosine sine wave inverters. The Exeltech XP1100 is a 1 KW unit with a street price of under US$750. It does not have a battery charger, so you may want to retain your UX and just use its battery charger. Xantrex makes several Prosine sine wave inverters in the 1 KW to 2 KW range. Some contain very powerful battery chargers that are far better suited to generator output than the UX's. Cost is a bit more for the Prosines.

Your only other option is to rewire the telephone wiring in your home and route it so that it's as far from the electrical wiring as possible. This solution may still allow RFI to couple into the phone lines. When dealing with RFI, it's always best to attack the source if possible. And since you have a modified square wave inverter, the upgrade to a sine wave unit not only eliminates the RFI problems, but also gives you better performance from all your appliances. Richard Perez • richard.perez@homepower.com

Homebrew Wind Controller

Hello *Home Power*, I have been trying for quite some time, without success, to find plans for a wind generator charge controller. Can you help? Wally Moran • wmorann405@pop

Hello Wally, My axial flux windmill plans (www.scoraigwind.co.uk/axialplans) contain the circuit diagram for a simple charge controller. The controller switches two dump loads. I normally use 16 amp relays. Multiple circuits could be used to switch a larger number of loads if necessary. The loads switch on at 14.5 volts and off at 13.5 volts, thereby maintaining a reasonably suitable charging voltage. There is a list of components, but the project would require some initiative in the layout of the actual circuit board. I use stripboard to build them. A homebrew article about building your own charge controller was published in HP33. *Hugh Piggott • hugh@scoraigwind.co.uk*

Running a Well Pump Off-Grid

Hello! I'm attempting to run a 240 V well pump on a Xantrex SW4048 inverter via a 120/240 V, 4 KVA step-up transformer. The pump will start and run if no other load is present, but with even a few lights on, the inverter overloads and trips out. I called the pump motor manufacturer and they confirmed that the two-wire, 1 hp pump pulls 48 amps at 240 V for about 0.2 seconds during startup. However, since the inverter is supplying 120 V, the actual current the inverter has to supply is 96 amps! The surge ratings for the Xantrex SW4048 from the literature I have says 110 amps for 0.01 second, 77 amps for 0.1 second, and 73 amps (resistive load) for 5 seconds.

I also reviewed the manual for our newly installed submersible well pump (Goulds), and they have a section on sizing a generator to run the pump. For a 1 hp, three-wire pump, they recommend a minimum of 4,000 watts. For a two-wire pump, they recommend increasing the generator size by 50 percent.

I'm not sure why the 4,000 watt inverter *isn't* having problems starting the pump without any other loads. The calculated pump motor inrush current of 96 amps for 0.2 seconds surely seems like it would exceed the short time ratings of the inverter. Maybe the motor manufacturer was being conservative with the 0.2 second duration for the inrush current. I think even if it works, it's on the hairy edge of overload. Given the pump that's been installed, I think I need a bigger inverter.

The 1 hp pump seems rather large for a residential well, especially a cabin in the woods. It's more common to find a $^3/_4$ hp unit. Is a pump that big really necessary, or was the well guy just covering himself? The well is 146 feet deep. My conclusion for fixing the problem is to install a bigger inverter or a smaller pump. Am I missing something? Help! Best Regards, Kirk Wishowski • vanwish@netpenny.net

Hello Kirk, You have correctly diagnosed the problem. This problem is compounded by the fact that the pump is not a resistive load, it is inductive. The power factor of the pump is probably in the range of 0.75 to 0.80 and this means that the inverter must produce roughly 25 percent more current than the pump's rating.

This is a common problem. Well pump installers are not used to powering pumps with inverters, and routinely install huge pumps, since they assume that the grid is present. The best solution is to replace the pump. Here's an example from our own system here on Agate Flat. Our well is 300 feet deep and the pump is located 260 feet down the well. We use a $^1/_3$ *hp Franklin motor, running on 120 VAC, driving a standard Goulds rotary pump. This unit can easily be started and powered by a 1 KW sine wave inverter. This pumping setup will deliver 5 gallons per minute to our water storage tanks.*

Consider having the pump hauled out of the well and replacing its motor with a $^1/_2$ *to 1 hp motor running on 120 VAC. If the wire run to the well is very long, consider powering the pump on 240 VAC since you already have the step-up transformer. But running it on 120 VAC will be more efficient since you will not have the transformer's loss. Richard Perez • richard.perez@homepower.com*

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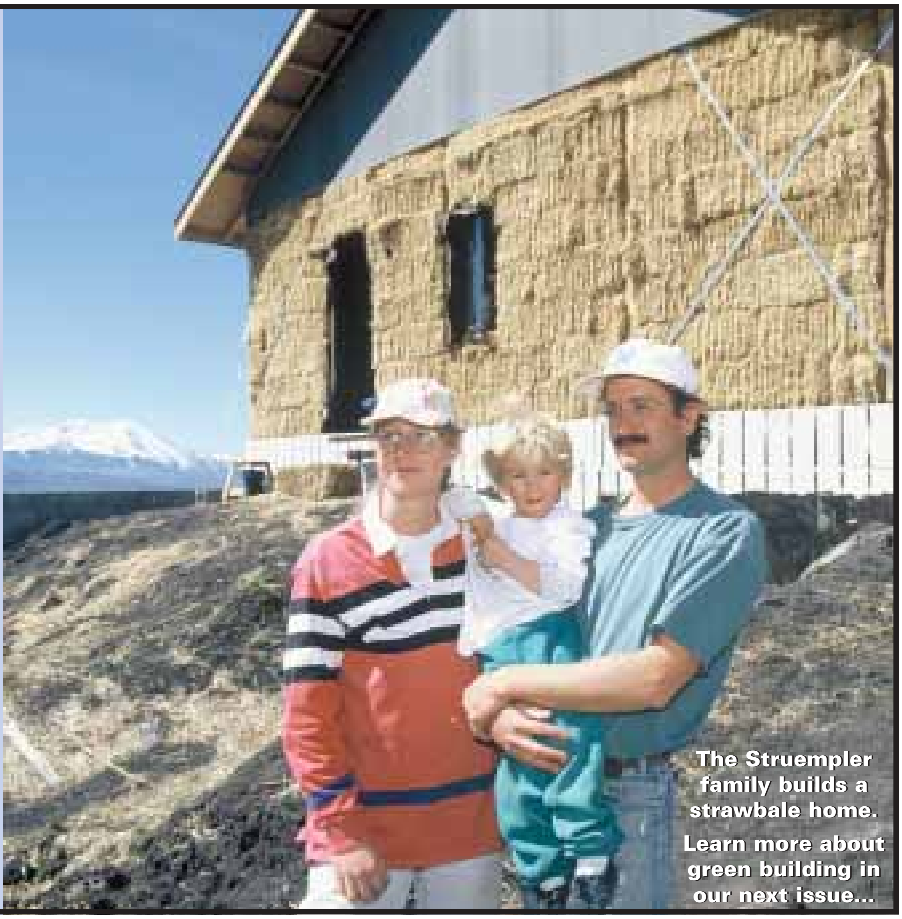

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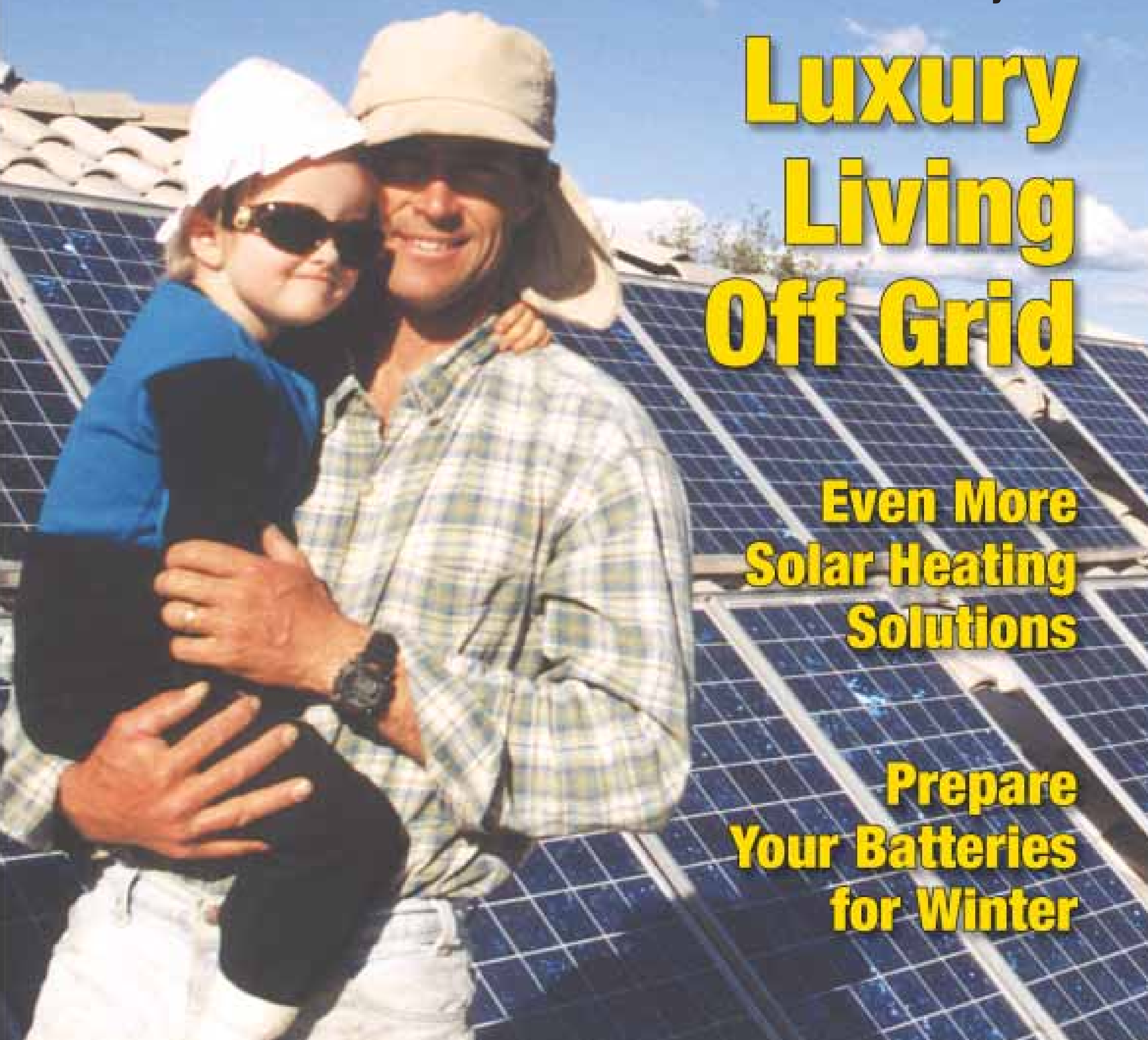

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The following information about your renewable energy usage helps us produce a magazine to better serve your interests. This information will be held confidential. We do not sell our mailing list. Completion of the rest of this form is not necessary to receive a subscription, but we would greatly appreciate your input.

NOW: I use renewable energy for (check ones that best describe your situation)

- ❑ All electricity
- ❑ Most electricity
- ❑ Some electricity
- ❑ Backup electricity
- ❑ Recreational electricity (RVs, boats, camping)
- ❑ Vacation or second home electricity
- ❑ Transportation power (electric vehicles)
- ❑ Water heating
- ❑ Space heating
- ❑ Business electricity

In The FUTURE: I plan to use renewable energy for (check ones that best describe your situation)

- ❑ All electricity
- ❑ Most electricity
- ❑ Some electricity
- ❑ Backup electricity
- ❑ Recreational electricity (RVs, boats, camping)
- ❑ Vacation or second home electricity
- ❑ Transportation power (electric vehicles)
- ❑ Water heating
- ❑ Space heating
- ❑ Business electricity

RESOURCES: My site(s) have the following renewable energy resources (check all that apply)

- ❑ Solar power
- ❑ Wind power
- ❑ Hydro power
- ❑ Biomass
- ❑ Geothermal power
- ❑ Tidal power
- ❑ Other renewable energy resource (explain)

The GRID: (check all that apply)

❑ I have the utility grid at my location.

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

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

❑ I sell my excess electricity to the grid.

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

(continued on reverse)

I now use, or plan to use in the future, the following renewable energy equipment (check all that apply):

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

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