An Open Letter to Renewable Energy Dealers/Installers

Energy Outfitters is a value added distributor of renewable energy products, serving the industry from facilities in Oregon and New Jersey. Our job is to provide the best products, technical support, and service to the industry's RE dealers/installers.

WE DO

- Provide technical support with a strong team of RE practitioners
- Have over $2.0 million of inventory of the industry's best products - ready to ship
- Build ETL® listed systems to your specification
- Develop customized marketing materials for our dealers/installers
- Provide ongoing technical and product training
- Offer new business opportunities and a lead referral program
- Select and support dealer/installer partners for specific geographic areas

WE DON'T

- Sell directly to end users - even on large projects
- Support "low ball" equipment brokers and discount houses
- Sell products that don't meet our high standard of quality
- Say we've shipped a product until we actually have

Our industry's responsibility is to ensure that ALL end users of RE products have the best experience possible before and after the sale. Satisfied consumers will spread the RE word to their family, friends and community. Our industry's reputation must be spotless.

The RE Products Channel

Strong Manufacturers
↓
Value Added Distributors
↓
Professional Dealers/Installers
↓
Satisfied Consumers

Since our inception in 1991, our business model has changed from retail store to installing wrench to distributor. We've learned that manufacturers, distributors, and dealer/installer partners need to focus on being the best at what they do. Energy Outfitters is committed to furthering our leadership role as a value added distributor.

If you agree with our philosophy we encourage you to join us.

Best Regards,

Bob

Bob Maynard
President

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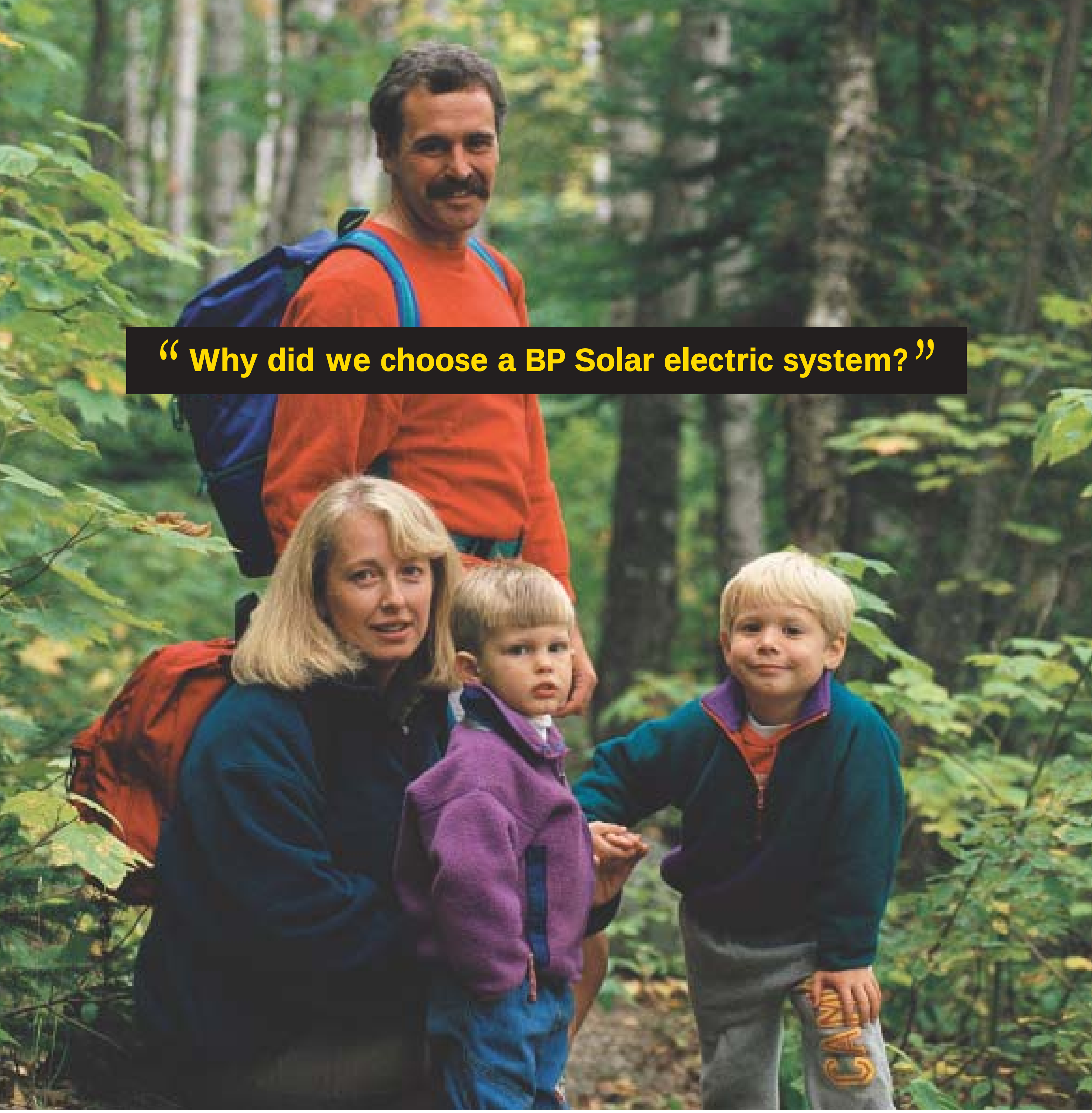
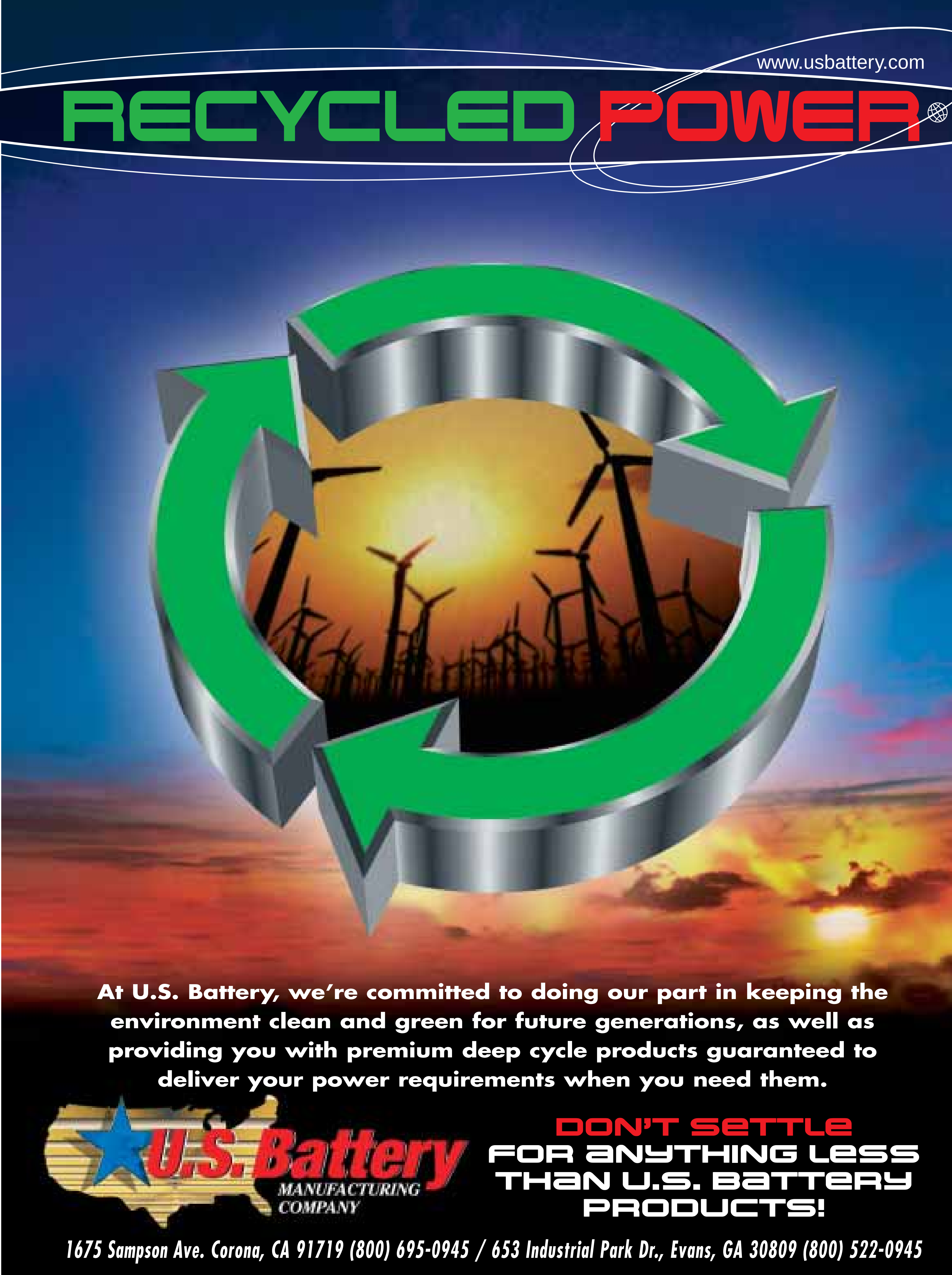

"Why did we choose a BP Solar electric system?"



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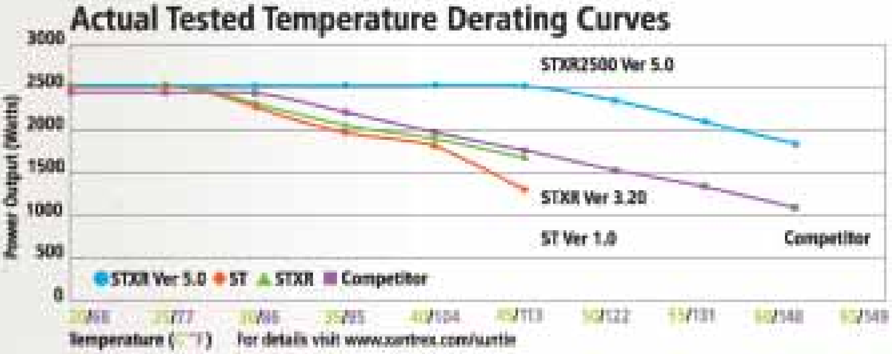
Xantrex Revamps SunTie XR

After ten months of design review and 10,000 hours of field-testing, the latest version of the SunTie XR from Xantrex Technology Inc. is entering the market with competitive energy harvest and unmatched thermal performance.

The SunTie XR Version 5.0 incorporates significant upgrades to address performance issues reported by a number of users last year. The upgrades have been beta tested by homeowners, at commercial sites, and at Sandia National Laboratories and the Florida Solar Commission. Following are key product improvements.

Thermal performance

Thanks to new air flow management, fan control software, and optimized power converter design, SunTie XR now offers 2500 watts continuous inverter output up to 45°C/113°F and over 1800 watts at 60°C/140°F. Competitive inverters start to derate as early as 30°C/86°F. The SunTie XR is capable of producing power beyond most PV module's temperature derate curve, ensuring you get the most from your solar system in hot climates.



New MPPT Software

The new SunTie XR software is far more responsive and causes the inverter to react 50% faster to changes in insolation events (typically rapidly changing cloud cover). The result is improved energy harvest in all conditions.

Improved Display

The SunTie's LCD display now offers installers and home owners more information and is approved by the CEC for rebate applications. The multi-page scrolling display reports grid voltage, array and Maximum Power Point reference voltage, daily watt hours delivered, inverter output in watts, text fault logging, daily time online, and non volatile lifetime kWH produced.

New Combiner and Built in Balance of Systems

The six-string PV array combiner has improved wire access and bypass lugs for the use of optional external combiners. The SunTie XR also includes PV ground fault protection and all necessary AC and DC breakers and disconnects to make a code compliant PV system, without adding an external disconnect or breaker box.

Standard Five Year Warranty

All new STXR version 5.0 inverters come with a standard five year warranty.

What Users Are Saying About the SunTie XR Version 5.0

"I was very impressed with the effort they put into this project to ensure that the inverter would operate at peak efficiency under all conditions. In the end, I personally saw a 10% improvement in overall inverter output. I feel that Xantrex has stepped up to the plate and proven that they not only stand behind their product, but are determined to remain competitive with the improvements that they have made."

Mark Lopez, Customer

"The STXR/GP inverter provides a significantly greater return on investment than its predecessors. … day after day of performance data logging and data analysis, demonstrated the inverters were reliable and produced consistently superior power production."

Richard Martin, Customer

"The Xantrex SunTie is now a worthy, American made product that offers features competing products can't match. It allows systems to start small and grow with your budget if need be, provides detailed display of performance, and the best hot weather performance of any commercially available inverter. Fishbowl is now available as well, so any SunTie user can track and log the performance of their inverter using a standard windows PC.

Xantrex has proven their resolve by supporting me, their most vocal critic, and my efforts to improve the SunTie."

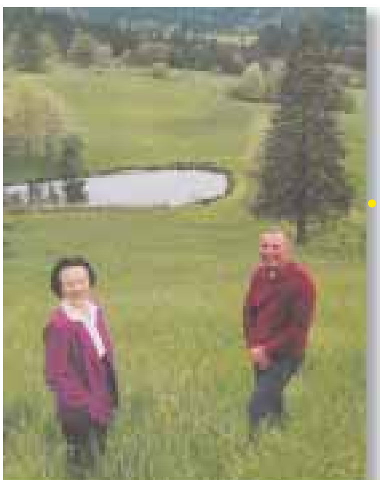
Henry Cutler, Contractor

Henry Cutler worked with Xantrex on contract to develop and test the new SunTie XR.

As part of the Bonneville Environmental Foundation Green Tags program, Xantrex manufacturing facilities in the US operate on 100% green electricity.

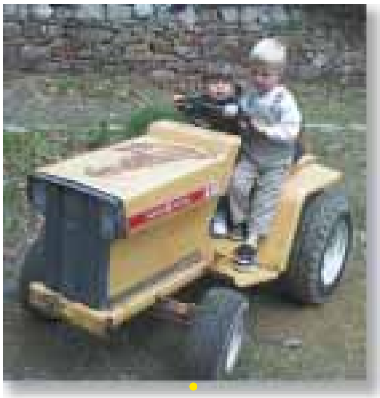
www.xantrex.com

HP96 contents



On the Cover

Scott Jernigan, Nicole Smith, and Scott Harding come together to help Tiffany Grisen move the Grisens' 300 watt PV array from a rental house to their own home.



Regulars

The Right Stuff

Let's face it—purchasing a renewable energy (RE) system is a big investment. This is true whether you're hiring a pro to design and install your system, or you're electrically savvy and will be doing the work yourself. Either way, you have some important decisions to make.

Hiring pros may look expensive at first, but when you consider their level of expertise and the value of your own time, it may very well be the most cost effective approach. As the use of RE becomes mainstream, we're seeing more and more professionally installed systems. As a result, it's getting easier to find a local pro to install your system. A decade ago, this definitely wasn't the case.

Jay Peltz of Peltz Power is one of many worthy wrenches ready to install an efficient, code compliant RE system for you.

We want to make it even easier for you to locate qualified help for installing RE at your place. *Home Power* has an RE Business Directory on our Web site, and we are planning a new RE installer directory in the magazine, focused on full service, installing dealers. This directory will make it easier to find the pros who will not only sell you the gear, but install, service, and support it.

Whether you're looking for an installing dealer or buying RE equipment for a do-it-yourself project, use the same common sense you would use when purchasing any expensive product. First, learn what questions to ask. Second, research who can provide you with the goods and services you need. Third, get both customer and business references on the quality of the service. Keep in mind that you'll have some questions along the way—the installer or company you purchase your equipment from needs to be your first and best source of information. Finally, remember that the lowest price is not always the best deal.

Home Power is all about giving people access to the information they're after. Whether you're a do-it-yourselfer, or a customer looking for a pro, you need to be an educated consumer. For close to 18 years, *Home Power's* goal has been to help promote RE, create educated consumers, and get people excited to take the solar plunge. Just make sure to look before you leap. Shine on!

–Joe Schwartz for the *Home Power* crew

Think About It

The ability to properly *build* a solar energy system can make or break it, regardless of how good the design is.

—Zeke Yewdall, page 56

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Powerful Dreams

Crown Hill Farm's Hydro-Electric Plant

Juliette & Lucien Gunderman

Most Photos by Greg Wheeler

The big lake (6.1 acres) supplies the larger of the two hydro-electric turbines located 170 vertical feet below.

Several people who have heard about our hydro plant have all had the same questions! Where on earth did you come up with the idea to build a hydro-electric plant on your farm? They also wonder what it takes to design and build a hydro system.

Well, it takes an idea first and foremost. Actually, it takes a lot of ideas. It takes frequently waking up in the middle of the night with many ideas, and writing them down. It takes water, optimism, more water, diligence, more water, patience, water, practical common sense, and the will to succeed.

The idea came twenty years ago while Lucien was attending his high school's ten-year reunion at the Von farm in Carlton, Oregon. Dick Von, a logger and farmer, had always wanted to build a hydro-electric system on the farm. The Vons were just getting started with their project at the time of the reunion, so Lucien got to see the beginning phases of the system. Pipelines had been laid, and the powerhouse had been started.

The gears in Lucien's head started turning. Soon after the reunion, and every three or four years, Lucien contacted the local utility to see what they thought of the idea of a small hydro plant being built and intertied with the utility. Each time the question was asked, the same answer was given: "It's a great idea, but with the low rates that McMinnville Water & Light currently has, it's simply not an

Lucien Gunderman and the twin Canyon Industries turbines.

economical thing to build, and the payback would be too many years to count." McMinnville Water & Light still has one of the lowest electricity rates in the nation.

Eighteen years went by. The year was 2000, and an energy crunch was upon us. This energy crisis prompted us to hire an engineer and pursue the hydro project in earnest. The engineer saw promise in the project.

Lucien again contacted the Vons, and arranged for a personal visit and tour of their system, which had been in operation for nearly two decades by then. Juliette, Lucien's mother, and Lucien were both hooked after seeing the Vons' system. We both knew that Crown Hill Farm had the potential for a hydro system if Lucien's ideas could be put together into a finished package.

McMinnville Water & Light

Lucien again made a trip to the local utility, and this time got a much different response. Rates were increasing and were expected to keep increasing, and electricity was now in short supply. Amazing how a few years and an energy crisis can change a situation.

However, no one in the utility's service area had ever built a grid-tied microhydro project in its 113 year history. They were reluctant to be more accommodating than they were legally required to be. And they were completely unfamiliar with the interface and the induction generation system that we were proposing.

Photo by Dave Dillon

Juliette and Lucien Gunderman in their watershed.

Hydro History—Full Circle

When Crown Hill Farm was started, Juliette's parents were the first rural electric customers of the utility on Baker Creek Road. They also supplied cordwood to the utility to operate a steam turbine that was used to power the electric plant for the city of McMinnville in the early years. This power plant was located just one mile above the farm's entrance.

It was a combination hydro/steam turbine. When water was not available in sufficient supply from Baker Creek to turn the Pelton wheel turbine, steam was generated by a wood-fired boiler.

This plant was a 200 KW system that was the only source of electricity for the city of McMinnville in the early days. It was built in 1907. The vertical head was 237 feet (72 m), only 50 feet (15 m) more than we have on our system. The water was carried via a 24 inch pipeline approximately 1 mile (1.6 km). A dam was installed, complete with fish ladder and a large vertical slide gate for flushing the dam.

As a child, I played at the dam on countless occasions, and was always intrigued with it, the fish ladder, and all parts of the system. Recently I got to see the remains of the original turbine that was decommissioned in 1952. When McMinnville Water & Light came on-line with Bonneville Power, it was required that they shut down their own power plant.

Lately there's been talk of recommissioning this plant. The Crown Hill Farm project is a demonstration of the viability of hydro-electricity. "Things have come full circle with the completion of Crown Hill Farm's hydro project," said Juliette.

Juliette's father delivers wood to the Baker Creek power plant.

The two Canyon Industries turbines flank the 30 KW, three-phase generator.

go ahead with the project, so we started to make arrangements and plans. Various sources were used to research the project, from the Internet to Oregon State University.

We dug several small collection ponds and nearly 5,500 feet (1,700 m) of ditches. This included ditches to divert water to two reservoir ponds that supply water to the project, as well as for the main lines to the turbines.

Water for this power plant is from upland sources, including several artesian springs that run year-round, and from collected rain runoff. The head (vertical distance the water falls) from the little lake diversion is 85 feet (26 m), and the head from the large lake is 170 feet (52 m). The water leaving the powerhouse runs into Baker Creek, which borders our property, and eventually into the Yamhill, Willamette, and Columbia Rivers.

After several meetings with us, the McMinnville Water & Light Commission and the staff of the utility saw the value that local renewable energy would provide to the community. They offered to be more flexible and to install a pole and dual meters for the project. One meter was for incoming electricity and one for generated electricity flowing back into the grid.

Crown Hill Farm Hydro

Our farm was started in 1920 by Damien and Zephirine Mochettaz, Juliette's parents. It encompasses nearly 800 acres. Crown Hill Farm is aptly named—it sits in the rolling hills west of McMinnville, and actually has a crown of high hills around the south and west ends of the property above our main farm buildings and residences. We recently put a conservation easement on the farm to protect its natural beauty and open space in perpetuity.

Once we got started on the hydro project, a hydrologist was hired. He determined that approximately 175 acres could be used as the watershed for the project. There were already two lakes on the farm. The large one was built in 1954 and is used for irrigation; it holds roughly 22 acre feet (2,700 m^3; just over 7,000,000 gallons) of water. The second lake was quite small, but could act as a collector for the new lake that would be built at a slightly lower elevation. It was in a more beneficial location for collecting and regulating water for this project.

We verified rainfall for the last 50 years, which showed that adequate water would be available, at least in the winter months, to run the system. The farm, located 6 miles (9.6 km) west of McMinnville, gets 46 to 50 inches (117–127 cm) of rain per year. After doing this research, we decided to

Intake & Pipe

The penstock system includes two main pipes. The 10 inch pipeline from the big lake runs 1,850 feet (564 m) and feeds the larger of the two turbines. The 8 inch pipeline from the little lake runs 950 feet (290 m) and feeds the smaller turbine. Both pipelines are buried 5 feet (1.5 m) deep. Both lines are straight runs except one 45 degree elbow in each line, where there are thrust blocks—large concrete blocks attached to the pipe. The thrust blocks anchor the pipe and absorb the force of the water on the fittings and pipe. There are also thrust blocks on the 10 inch line where it comes up and into the filter, which is adjacent to the powerhouse.

At the little lake, a blue intake pipe is drilled with hundreds of 1/4 inch holes. The galvanized shroud prevents debris from clogging the intake.

We did a lot of the manual work, and used our backhoe and dozer for much of the excavation. All four small diversion ponds and the second lake were built by Lucien and a friend, Jim Modaffari, who does excavation work. Pipelines were laid by a professional who deals with high pressure irrigation lines all of the time. All pipeline ditches were backfilled by Lucien. We also designed and helped build all portions of the tailrace and powerhouse.

The big lake has a filter screen on the end of a pipe in the lake. The stainless steel screen box is approximately 5 feet tall by 2 feet wide by 2 feet deep (1.5 x 0.6 x 0.6 m), and is clamped to the pipe with a steel clamp. It will not allow any particles or debris larger than 3/4 inch (19 mm) in diameter to enter the penstock. The penstock is the pipe that delivers the water from the intake to the turbine.

We installed a 2,000 gpm in-line filter that removes any debris that might get through the main screen in the bottom of the lake. This filter has a built-in brush and blow-off valve so that it can be cleaned and flushed even while in operation.

Canyon Industries manufactured our two Pelton turbines. They did not want any particles larger than 1/4 inch (6 mm) passing through the turbines. When we ordered the filter, the manufacturer opted to use 1/16 inch (1.5 mm) stainless steel mesh for the screen. They felt that we would have little or no trouble with organic material getting hung up on this size mesh. We've flushed the filter four times since it was installed eight months ago. The filter has two pressure gauges mounted on the body, and it is recommended that it be flushed when there is a 5 psi difference between source, and output ports on the filter. When we did flush the filter, it had never reached the 5 psi difference. We just wanted the system to work at optimum efficiency. The filter has worked very well.

The little lake intake screen is a combination screen and filter. It was made from a piece of schedule 40, 8 inch PVC pipe that is vertical in the lake. Lucien drilled 1/4 inch (6 mm) holes for seven hours one day to make this intake filter/screen. It works perfectly. We used some 24 inch (61 cm) galvanized heat duct to make a shield that surrounds the intake pipe. Water must enter at the bottom of the shield, so a very limited amount of debris is pulled up to the actual screen pipe. We plan to build a catwalk this summer so we can run a brush up and down the pipe to dislodge small particles that are sucked against the pipe during operation.

Latest Technology

The system is designed to run with water from one or both lakes in combination, and uses two, twin nozzle, Canyon Industries Pelton wheel turbines that are synchronized via a belt drive to operate in unison. The turbines are a fixed-nozzle design, and nozzles can easily be changed depending on the available water. The low-end output of the system is approximately 500 watts, and the high-end rating is 30 KW. The turbines will run efficiently with a volume as low as 65 gallons per minute or as high as 1,850 gallons per minute.

Technical Specifications

System type: Batteryless grid intertie, three-phase, 240 volt, open delta wiring configuration

Static head: Little lake, 85 feet; big lake, 170 feet

Flow rate: 65 to1,850 gallons per minute

Large turbine: Canyon 1215-2, twin nozzle Pelton, 12 inch (30.5 cm) pitch diameter

Small turbine: Canyon 9513-2, twin nozzle Pelton, 9.5 inch (24 cm) pitch diameter

Both have manganese bronze runners.

Our system is unique in that two turbines actually run one generator. Either turbine can run the generator with one nozzle or two, or both turbines with one, two, three, or four nozzles. Valves are automatically opened and closed through the secondary control panel according to lake levels. We have two on/off setpoints in both lakes according to levels that we can select at the powerhouse. The system can operate completely unattended, with a variety of weather conditions and available flows.

Nozzles: Minimum nozzle size for both turbines is 0.63 inches (16 mm). Maximum nozzle size for the large turbine is 1.6 inches (40 mm). Maximum nozzle size for the small turbine is 1.4 inches (36 mm). Nozzles are fixed-jet type nozzles that are easily changed for seasonal water fluctuations.

Generator: Marathon, M/N 324TTDP7071, 240 VAC, three-phase, induction, 60 Hz, 0.5 to 30 KW, 1,800 rpm, belt driven

Main disconnect fuse/breaker: 100 A at 240 V, three-phase

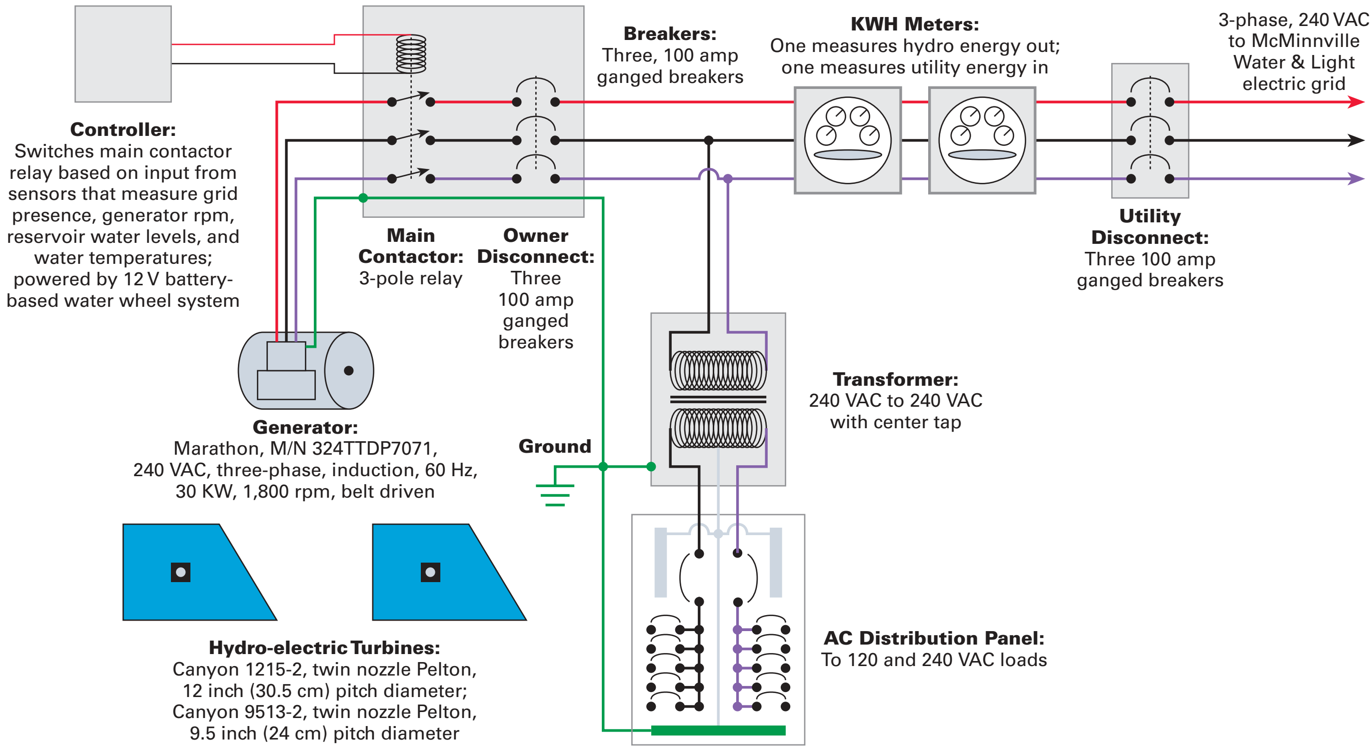
System performance metering: PQM, Multilynn. Shows voltage, amperage, instantaneous power output, and approximate KWH

Average KWH per month: 3,000 KWH January–April 2003

Utility residential KWH cost: 3.8 cents for the first 1,000 KWH; 4.1 cents over 1,000 KWH

Percentage offset by system: 50 percent in first six months of operation

Crown Hill Farm's Dual-Turbine Hydro System



Since we have a net metering contract with McMinnville Water & Light, we cannot exceed 25 KW at any time during the year. Oregon law for net metering limits the output to 25 KW. This system is a three-phase, 240 V grid interface system that is wired directly into McMinnville Water & Light transmission lines. Electricity generated is credited by the utility through a net metering agreement signed earlier this year.

This hydro plant incorporates the latest technology, and has automated features that monitor lake levels and temperature, as well as generator function, frequency, KW output, power quality, etc. It has automated controls that open and close valves on the turbines according to lake levels. Level options are programmed on a keypad on a secondary control panel, and a digital readout gives water levels in both lakes, as well as a temperature reading of the lakes and Baker Creek.

This control panel governs shutdown and startup of the turbines based on input from several sensors. The batteries below power the control system even if the utility grid fails.

The system also has a dual timer option for turbine operation, and a manual override for select situations. It has six fail-safe controls that will automatically shut down the generation system when necessary. These controls protect the equipment, and ensure that no electricity will flow into the local utility lines when they are being repaired by utility workers during a grid outage.

An automatic water shut-off feature will turn off all water to the turbines in the event of a utility failure, or any other system malfunction. Lucien designed this feature so that a valuable resource—water—will not be wasted.

Taking Care of the Fish

The system monitors the temperature of the water and the levels of each lake, to protect the fish. If the levels get too low or the water is too warm, it can't be run through the turbines and introduced into Baker Creek. Each lake has a two-stage setting with level controls to maximize resource usage, and allow for automatic control of generator output.

Water leaving the turbines through the concrete tailrace is slowed, to alleviate erosion and eliminate water turbulence when it merges with Baker Creek. The water is aerated thru a series of diversion bars of expanded metal, oxygenating the water to facilitate fish habitat in Baker Creek. The creek is listed as a fish bearing stream, which includes such species as dace, sculpin, cutthroat trout, lamprey, crayfish, winter steelhead, and coho salmon.

The main contactor enclosure contains the overcurrent protection, manual disconnect, and main relay.

The temperature standard for cutthroat trout, steelhead, and salmon is quite cold. Technically, the temperature is not to exceed 55°F (13°C) May 1 through July 15, 65°F (18°C) July 16 through October 15, and 55°F (13°C) October 16 through 31. We did a lot of talking about these temperature criteria with state and federal agencies, and ended up having to install the temperature monitoring equipment, and setting it up for auto shutdown if we exceed the creek

Two KWH meters measure grid energy to the farm and hydro energy to the utility grid.
Below is the disconnect required by McMinnville Water & Light.
The shed that houses the turbines and controls is in the background.

Induction Generation

When we looked at what type of generating system to use, the most economical and easily grid-intertied system was an induction generation system. With an induction system, you use a regular induction motor. When the turbine spins the motor shaft, the motor becomes a generator, and generates instead of consuming electricity.

Synchronization. One beauty of this system is the simple controls required to connect to the grid. There is an electronic tachometer that monitors the system speed. When the induction motor/generator hits generating speed, the control panel connects it to the grid. After the phases line up, the grid locks the generator at 60 Hz and it is generating. Induction generators are easily obtained, although ours, because of the double turbine drive, had to be special ordered.

Safety. Within the intertie panel are relays that will sense a grid failure and automatically shut down our system. So the system cannot endanger utility crews with an unanticipated electrical feed. Electrical codes are very specific as to auto shutdown in the event of a grid failure. The utility was very concerned about the intertie, since we are the first nonutility hydro plant to come on-line in their history. If the utility needs to work on main transmission lines, they can shut off our system with a manual disconnect switch, which in turn shuts down the generating system in a matter of seconds.

Induction or Asynchronous? We did also consider using an asynchronous generator. With an asynchronous system, we would have had the option of complete stand-alone power, even if the grid went down or failed. But it also would have meant more wiring, a grid-interactive inverter, batteries, and a high voltage utility disconnect. The additional cost would have been approximately US$20,000 to $25,000. We decided that since we already had backup generators, this additional investment really made little sense.

Transmission. Our transmission lines to tie in with the grid are only about 450 feet of overhead run, and we were able to tie into our existing 240 volt, three-phase, open delta irrigation service. This kept the cost down and is working very well.

Water Wheels

A small, 4 foot (1.2 m) water wheel is incorporated into the design of this hydro project, just for fun. The water wheel was constructed from an antique steel wheel that was 36 inches (91 cm) across, and the 1/2 gallon buckets were from a dismantled feed mill, the old Albers Mill on Front Street in Portland.

For the time being, it is just a functioning, aesthetic addition to the project. The dry seasons during these last two years have also limited the possibilities for the water wheel. Water for the water wheel comes from a third source of water so it does not take water away from the main turbines.

A new small water wheel, made from an old squirrel cage fan, mounted on a frame on roller bearings has been constructed, and direct coupled to a permanent magnet motor from a computer drive. This small water wheel, is mounted on top of the original tailrace, and is supplying a continuous output of between 1/2 to 1 1/2 amps at 12 VDC to two automobile batteries. A 700 watt inverter supplies emergency lighting, runs a battery charger for the DC portion of the main project, and runs some decorative lighting on the exterior of the hydro building.

A small, 4 foot diameter water wheel was built using parts from an old feed mill.

This portion of the project was just a brainstorm, and a fun part of the overall project. It uses the same water that is fed to the larger water wheel, so it does not take away from the main turbines. The inspiration for this project was a similar pico-hydro system at www.otherpower.com/otherpower_experiments_waterwheel.html.

temperature. Temperature monitoring is required from May 1 through October 31 of each year.

Alarms & Controls

Lucien installed signal lighting that is visible from our home to show when the system is operational. An audible and visual alarm were also designed and installed to alert us of a grid failure or system shutdown.

A low voltage power supply and low voltage actuators are used for the auto valve control that is run from the head level sensors in each lake. The actuators were purchased from Burden's Surplus Center in Minnesota. A 24 VDC battery charger charges two small 12 volt batteries in series, which allows the system to close valves in the event of a grid failure. If the grid goes down, a relay simply tells the panel to close all valves and shut off the water.

Even though Lucien thought up many of the details in this system, the turbines, panels, and most of the control mechanisms were not manufactured on site. There were countless phone calls and e-mail messages, as well as continuing research into many of the details of this project. It would not have come together without the help of Canyon Industries, Bat Electric, and Inertia Controls. The equipment used for the project has a long life and is expected to perform for a century or more with little maintenance.

Determination

This 30 KW capacity microhydro plant is the first newly licensed hydro plant in the state of Oregon in the last twenty years. Several people have told us that they would not have had the determination, persistence, and patience to deal with all of the agencies and their rules, regulations, restrictions, and timetables.

Local, state, and federal agencies that had jurisdiction or commented on the project included: Yamhill County Planning, Oregon Department of Fish and Game, Oregon Department of Environmental Quality, Oregon Division of State Lands, Oregon Department of Forestry, Oregon Department of Agriculture, Oregon Office of Energy, State Historic Preservation Office, Oregon Department of Water Resources (the lead agency), Northwest Power Planning Council, Oregon Parks and Recreation Department, Oregon Land Conservation and Development Department, Oregon Public Utilities Commission, U.S. Department of Fish and Wildlife, and the National Marine Fisheries Service. Our commitment was tested when dealing with these agencies during the licensing process, which took a year and a half.

Benefits

We see many benefits from our hydro project. The major one is supplying electrical energy. The system is expected to generate 96,000 KWH of electricity per year, enough to supply approximately eight typical Oregon homes. It should generate enough electricity to meet all of Crown Hill Farm's electricity, and about 25 percent more, which McMinnville Water & Light will buy at wholesale and resell to other consumers.

Hydro System Costs

Item	Cost (US$)
Turbines & switchgear	$40,000
Pipe & installation	22,500
Building & concrete	10,000
Excavation	7,500
Misc. unanticipated costs	7,500
Electrician, etc.	6,500
Misc. pipe & hardware	5,000
License & permits	3,000
Engineering & misc. costs	2,500
Hydrologist report	1,600
Water wheels (both) & equipment	500
Total	$106,600

Another important benefit is that our project is a renewable resource and does not deplete any natural resources. The two main lakes already existed and needed no structural changes. The diversion ponds provide additional wildlife habitat. The project adds cold, aerated water to Baker Creek, which enhances fish habitat.

"A hidden benefit is that this little hydro system is actually improving the power quality for their neighbors," said Christopher Dymond of the Oregon Office of Energy. "Lucien and Juliette's investment in local clean energy reflects both their patriotism and good stewardship."

One of the main pipelines also incorporates irrigation risers that will add efficiency to summer irrigation because of the larger supply line with more pressure. The large lake has been used for irrigation purposes since 1954.

The project better controls runoff water. It collects and diverts water to the new diversion ponds and two regulation lakes. This dramatically reduces erosion, sedimentation, and water damage to drainage ditches and Baker Creek.

Hydro Dreams

It has been said that dreams come and go. In this case, our dream has come true, especially for Lucien, who never gave up hope on the idea that our farm and its natural resources could one day be used to supply electricity to ourselves and others.

A project like this is a big undertaking, with many unexpected costs and hurdles along the way. But the feeling of satisfaction, pride, and good stewardship is well worth the time, energy, and hard work to bring it all together. It is a great feeling to see a project come together and work after dreaming and planning for many years.

Access

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Canyon Industries, Inc., Brett Bauer, 5500 Blue Heron Lane, Deming, WA 98224 • 360-592-5552 • Fax: 360-592-2235 • CITurbine@aol.com • www.canyonindustriesinc.com • Turbines

Bat Electric, Inc., Dan Batdorf, 20200 Charlanne Dr., Redding, CA 96002 • 530-221-1336 • Fax: 530-221-3496 • BATELECINC@aol.com • Co-generation control panel

Inertia Controls, Inc., Darin Malcolm, 381 S. Redwood, Canby, OR 97013 • 503-266-2094 • Fax: 503-266-1152 • darinm@canby.com • www.saftronics.com/pages/INRT.htm • Temperature sensor and valve actuator panel

Familian Northwest, 2979 N. Pacific Hwy., Woodburn, OR 97071 • 866-537-7635 or 503-982-6141 • Fax: 503-982-1106 • www.familiannw.com • Pipeline, valves, plumbing

Precision Controls, Yvonne Vonderaye, 7110 SW 33rd Ave., Portland, OR 97219 • 800-441-8246 or 503-245-7062 • Fax: 503-245-4825 • yvonnev@teleport.com • www.ifmefector.com • Temperature sensors and controls

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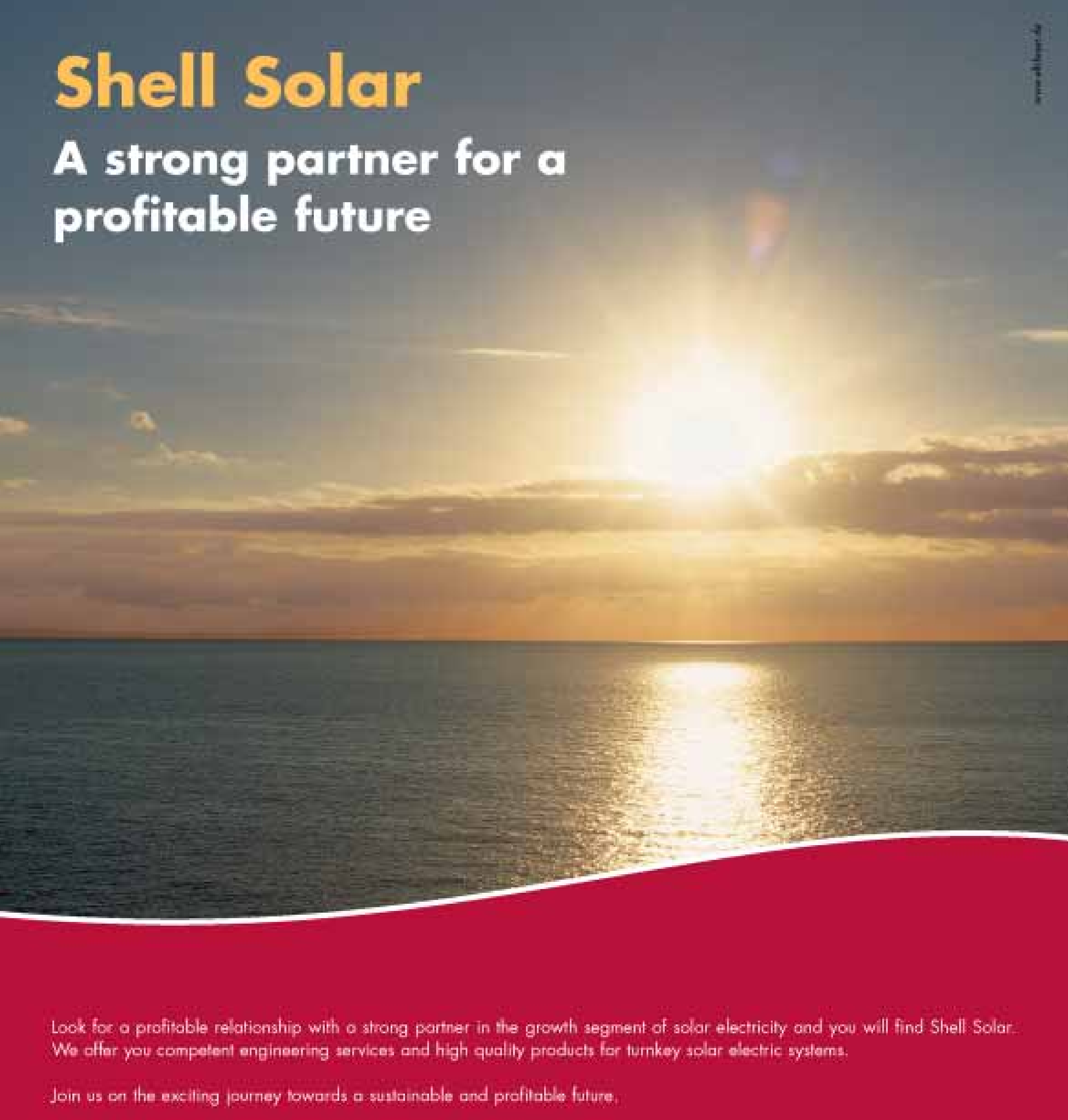
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Office-Sized Solar-Electric System for Renters

Eric Grisen

Do you want to live with renewable energy, but don't think you can because you're renting? You can. With a little creativity, you can design and install a solar-electric system that has minimal impact on your rented house. We did!

This renewable energy system is big enough to power a home office, but it's small enough to live in a closet or travel in the back of a pickup truck.

Last year, my partner Tiffany and I turned on a 300 watt photovoltaic (PV) system to power my home office. We were able to install the system with minimal impact to our rented house—six lag screws into our patio's roof, and one hole into my office's ceiling. We also designed the system to be portable, so when we moved, we were able to pack it into our pickup truck in a matter of hours. You can build a system like this for less than US$4,000.

Our photovoltaic (PV) system powers the equipment I need for my telecommuting job at *Home Power*, including a Macintosh G3 desktop computer, Radius 21 inch CRT monitor, Aiwa boom box stereo, Umax Astra 2000U scanner, and an APS Pro 18 GB external hard drive.

Energy Efficiency First!

Before we installed the PV system, we applied lots of energy efficiency measures to our rented house. Why is that important? If part of your motivation is to have a lighter footprint on the planet, it makes sense (and cents) to reduce your energy consumption first. Inexpensive, even free, energy efficiency steps (like turning off appliances when you're not using them) result in a decreased daily energy requirement, and a smaller and less expensive PV system.

For example, by replacing our heat-producing, 100 watt, incandescent lights with cooler, compact fluorescents, we reduced our household lighting load by 70 percent. We further reduced our electrical load by turning our electric water heater way down, and wrapping it with an R-9 insulating blanket. Sensible energy conservation and modest consumption have always kept our utility bills relatively low. But in our all-electric suburban house that we were renting, we were unable to use less than 10 KWH a day on average.

Load Analysis

For our PV system to make sense to us, it had to be big enough to power all the loads in my office. If the system could cover my office's loads, it would give us to the flexibility to live off-grid, and I'd have enough electricity for my telecommuting work at *HP*. It would also be a good beginning to a home-sized system.

To find out how much energy all my computer equipment uses, I did a load analysis. Using a Brand Electronics digital power meter, I measured how many watts each appliance draws (see load table). I did this by plugging them into the meter, and then plugging the meter into the wall. The meter's kilowatt-hour (KWH) figure, recorded over a 24 hour period, allowed me to determine the average daily watt-hours used by each piece of equipment.

After I recorded the data from the individual loads, I gave myself a reality check by plugging the whole workstation's plug strip into the meter. This confirmed the individual measurements. My entire computer system uses about 1.3 KWH a day, or 6.5 KWH in a five-day work week. This is the amount of energy we wanted our PV system to cover.

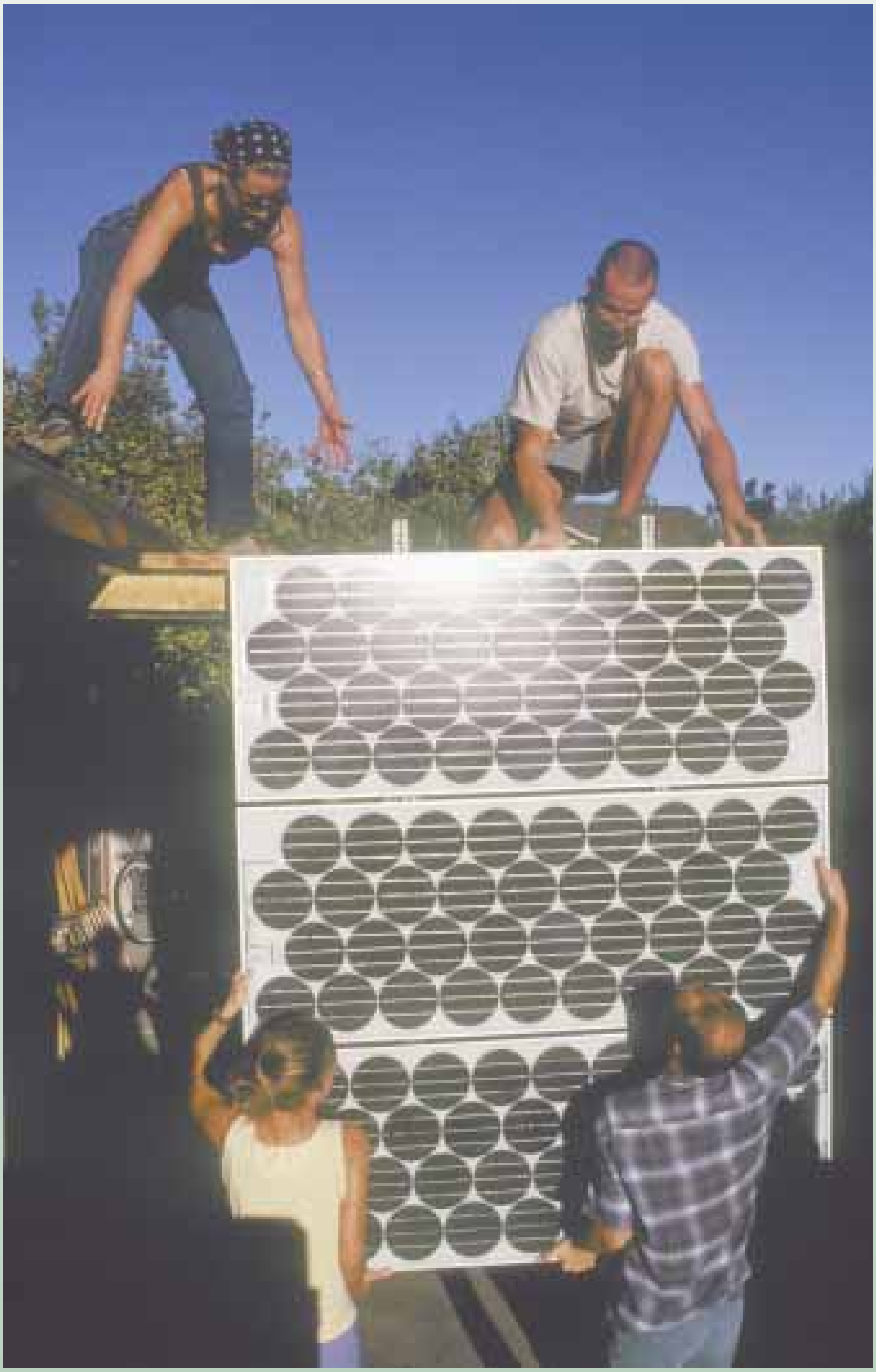
The load table shows how I calculated how much energy my office uses. I learned this method from Solar Energy International (SEI). If you don't have a power meter, you can use the wattage information published on the appliance's label. But keep in mind that these figures represent the maximum draw of the appliance. Actual power requirements are typically lower, often substantially. By calculating or measuring exactly how many watts each appliance draws and multiplying it by how many hours a day it gets used, you can come up with a total daily kilowatt-hour number.

System Design

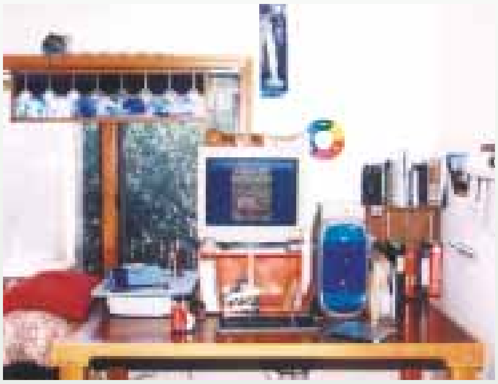
After the load analysis, we looked at other project considerations as we designed the system. The system had to be easy to move, have low impact on the house, and stay within our budget. It made sense for us to build the smallest system we could and then expand it later. After all, we do live on the grid. If the system can't keep up with my office usage, I can always plug into the wall for a little juice from the utility grid. We designed the system so that it would at least power my office's loads in the summertime.

Grisen System Loads

Load	W	× Hrs. / Day	× Days / Wk.	÷ 7 = Avg. Daily WH
Computer & monitor	149	10	5	1,064
Stereo	25	10	5	179
Scanner	17	1	5	12
External disk	13	1	5	9
Totals	204			1,264



The de-installation crew lowers the rack and PVs—Tiffany, Scott, Nicole, and Scott. We designed the system to be easily movable because when you move a lot, what goes up, must come down.



The system's loads.

Battery Sizing Computations

Avg. Daily WH	÷	Inverter Efficiency	÷	DC System Voltage	=	Avg. Daily AH
1,264		90%		12		117

Avg. Daily AH	x	Days of Autonomy	÷	Discharge Limit	÷	Battery AH Capacity	=	Batteries in Parallel
117		1		50%		105		2.2

DC Voltage	÷	Battery Voltage	=	Batteries in Series	x	Batteries in Parallel	=	Total Batteries
12		12		1.0		2.2		2.0

Seasonal Output Comparison

Season	PV Watts	x	Peak Sun Hrs.	x	System Efficiency	=	WH / Day
Summer (July)	300		7.7		65%		1,502
Winter (Dec.)	300		2.0		75%		450

I began crunching numbers to find out how many batteries the system would need. The data revealed that I'd need at least two of the 105 amp-hour (AH), absorbed glass mat (AGM) batteries that I wanted to use (see battery sizing table). Two of these batteries in this system provide a very modest amount of energy storage. But utility outages here in southern Oregon, are few and far in between. Also, I work during daylight hours most of the year, and have the utility grid available, so I really don't need too much battery capacity.

To figure out how many PV modules were needed, I did a little more math. The formula I learned at SEI suggested that I needed 3.39 of the PV modules I had decided to use. "Hmmm," we said to ourselves. "Can we afford to round up—three modules or four?" Well, we rounded down. Three modules were enough for us to start the system. PV is modular, so whenever funds allow we can easily add to it.

System Components

The PVs we chose are Siemens (now Shell Solar) SR100, 100 watt modules. These are nice, efficient, single-crystalline modules. They're stout, easy to work with, and they have cool silicon wafer polka dots. This particular model has since been discontinued, but at the time we were buying modules, they came to us at a good price.

We bought two of them with plans to buy another soon. Our plans to buy the third module were foiled when the *HP* crew gave us one wrapped up as a surfboard for a wedding present. I'm glad there was a PV inside that surfboard facade because it looked way too thick and klunky to ever carve any turns on a wave.

The other key component in the system is the sealed, lead-acid, maintenance free, absorbed glass mat (AGM) battery bank. I wanted these because they are OK to house inside living spaces, as long as the batteries' terminals are protected. AGMs don't have to be vented like flooded, lead-acid batteries. This means they can live in my office and I don't have to worry about explosive and corrosive gases.

I landed two, Concorde PVX-12105, 105 AH, AGM batteries, used, for next to nothing. They were still in good

System components: Class T fuse, shunt, batteries, meter, DC breakers, charge controller, and inverter with extension cords. Note the conduit (bottom left) that brought the PV wiring in from the roof.

condition—despite a traumatic past—so I snatched them up. In their previous life, they were part of a stand-alone PV system for *HP* Central's remote, off-grid radio telephone communication system. One day, some dishonorable scumbag stole the two, 75 watt PVs that charged this system. The batteries held up for a while, but eventually went dead from giving all their chemically stored energy to the repeater. After being removed, they were nursed back to life over several months. Now they're living a second life in our system.

The batteries, other system components, and breakers live in a wooden box Tiffany and I found at a junk store. Because all the components fit in or on the box, this half of the RE system can be moved easily with a hand truck.

On one side of the box, a Statpower ProSine 1000, 1,000 W inverter provides all the AC power my office will ever need, with significant room for expansion. My computer equipment likes its sine wave output. I like its easy-to-read digital display and two GFCI receptacles.

An RV Power Products Solar Boost 50 (SB50), 50 amp (A) charge controller, two DC-rated 30 A breakers in a Square D two-circuit box, and a Cruising Equipment E-Meter (now Xantrex Link-10) are mounted on the front of the wooden box. We chose the SB50 because we wanted a maximum power point tracking (MPPT) charge controller that we could grow into. The two breakers allow us to safely isolate any one current source in the system for maintenance, removal, transport—whatever. The E-Meter measures the amp-hour activity of the batteries. I like this meter because it tells me the system's status at a glance. I have it in scroll mode so I can see what's going on from across the room at my desk.

Installation Day

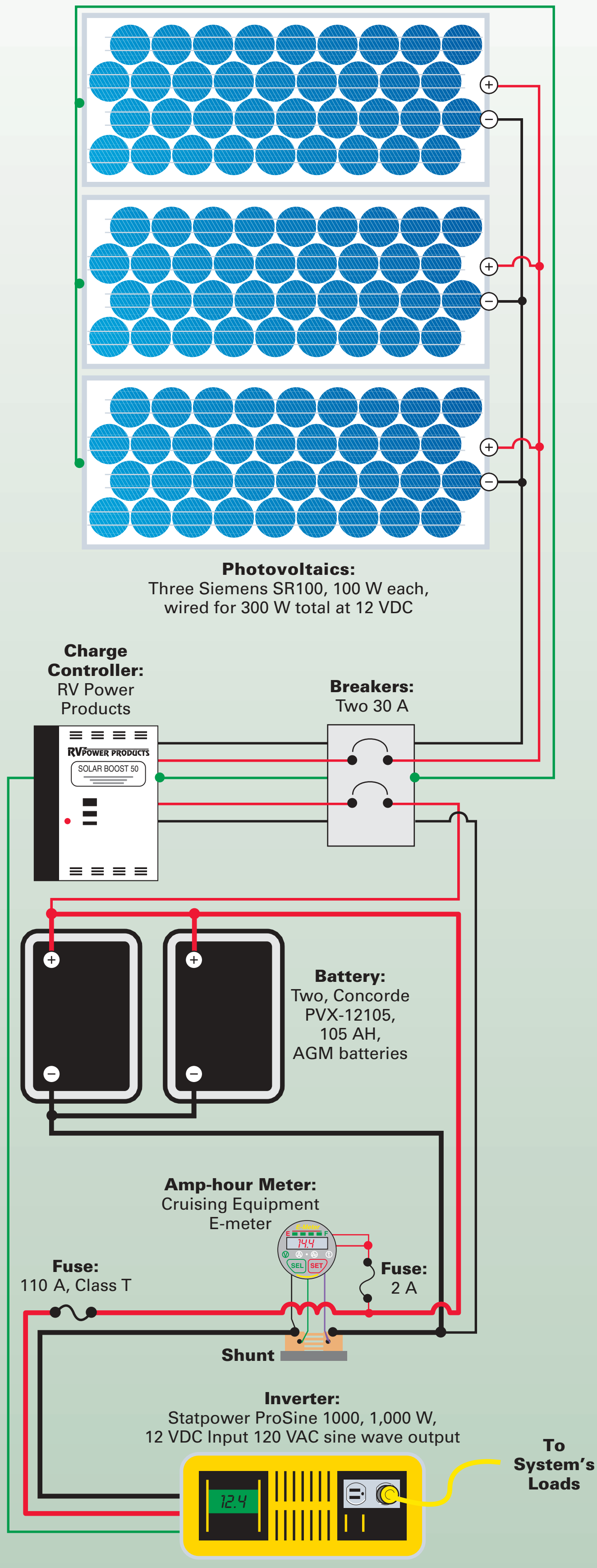
Before we installed the system, we had an impressive heap of renewable energy (RE) gear in the garage. It was pretty cool to look at, but the real fun began when we started to put it all together. I enlisted our friend Joe Schwartz to give me a hand. Start to finish, it only took us about six hours to install the system.

The first step was to install the PVs on the rack before we hoisted them up on the roof. We bolted them to the 1 1/8 inch (29 mm) galvanized, angle iron rack, using stainless steel hardware with lock washers. Then we wired the PVs up in parallel with #10 (5 mm^2) THWN-2 CU wire in Liquidtight conduit. We checked the module's short circuit current (Isc) and open circuit voltage (Voc) as we went to make sure the panels were working and wired properly. Then we climbed up on the roof to prep it for the array.

The patio roof is built with 4 by 4 posts and 2 by 4 rafters. The roofing material is translucent, corrugated, fiberglass sheets. These sheets are affixed to the 2 by 4s with 1 inch (25 mm) "wiggle molding" below and above. I laid down a few 2 by 12s on the wiggle molding so we could walk around on this fragile roof.

With the 2 by 12s providing a safe working surface, we lifted up the array. Lifting up the rack with the PVs installed was hard work, and a bit awkward. But once we got the

Grisen PV System



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

Grisen System Costs

Item	Cost (US$)
3 Siemens SR100 modules, 100 W	$1,680
Xantrex ProSine 1000 inverter, 1,000 W	840
2 Concorde PVX-12105 batteries, 105 AH	408
SolarBoost 50 charge controller, 50 A	399
Cruising Equipment E-Meter	194
Cables, wire, conduit, J-box, disconnects	150
Steel & misc. hardware for PV mount	91
Trace TFB110 fuse, class T, 100 A	51
Shunt, 50 mV 500 A	25
Battery box, used	20
Total	$3,858

array up on the roof, we were glad we did all the wiring on the ground, because working space on the 2 by 12 planks was limited.

Next we positioned the array towards true south—that's about 18 degrees east of magnetic south in southern Oregon. Then we screwed the array down tight through the wiggle molding to the 2 by 4 rafters. We used six, 3 inch long, 3/8 inch (25 x 10 mm) lag screws to attach the array to the roof.

After the array was in place, we were ready to get the wiring into the house. The PV wires were run through Liquidtight conduit into the attic via an attic vent. To get the wire runs through the vent, all we had to do was pull a corner of the vent's metal screen back. Once in the attic, the wire runs entered a combiner box that transfers the PVs' output to a pair of #2 (33 mm²) copper wires.

The #2 wire ran in conduit through the attic, and dropped through the ceiling into the closet in my office, where the rest of the system's components were located. At this junction, we had to drill a 1 3/8 inch (35 mm) hole for the conduit. *Don't tell our landlord—we patched it before we left. We think it was a minor thing to fix for installing the system safely.*

After the PV wiring was inside the office via conduit, we had to get the wires inside the wooden box that houses all the RE equipment. Using a 1 3/8 inch drill bit, we made a hole in the box for the conduit.

Before we started wiring up the DC breaker box, charge controller, inverter, and amp-hour meter, we popped the knockouts on the back side of each unit. Next we mounted the components onto the box, and marked where the knockout holes were. Then we drilled out the holes and permanently installed the components on the box. Each component has all its wiring concealed inside the box—it's safe, tight, and clean looking.

The PV wires were fed to a Square D breaker box that has two, 30 A breakers. The first breaker functions as a PV-to-controller disconnect and breaker. The second breaker is the controller-to-battery disconnect and breaker. These breakers' wire runs are made with #6 (13 mm²) copper wires. After we had all the gear affixed to the box and connections made between PVs, breakers, and controller, it was time to work on the batteries.

We made the battery cables using #2/0 (67 mm²) welding cable, lugs, and color-coded heatshrink tubing. This step requires a crimper, torch, vise, and solder. The nice thing about making the cables from scratch is that you end up with exactly what you want without unnecessarily long cables.

First the batteries were connected in parallel with short cables. Then the positive battery cable was connected to a Class T, 110 A fuse and the inverter. The negative battery cable was connected through a shunt to the inverter. Connections between the batteries and charge controller were made to the major positive and major negative. Connecting the battery cables to the inverter was convenient because the ProSine 1000 accepts battery connections from many angles. Once all the battery connections were made, we made the five connections for the amp-hour meter, fused it, and programmed it.

Six lag screws attached the PVs and homemade rack to the patio roof. After we de-installed the system (to move), we filled the holes with sealant and then put the screws back in.

System Performance

We've been really happy with the system's performance. It's functioning just as we expected without any glitches. We've lived with the system for over a year now. The loads and sizing figures have proven accurate. Our system delivers enough energy in the summer months to run my office

This hole we made in the ceiling for the conduit was the only interior impact our PV system had on the house.

full-time. In the winter, I use the grid about half the time (see seasonal output comparison table on page 28).

It's been an educational and empowering experience for us to run my office with solar electricity the past two summers. Although the system is modestly sized, we're very happy with it, and we'll be adding more PV to it. Our goal is to incorporate some of the components we have into a larger system that will cover all of our loads.

Sometimes we have surplus energy in our system. Tiffany and I have had a good time using up the surplus by having friends over to watch solar powered kayaking videos or to drink solar powered margaritas from the solar powered blender. As RE professional Bob-O Schultze says, "The only way you can waste renewable energy is to not use it."

Why did Tiffany and I choose a battery-based RE system over a utility-intertied system? We wanted to build a small system that we could take with us when we moved. Our setup guarantees that if we live off-grid, we'll have lights at night and I'll be able to work from a remote location. We also didn't want to make the wiring modifications to a rental that utility-interactive systems often require.

Go For It!

You don't have to own your own home or be wealthy to live with renewable energy. It's possible to install a PV system and still tread lightly on your rental with creative system design and installation. My advice to anyone who wants to live with a renewable energy system is to start by making your home as energy efficient as possible, and then go for it!

Access

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Brand Electronics, 421 Hilton Rd., Whitefield, ME 04353 • 207-549-3401 • Fax: 207-549-4568 • info@brandelectronics.com • www.brandelectronics.com • Digital power meter

Concorde Battery Corp., 2009 San Bernardino Rd., West Covina, CA 91790 • 800-757-0303 or 626-813-1234 • Fax: 626-813-1235 • skipkoss@aol.com • www.concordebattery.com • AGM batteries

RV Power Products, 12598 Fortune Way, Suite K, Vista, CA 92083 • 800-493-7877 or 760-597-1642 • Fax: 760-597-1731 • info@rvpowerproducts.com • www.rvpowerproducts.com • MPPT charge controller

Shell Solar Industries (formerly Siemens Solar), 4650 Adohr Ln., Camarillo, CA 93011 • 800-272-6765 or 805-482-6800 • Fax: 805-388-6395 • solarsalesusa@shell.com • www.shell.com • PVs

Solar Energy International, P.O. Box 715, Carbondale, Colorado, USA 81623 • 970-963-8855 • Fax: 970-963-8866 • sei@solarenergy.org • www.solarenergy.org • Hands-on education

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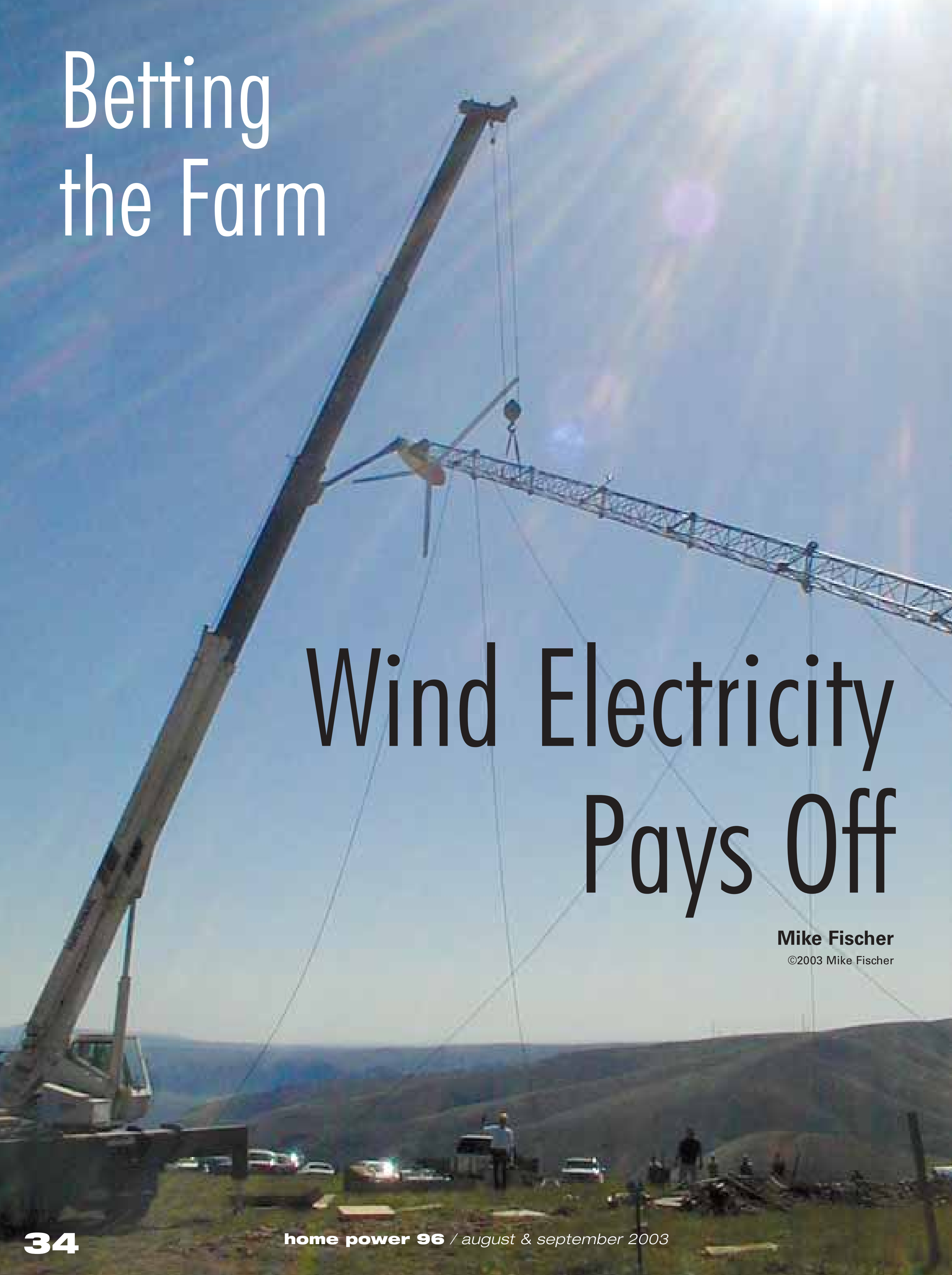
Betting the Farm

Wind Electricity Pays Off



Mike Fischer

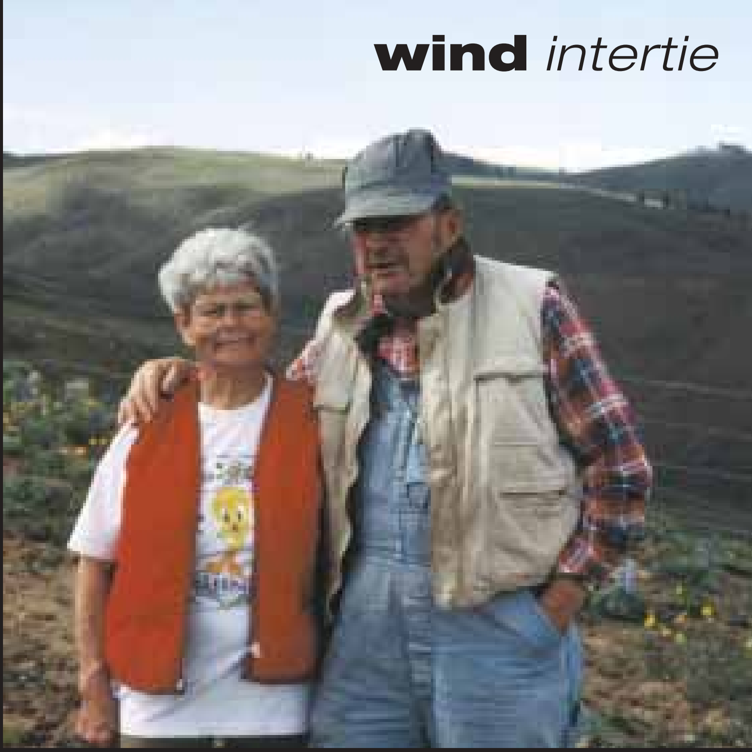
In spring 2001, June and Charlie Nichols met with Brooks Solar to discuss putting up some solar-electric panels on their property. What ended up happening just might be the best retirement present anyone could get.

Anne and Randy Brooks of Brooks Solar, Inc. in central Washington state have a systematic approach to helping others tread lightly on the earth, based on cost effectiveness. When dealing with a prospective client, they first recommend conservation, followed by an efficient, south-facing, passive solar home design. Next they recommend using solar hot water, since water heating accounts for the equivalent of about 20 percent of electrical consumption. For electricity production, they recommend a microhydro system as the first choice if you have falling water, then exploration of your wind-electric potential, and consideration of solar electricity last because, comparatively, it's the least cost effective of the options.

Going through this process got June and Charlie to thinking about when a large stack of hay bales was blown down their ridge, even though it was tied down with barbed wire, tarps, and old tires. They also remembered the time some pasture seeds blew a half mile to a neighbor's property. They became intrigued by wind power. Charlie was already predisposed to wind—in the 1940s, his family used a windmill to run a pump to get water to their 300 head of cattle.

Then the greatest selling point of all unfolded. The local utility's renewable energy incentive program, Sustainable Natural Alternative Power (SNAP), will pay producers in Chelan County up to US$1.50 per kilowatt-hour.

After a few calculations, Randy told June and Charlie that through the SNAP program, they could pay off their system within three to five years. After monitoring the progress of SNAP contributions, the Nichols made their decision in January 2002. They chose a grid-connected, 10 KW, Bergey Excel turbine, with a 21 foot (6.4 m) rotor diameter, on a 100 foot (30 m) guyed lattice tower.



June and Charlie Nichols chose wind as the power generating resource for their ranch in Washington.

Site Evaluation

The proposed turbine location had no trees to check for wind flagging. Older wind resource maps indicated that the exposed ridge experienced class 4 winds (13.4–14.5 mph; 6.0–6.5 m/s average) and newer maps indicated class 3 winds (12.3–13.4 mph; 5.5–6.0 m/s average). But both are mathematical extrapolations that might not define the site's actual microclimate. June and Charlie decided to forgo potentially sophisticated (expensive) wind measurements and follow their gut by putting up the Excel.

Laying out and bolting together the ten, 10 foot tower sections.

Rolling out the guy wires.

Later, after the trench to the power shed had been dug, Randy noticed that there was no topsoil on the ridge at the turbine site, but several feet of topsoil down by the shed. Also, the wildflowers and sage on the southeast sides of the hills in this high desert area were robust, while there was stunted vegetation on the ridge at the turbine site. All these subtle indications, combined with Charlie Nichols' experience in this country, pointed to the likelihood of consistent winds on the ridge.

Pre-Installation Preparation

June and Charlie contracted out with a neighbor to dig the trench and the holes for the guy wire anchors with a backhoe. Randy later dug the slots for the sloping anchor rods by hand to reduce disturbance of the soil on the tower side of each anchor hole. After fighting with the rocky soil, Randy concluded that he'd have a backhoe do this next time. The three anchors were located so that two shared the load of the prevailing winds on this fixed tower. As recommended by the manufacturer, a 50 foot (15 m) guy radius was used.

It was thought that direct burial electrical wire would be best to use. But after doing it, Randy decided that it was not worth the extra labor to fill in the rocky sections of the trench with sand, and then lay the wire and cover it with sand and caution tape before backfilling the hole. Conduit with ground wire running outside it will be Randy's preferred method next time. Three, #2 (33 mm^2) transmission wires and a #8 (8 mm^2) copper ground wire were run 924 feet (281 m) from the tower base to the inverter.

Portable power runs tools on the site.

Weather & Logistics

Only one paved road leads to the Nichols ranch, and a spring thaw load restriction was in place that delayed the project and required a special permit for passing over the road with the concrete truck and semi that would deliver the turbine and tower.

After the weather settled down, the turbine and tower were delivered, but the blades and inverter were missing. A few weeks later, a second set of pultruded fiberglass blades were air freighted from the Bergey factory in Oklahoma and the inverter arrived shortly after from the Trace factory in California. The original blades are still missing. Only one year after June Nichols approached Brooks Solar, and after three months of installation preparation and delays, the tower and turbine were set to go up.

Installation Crew

Randy Brooks, who traveled to Norman, Oklahoma before the installation to be trained as a Bergey installer, led the crew. This is first and foremost why the installation and grid-intertie went so well. You know how some people have their ducks in a

The crane holds the weight while the Bergey Excel is bolted to the tower top.

Muscling the Bergey's tail into position.

row? Well Randy knows what temperature the ducks like the water, and you can rest assured that the pond will be just that. He is an asset to the industry!

Rose Woofenden, and her dad Ian, came over from western Washington to help. Rose was born in a wind and solar-electric powered house, and Ian works for *Home Power* and coordinates workshops for Solar Energy International (SEI). Kelly Keilwitz of Whidbey Sun & Wind, also a Bergey dealer, traveled over the mountains with the Woofendens to help. Bill Hoffer, an energy efficiency and renewable energy consultant who often collaborates with Brooks Solar was on hand as well.

Randy Brooks and the owners were willing to allow the installation to be a demonstration project. Northwest Sustainable Energy for Economic Development (NW SEED) invited a group of individuals to monitor the installation. The group included a solar equipment distributor in Oregon interested in getting into the wind industry, a business development director for a general contractor from central Washington, and an SEI graduate and Bergey certified dealer from Spokane, among others. All fees the NW SEED participants paid were used to offset the cost of the installation. In return, June had an endless flow of coffee, snacks, and sandwiches for all.

Overcurrent protection at the tower's base.

Volunteers included Lance Moore, an electrician from Whidbey Island who wanted to gain some RE experience; Ed Kennell, part of the energy program at Washington State University's Cooperative Extension, and whose knowledge and equipment from two and a half decades in the wind industry were indispensable; and me, another SEI intern/graduate, there for documentation and experience.

Installation

On Monday, April 29, 2002, the crew and volunteers headed up into the high desert of Malaga, Washington to the ranch. After setting up camp, Randy oriented us by showing

Mounting the blades using an impact wrench.

the first cut of a Bergey installation video, and mentioned updates both to it and the installation manual.

On Tuesday morning, we woke to the loud squawking of guinea hens. We headed up the wildflower littered hill to the turbine location. It was a gusty day on the ridge, which was both encouraging and a bit worrisome. No one wanted to work in high winds the next day when the crane would show up.

After the NW SEED folks arrived, Randy had an orientation and safety briefing, and also explained the SNAP program. Our first task was to assemble the ten, 10 foot (3 m), 250 pound (113 kg) tower sections. We found it best to rest the tower sections on pieces of 4 by 4s to keep dirt out of the holes. The ground was sloped and wavy, so

Ready to raise.

we had to wiggle the sections and use drift pins to get all the holes to line up to connect the sections.

After assembling the tower and torquing the bolts to 150 foot-pounds each, we ran the transmission wires through the tower, and tied them to a tower leg with zip ties. As the wires were run through the tower, the equalizer plates were being attached to the anchor rods. The equalizer plates help evenly distribute the load from the guy wires to the anchor rods. Then the guy wires were laid out from the tower, a pair running to each anchor rod set at 50 feet and 90 feet (15 and 27 m) on the tower.

After all the wires were run, the junction and disconnect box was attached at the base of the tower, as was a Delta LA603 lightning arrestor and the furling winch. Bergey installed plates at a comfortable height on the bottom tower section to attach the winch and junction box. The furling winch allows someone at the base of the tower to move the tail 70 degrees, taking the turbine out of the wind. The tail has a shock absorbing system that prevents the tail from snapping back into position after releasing the winch, to prevent unnecessary wear and tear on the machine.

Down in the shed, Lance was wiring the inverter and replacing the #8 (8 mm^2) ground wire from the service disconnect to ground rods with #6 (13 mm^2) to comply with code. Lance also used wire pulling lubricant to snake the #2 (33 mm^2) wires from the system disconnect to the inverter. This stuff is messy, but easy to clean up and worth its weight in gold. A lot of sweat and many a smashed knuckle has been saved by this goop.

By the end of the day, the tower was ready and everything was in place for the crane to come in—everything except the tail, that is. Charlie's granddaughter was painting his cattle brand on it.

Crane Day

Fortunately, the sun was shining and the winds had died down for the tower raising. Lance finished all the wiring for the inverter and second disconnect, located down by the shed. Duncan Crane Service out of Moses Lake showed up right on time, and everything was ready. The crane was positioned between two anchors on the uphill, prevailing wind side of the tower.

Going up.

Snagged on the crane.

Bill Hoffer brought an inverter and Randy brought some batteries, charged from his Bergey XL.1 wind machine at home, to provide remote power for electric tools on site. This came in handy when a little on-site engineering was needed to help hold the tower off the ground. Randy used his Sawzall to turn the 4 by 4 framed turbine-shipping pallet into a brace for the tower.

This freed up the crane to lift the 1,060 pound (481 kg) turbine head, so we could bolt it to the tower. The crew lined up all the holes, making sure that the furling cable and electrical wires were all aligned properly. Once the turbine was attached, Randy used a RotoFlex to strip the metal casing around the wire housing, setting the depth so that it didn't cut the wires. All the final wiring was completed, the furling cable was attached, and we caulked around the electrical box on the turbine head.

After all the bolts were properly torqued, it was time to put the branded tail on. This was a snug fit to say the least. The 145 pound (66 kg) tail was supported by the crane, and with some extra elbow grease, the pivot pin was inserted into its hole on the turbine. Then it was time to attach the blades. Anti-seize compound was used on the bolts to prevent rusting and seizing, and CRC SP-400 severe environment corrosion inhibitor was sprayed on the alternator to keep the blades from sticking to it. After using an impact wrench to torque down the blade bolts, we were ready to raise the tower.

The strap from the crane was attached at 80 feet (24 m). The position of the assembled tower and crane allowed the

Putting the base in place.

Chelan County PUD SNAP Program

Senior energy services engineer Dr. Jim White of Chelan County PUD instituted the SNAP program in 2001. Local utility customers pay a voluntary amount, from US$2.50 to US$50 per month, to support locally generated, grid-connected, clean electricity. The program is designed for small producers only, with a maximum rated generation capacity of 25 kilowatts each. Producers are paid a percentage of the pool based on their percentage of the total renewable KWH generated.

All the money donated for the SNAP program goes directly to renewable electricity producers. Chelan County PUD covers promotional costs separately. The SNAP program collected US$30,000 its first year, and rolled over US$9,000 to 2002. To reduce administrative costs, SNAP producers are paid once a year (on Earth Day).

Jim White hopes that other counties and states have the foresight to establish programs similar to SNAP. Think of what could happen if participating generators all across the country were paid up to US$1.50 per KWH from a voluntary fund. The SNAP plan might be a more effective incentive than ordinary net billing plans.

"What happens in the future depends on customer participation," White said. If customers are eager to support renewable energy, producers will be eager to generate it. That's what's unique about the program," he added. "It allows customer demand to set the supply. If enough PUD customers sign up to pay a little more on their bills each month, we can show the world that these renewable energy technologies are cost effective today, even here in Chelan County, where our electric rates are among the lowest in the nation."

While the PUD is not funding local producers per se, the utility is lending its expertise to potential producers, and providing a means for consumers to support renewable energy. SNAP is a rate-neutral, pay-as-you-go system. It will not affect the electric rates of customers who do not want to participate.

Tensioning the guy wires and plumbing the tower.

wire length. After final guy wire tensioning, ground rods were connected to each anchor rod, electrically grounding each guy wire. The turbine disconnect was wired, and it was time for commissioning tests.

The turbine started spinning and there were smiles all around. Ceremonial tower climbing allowed for sweeping vistas of the high desert country, and we were proud of a job well done.

Connecting to the Grid

Chelan County PUD responded quickly and arrived Friday morning to connect the approved system to the grid. After connection, grid voltage was checked and the inverter was turned on. The system started flawlessly and became the first grid tied wind turbine in Chelan County, and the first wind turbine to supply

crane to make a straight-up lift without reaching too far out, which limits how much weight the crane can lift. The crane dragged the base until the whole assembly was vertical.

As the crane lifted the tower closer to the tower base, we heard a loud snap. Hearts started pounding and eyes got big as we covered our heads. The crane strap was attached incorrectly such that one horizontal girt bore the entire weight of the tower and turbine when the tower became vertical. The girt couldn't hold it and broke, allowing the tower to be supported more evenly. The broken girt was later replaced.

Just as the tower was close to vertical, there was a delay and we couldn't figure out why. One of the many onlookers (local television and newspaper crews as well as curious friends) saw that the top of the crane had become stuck in the tower. After a little finagling, the crane operator got it loose, but we later concluded that the crane's swing out boom, which had fewer things to snag on the tower, should have been used.

The tower was placed on a pin in the concrete base and turned to line up with the wires coming up out of the trench. We secured the tower with cable clamps on the guy wires, and Randy became the first to climb the tower when he released the crane strap. The crane headed home, and we took a well-deserved lunch break, but we still had lots of work to do.

The tower was plumbed (made vertical) with an elevating transit, adjusting turnbuckles at each anchor. The crew tensioned the guy wires, using the oscillation method. To do this, you twang the wires and count the oscillations, and adjust the tension based on a formula using the guy

Climbing to unhook the crane.

The Nichols' ranch as seen from 100 feet up.

State. She obtained a state tax number and registered as a business to qualify as part of the SNAP program.

The turbine was connected to the grid on May 3, 2002. On March 27, 2003, the PUD read the meter, recording the Nichols' production at 7,222 KWH for the first eleven months. Their check was for US$8,590, or US$1.19 per KWH. That's a pretty good chunk of change—just short of a quarter of the cost of their installation.

There is hope for utilities. People like Jim White from Chelan County PUD and groups like NW SEED are helping pave the way for a sustainable energy future that helps local economies by supporting locally generated clean electricity. As June says, "It's the right thing to do."

electricity to the Chelan County PUD SNAP program.

The electrical wiring to connect the turbine to the utility is straightforward. There is a turbine disconnect at the base of the tower and an extra one at the power shed (so nobody has to walk up the hill to disconnect the system). The Excel produces 240 V, three-phase wild AC that runs from the tower to the inverter.

The inverter takes the wild AC and converts it first to DC and then to a grid-synchronized AC output. From the inverter, the system is wired to a fused service disconnect and production meter. June and Charlie get paid for what they produce, regardless of their farm's consumption. From the production meter, the wires run to the transformer on the utility pole.

Betting the Farm

June and Charlie were able to secure a 6 percent low-interest loan from Key Bank to pay for the installation, using the farm as collateral. June waited till after July to order and purchase the equipment, when a sales tax exemption for RE equipment took effect in Washington

Wind System Costs

Item	Cost (US$)
Bergey equipment (turbine, tower, inverter, tower wiring kit)	$26,400
Labor	4,000
Materials (forms, rebar, concrete, wire, conduit, etc.)	3,000
Owner services (permits, excavation, freight, PUD connection fee)	2,400
Equipment rental (compactor, crane)	2,000
Total	$37,800

The hard-working crew pauses for a group photo.

Access

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Check the wind resource for Pacific Northwest locations at www.windpowermaps.org, and see other wind maps at www.homepower.com/windmap.htm


AP-30
AP-50
AP-75
AP-120
APx-140
APx-75
APx-50

What the Heck? 7

Inverter

Used In: Off-grid, on-grid, and mobile power systems

AKA: Power conditioner, power "converter," (though these terms refer more properly to cleaning up a wave form and DC to DC voltage changing, respectively).

What It Is: An electronic device that converts direct current (DC) electricity to alternating current (AC) electricity

What It Ain't: A skateboard trick or a Schwarzenegger movie

The utility grid delivers AC electricity. For the last century or so, virtually everyone that was within reach of the grid has purchased their electricity from it. As a result, the appliances we use are designed to run on AC. But solar-electric panels and batteries generate and store DC electricity. AC appliances can't be run directly on DC, and vice versa.

Inverters convert DC electricity to AC electricity by using complex electronic switching mechanisms to break the continuous current into pulses. Originally, inverters were primarily used to power equipment in mobile applications—ambulances for example. These days, the proliferation of electronic devices, and the growing popularity of solar-electric systems, have given rise to a whole new generation of inverters. Now we have inverters small enough to toss in your backpack along with your laptop for working on the road, and large enough to send megawatts of renewable energy onto the utility grid. Different inverters also have different power output quality and expected service life. Like most things, you typically get what you pay for.

Inverters change DC electricity from PV, wind, hydro, and batteries into AC electricity you can use around the house.

In off-grid systems, inverters convert the DC energy stored in batteries to AC for your appliances. The electricity many of these inverters produce is of better quality than what people buy from the utility. On-grid, inverters are used to supply power from batteries during grid outages when the utility fails to deliver.

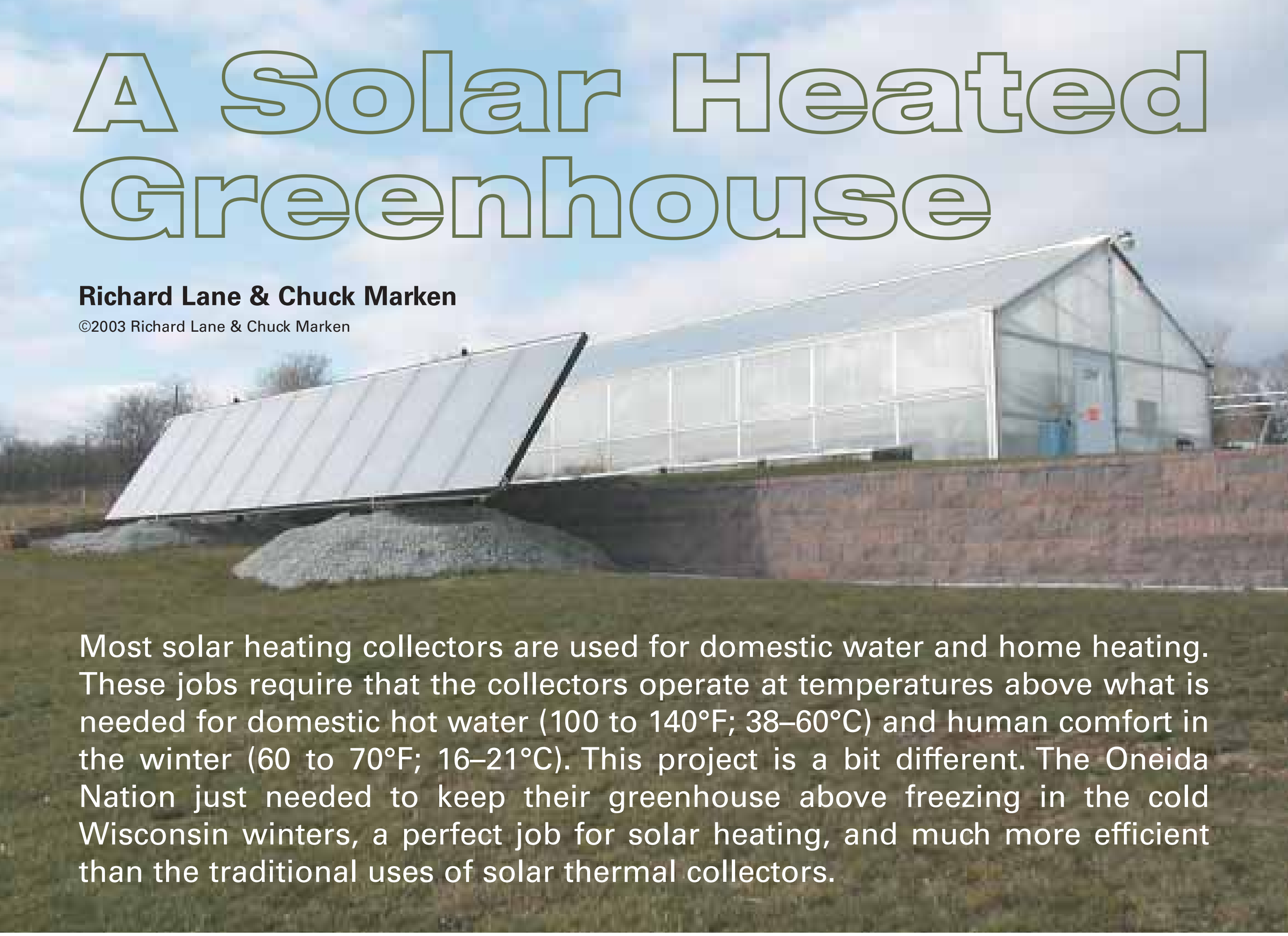
Many on-grid inverters are designed to be used in solar-electric systems without batteries. These inverters convert the DC energy generated by PV panels or other sources directly into AC electricity to power appliances and sell to the utility. If you generate more electricity than you use, the majority of U.S. states require the utility to buy your surplus at the retail rate.

For more information on inverter basics, check out "How to Choose an Inverter for an Independent Energy System" by Windy Dankoff in *HP82*, page 74.

Joe Schwartz, *Home Power* • joe.schwartz@homepower.com

A Solar Heated Greenhouse

Richard Lane & Chuck Marken



Most solar heating collectors are used for domestic water and home heating. These jobs require that the collectors operate at temperatures above what is needed for domestic hot water (100 to 140°F; 38–60°C) and human comfort in the winter (60 to 70°F; 16–21°C). This project is a bit different. The Oneida Nation just needed to keep their greenhouse above freezing in the cold Wisconsin winters, a perfect job for solar heating, and much more efficient than the traditional uses of solar thermal collectors.

A 1,200 square foot greenhouse is kept warm in winter by a 306 square foot solar collector and radiant floor system.

The Oneida Nation is a sovereign nation with a long and proud history. Their efforts toward economic self-sufficiency have resulted in a variety of enterprises. The Tsyunhehkwa Center produces organic foods and other products on an 83 acre site in northeastern Wisconsin. Just outside of Green Bay, the center has a 1,200 square foot (119 m^2) greenhouse that they use for giving their plants a head start in the late winter. The greenhouse is heated with a radiant floor heating system. Tubing in the concrete slab is heated with water circulating through a 37,000 BTU, 50 gallon (190 l) water heater.

The only fuel that was readily available to the greenhouse was propane. Even with an efficient radiant floor system (covered in depth in *HP49* and *HP79*), the heating costs to keep the greenhouse from freezing were substantial. The Oneida Nation has a strong belief in keeping the earth's environment healthy for future generations, and is a big supporter of renewable energy.

Richard Lane and the Solar Mining Company (SMC) have worked with the Oneidas before on many solar heating projects. When they needed to find a better way to heat the greenhouse, Richard was the natural person to call. He formerly ran the Packerland solar heating system in Green Bay. It consisted of 5,000, 4 by 8 foot (1.2 x 2.4 m) collectors, the largest system in the world. When the Oneidas described the greenhouse situation, Rich knew it was a great candidate for a solar heating system. Keeping a building from freezing is a piece of cake for a solar heating system—even in Wisconsin.

Starting plants early extends Wisconsin's growing season.

The 8 by 40 foot maxi-collector is all one unit, custom built for the greenhouse.

Maxi-Collectors

In Wisconsin, solar hot water systems are almost all closed loop antifreeze systems. The winter weather won't tolerate anything else for failsafe freeze protection. Greenhouses tend to heat themselves in the daytime, but they are subject to tremendous heat loss through the transparent glazing (glass or plastic) when the sun isn't shining. The collector size that would fit the Oneida's budget and put a serious dent in the heating bill was about 300 square feet (28 m^2) of surface area—the equivalent of about ten, 4 by 8 foot collectors.

The winter weather in Wisconsin can play havoc with scheduling outside work, which is best kept to a minimum. Since this was a mid-winter project, the best way to proceed was to build a custom maxi-collector of the size needed, inside the SMC shop in nearby De Pere. A maxi-collector is a large solar heating collector that combines the components for multiple smaller collectors into a single enclosure. For this project, custom absorber plates were plumbed inside the insulated enclosure that SMC built. The collector was built to the maximum width of about 40 lineal feet (12 m)—any larger would place undue strain on the collector header piping because of the expansion and contraction of the copper tubing.

In addition to helping with the outside work schedule, the cost was less with a custom-built maxi-collector. Historically, solar heating collectors have been either a modular installation of standard factory sizes or completely custom built on the job site. The maxi-collector is kind of in between these two design ideas, taking advantage of the

Solar Collector Efficiency

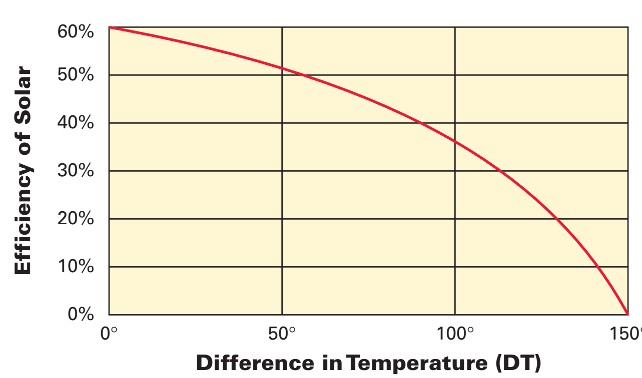
The efficiency of any solar heating collector is dictated by two significant factors, assuming the equipment is built to industry standards. The amount of sunshine available is of major importance. The other factor is the difference between the outside temperature and the operational temperature of the collectors.

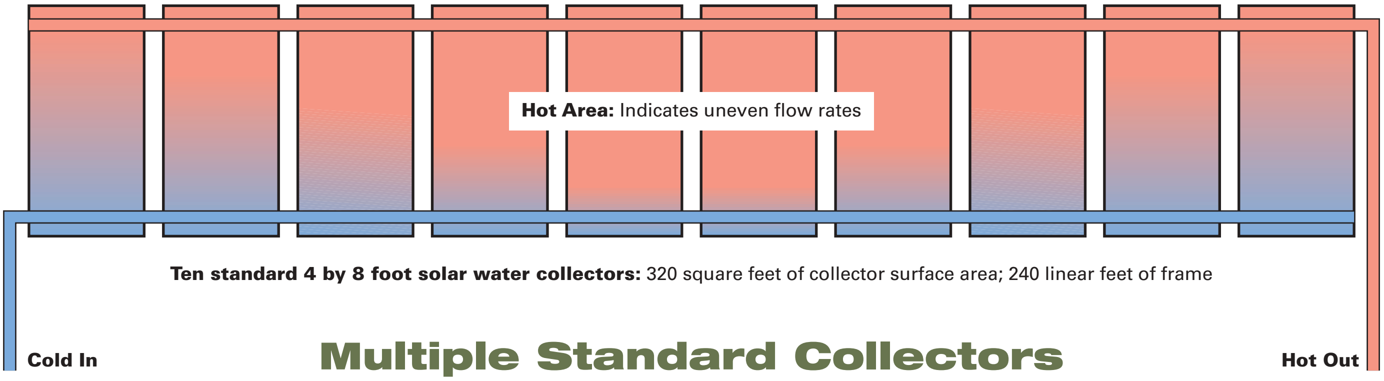
The lower the operational temperature, the better the efficiency. As any solar heating collector gets hotter than the surrounding air (ambient outdoor temperature), it starts losing heat to that colder air. As this temperature difference gets greater, the efficiency suffers. The drop in production of heat can be significant when the weather is cold and you need to heat water to 140°F (60°C). A solar heating collector shows dramatically better performance when the job is simply keeping a greenhouse at about 40°F (4°C).

The graph may assist you in understanding this concept of the efficiency of a typical solar collector at different operational temperatures. Flat plate collectors are capable of making steam (212°F; 100°C at sea level), but they won't make much—they're too inefficient at elevated temperatures. The colder it is outside and the hotter the collectors need to be, the less they produce.

The heating industry uses the Greek letter delta (Δ) to signify difference, and temperature difference is often referred to as delta T (ΔT). As the ΔT increases, the collector efficiency decreases. Because of the low operational temperature required in the greenhouse, this particular system will produce more than a fifty percent increase in heat when compared to more typical, higher temperature, domestic water heating systems.

Collector Efficiency per Temperature Differential





Multiple Standard Collectors

economy of the larger custom-built design, along with the standardization and savings of a shop or factory environment.

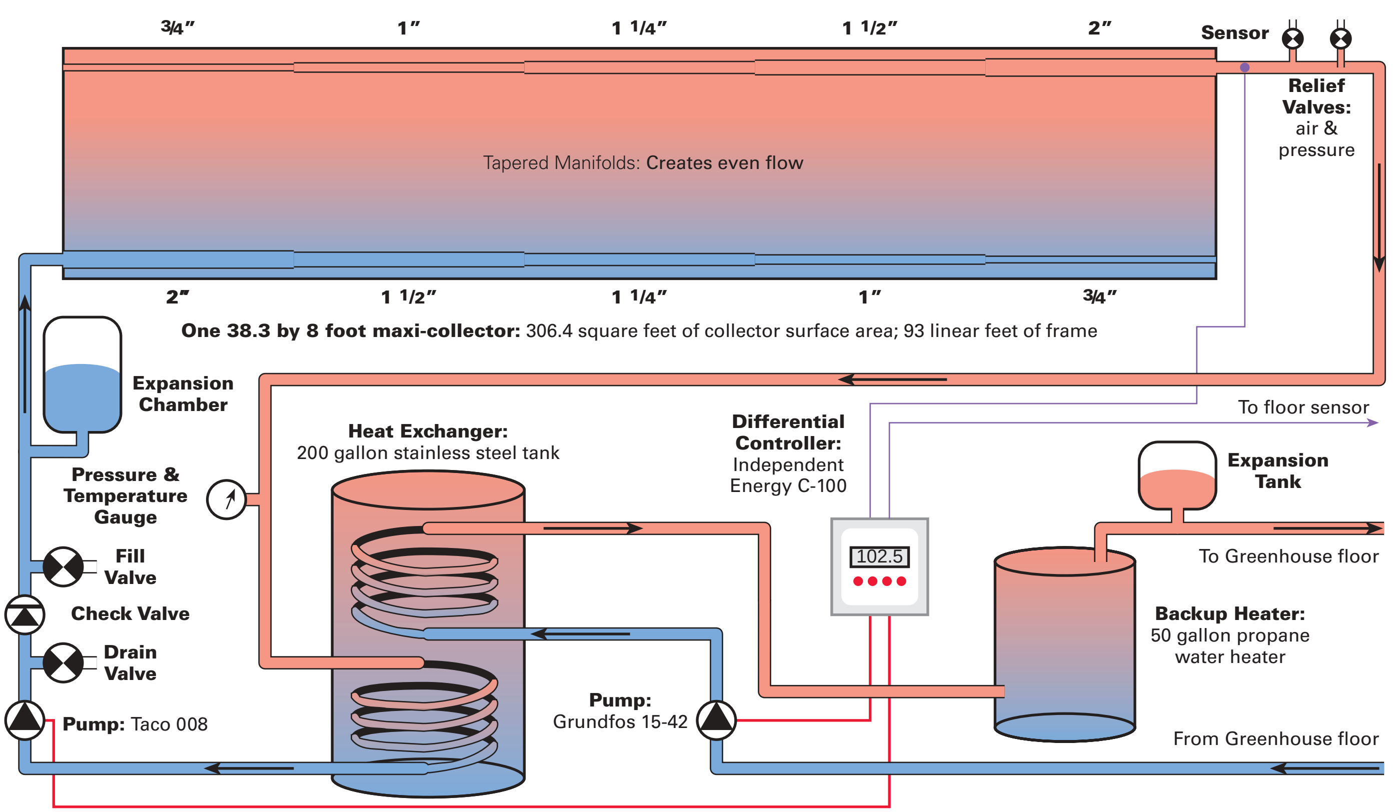
The retail cost of a standard 4 by 8 foot collector (net area about 30 square feet; 2.8 m^2) is US$700 to $850, including crating and freight. The maxi-collector cost for this job (equal to ten collectors) was under US$500 per 4 by 8 collector section. Ten individual collectors would have been much more expensive to install. Because of their size, maxi-collectors are very difficult to ship long distances, and probably only have significant cost savings within a half day to a day's drive to the job site from the shop. That's why the custom-built maxi-collectors made good sense for a job like this.

SMC ordered the custom absorber plates from AAA Solar Supply in Albuquerque. The painted plates they make are not quite as efficient as black chrome absorbers, but the cost is much lower. Richard figured that the extra expense of selective surface absorbers couldn't be justified for this lower temperature job. The advantages of selective surface absorbers are covered in *HP84*.

The size of low iron tempered (LIT) glass used in solar collectors is usually what determines the sizes of collectors available. Tempered glass cannot be cut by any conventional methods, and you are stuck with the standard sizes the glass factory produces unless you want to order a crate (4,000 pounds; 1,800 kg). LIT glass transmits more light than regular window glass, and improves glass performance by 8 to 10 percent.

Popular sizes of low iron glass are 34 by 76 inches, 34 by 96 inches, 46 by 96 inches, and 46 by 120 inches. In nominal terms, these sizes equate to the standard collector sizes of 3

Custom Maxi-Collector System



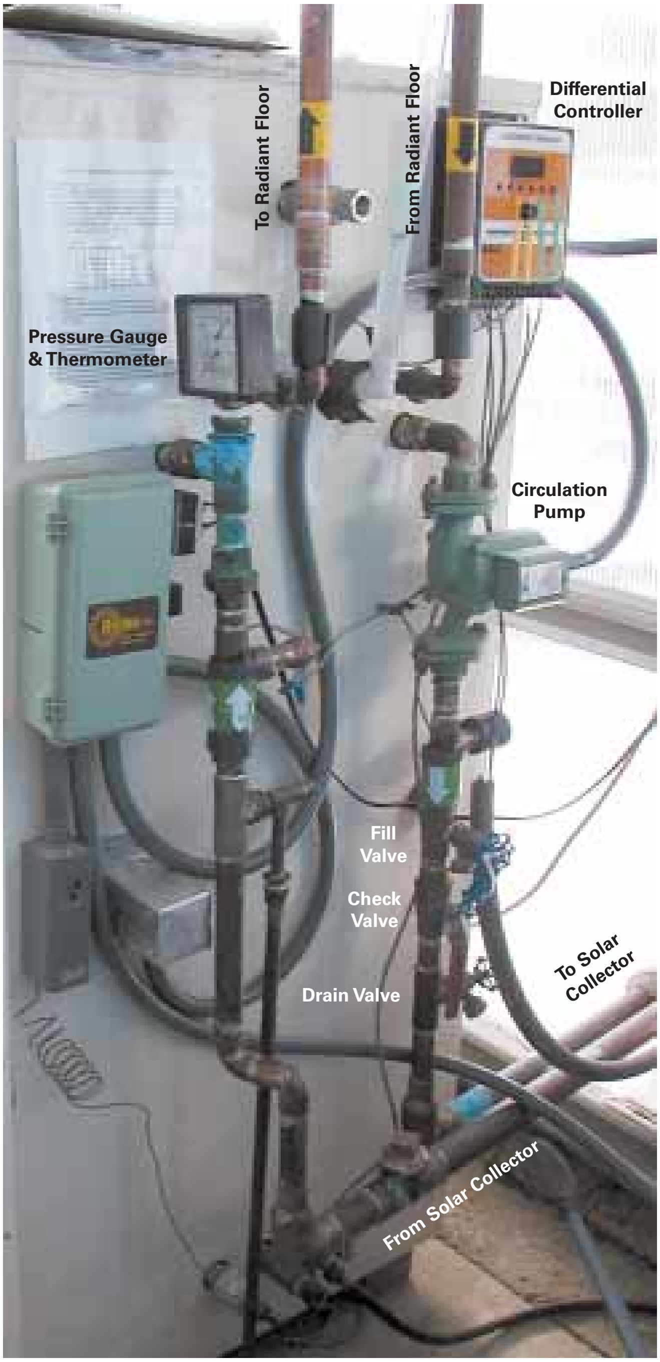
by 6 feet, 3 by 8 feet, 4 by 8 feet, and 4 by 10 feet (0.9 x 1.8 m, 1.2 x 2.4 m, 1.2 x 3 m). SMC purchased the LIT glass from AAA Solar—ten pieces of 46 by 96 inch glass, the equivalent of ten 4 by 8 collectors. The outer enclosure and absorber plates were built to accommodate the glass size, as are almost all collectors.

Experienced-Based Solar Engineering

The absorber plates and interior plumbing of the collector were designed with experience Richard gained when operating the large Packerland solar heating system. The Packerland system was originally set up with fifteen collectors in each row. Leaks developed from the expansion and contraction of the cumulative length of the copper tubing. The piping was modified to have only ten collectors in each row. This solved the expansion/contraction problem, and is the maximum length of solar collector that SMC will build.

Richard measured the collector temperatures constantly when operating the Packerland system. He noticed that the middle collectors in each row had different temperatures than the outside collectors. The difference of 10 to 15°F (6–8°C) in the middle collectors indicated a difference in the flow of the antifreeze solution through the riser tubes in the collectors. Any system is more efficient with even flow through all the collector absorbers.

The drawings show the traditional way of manifolding ten collectors in a row, and the way SMC constructed the maxi-collector for the Oneida greenhouse. The collector has 2 inch copper inlets and outlets, and the tubing narrows one size every two absorbers to 3/4 inch tubing at the opposite ends. Temperature sensors were built into the collector at numerous locations. The configuration was measured after the installation, and the temperatures were equal throughout, indicating an even, efficient flow through all the absorber plates.



Close-up view of the tank, with the pump, valves, and controls for the solar heating system.

Jill Martus-Ninham, Agricultural Food Production Supervisor, is shown with the 200 gallon storage tank with immersed coil heat exchangers and the controller and pumping equipment mounted on the tank.

A single large collector has an added benefit in efficiency over many small ones. The total outside surface area of the sides is decreased, and results in slightly less heat loss. A set of ten traditional 4 by 8 foot (1.2 x 2.4 m) collectors has a total outside area of 240 lineal feet (73 m), while the maxi-collector has a total of 93 lineal feet (28 m). Every foot less is a little less heat lost.

The outer enclosure for a collector of this size needs to be made with heavier duty materials than the standard collector. SMC used 5 inch (13 cm) steel angle iron to form the skeleton of the collector; it had to be strong to be moved

A crane lifts the 2,500 pound, 8 by 40 foot long maxi-collector to its mounts in front of the greenhouse for the Oneida Nation in Wisconsin.

to the job site. The rest was standard stuff: a 24 gauge sheet metal back to withstand the weather, 1 inch (25 mm) of high temperature foam insulation on the back and sides, with the absorbers and the LIT glass front facing south.

Putting the Balance of System Together

A 200 gallon (760 l) stainless steel storage tank, pumps, controls, piping, and valves were all available locally to complete the system. The storage tank is unpressurized, and would be considered undersized if this was not a radiant floor heating system.

A 15°F (8°C) rise in the concrete floor of the greenhouse (66,800 pounds; 30,300 kg) has the same thermal storage capability as the 200 gallon (760 l) tank of water (1,600 pounds; 725 kg) with a 90°F (50°C) rise in temperature. Two, 100 foot (30 m) coils of 3/4 inch copper tubing immersed in the tank provide the heat exchanger to transfer the heat from the antifreeze solution to the water in the floor. Immersed coil exchangers are covered in *HP92.*

A 120 VAC Taco 008 hot water circulating pump was used for the closed antifreeze loop. The pump is controlled with an Independent Energy C-100 differential controller (no longer available, but Goldline makes a suitable replacement). When the controller senses that the collectors are warmer than the greenhouse floor, the pump turns on and heats the tank. The Grundfos 15-42 SF radiant floor pump is controlled by a traditional room thermostat that is set to its lowest setting in the winter months.

The radiant floor system in the greenhouse runs water through the tubing in the slab. The water is heated with a 50 gallon (190 l) propane water heater when the sun doesn't provide enough energy. The tubing in the floor is PEX (cross linked polyethylene) tubing—see *HP49* and *HP79*. The system is a simple, efficient design.

The other valves and system components shown in the diagram are standard for antifreeze solar heating systems, and have been the subject of past articles on closed loop SDHW systems, notably "Closed Loop Antifreeze Solar Domestic Water Heating Systems" in *HP85*. The expansion chamber serves the same purpose as an expansion tank except that it is larger to account for the maxi-collector, and does not have a rubber bladder like a normal expansion tank. Expansion chambers (bladderless tanks) must always be plumbed on the bottom of the chamber, and need the airspace above the pipe connection to allow room for the fluid expansion.

Installation—Crane or an NFL Team?

A crane or NFL football team is needed to set a maxi-collector in place. This is where prior planning really paid off. The crane was a better fit in the budget. The maxi-collector was hauled to the job site on a 40 foot (12 m) flatbed semi-trailer. The crane picked it up and placed it on the ground mounts, the collector was secured to the mounts, and the inlet and outlet piping was soldered to the collector. The system was filled with a 50/50 solution of propylene glycol and water, the sensors were hooked up, and the system was running in a couple of hours.

The wiring harness for all the interior sensors to determine the collector performance was then connected to a datalogger on site. The datalogger records all the temperatures at the various locations and stores the data for later retrieval. Richard was able to verify even temperatures throughout, which indicated even flow.

George Zachariasen fills the maxi-collector with the propylene glycol antifreeze mixture.

Custom Maxi-Collector System Costs

Collectors	Cost (US$) Total	/ Sq. Ft.*
Absorbers; black aluminum, copper waterways	$1,989.00	$6.50
Fabrication labor	1,597.32	5.22
Glass; 5/32 inch, low iron, tempered	587.52	1.92
Structural steel	284.58	0.93
Insulation; 1 1/2 inch foil polyisocyanurate	177.48	0.58
Fabricated parts	177.48	0.58
Backs; 24 gauge steel	146.68	0.48
Total Collector Cost	4,960.06	16.21
Mounting		
Mounting labor & material	1,175.04	3.84
Cranes & trucking	624.24	2.04
Total Mounted Collector	$6,759.34	$22.09
Balance of System (BOS)		
Storage tank; surplus 200 gal. with 2 immersed coil heat exchangers	700.00	
Installation labor; less mounting as above	480.00	
Independent Energy C-100 control & sensors; surplus, no longer manufactured	285.00	
Piping, expansion chamber, & insulation	158.00	
Taco 008 pump	135.00	
Misc. valves & gauges; mostly surplus	78.00	
Misc. wire, fasteners, sealant, etc.	50.00	
Total BOS & BOS Labor	$1,886.00	
Total Installed Cost	$8,645.34	

*306.4 sq. ft. of net absorber area

This was a small installation in the scale of projects by SMC. The costs were kept down and the efficiencies maximized because of SMC's experience with large solar projects. SMC specializes in solar heating for commercial and industrial applications, mainly in the mining industry.

Money & Energy Savings

How much energy has the system saved? So far, only estimates can be given. The collectors have never been above 120°F (49°C), and always operate in temperatures just above the floor temperature. A conservative estimate for operating at these lower temperatures is about 160 to 180 thousand BTUs per day produced.

Propane heating appliances have an average output efficiency of 72 percent, and on average produce approximately 66,000 BTUs of useable heat per gallon of propane burned. The system will save about 3 gallons (11 l) of propane per day, with a conservative estimate of performance, and probably more. That may not sound like much, but depending on the volatile price of propane at any given time, it can amount to a savings of US$1,000 or more per year. The avoided emissions and lowered dependence on fossil fuels are the icing on the cake. Maybe they are the cake…

Operation & Maintenance

The operation of the system is completely automatic. The differential controller runs the system whenever the sunshine is sufficient. The controller is an Independent Energy C-100, which has five digital temperature readouts to monitor the collector inlet and outlet, storage tank, heat exchanger, and slab temperatures. The thermostat fires up the propane heater when there is not enough solar energy.

With the collector temperature below 120°F (49°C), the glycol solution will probably last a decade or two. The pumps will need replacement someday, but they also will have an enhanced lifetime with the lower fluid temperatures. The collectors are self-cleaning with each rainfall, and there is plenty of that in Green Bay. When the greenhouse gets too warm, automatic actuators open the windows, and the plants love the fresh air.

The end use of any solar heating system can dramatically affect how much the system produces. Heating a building or water to temperatures needed for human comfort are by far the most common uses. But other commercial and industrial applications that need less heat are out there, waiting for a little help from the sun.

Access

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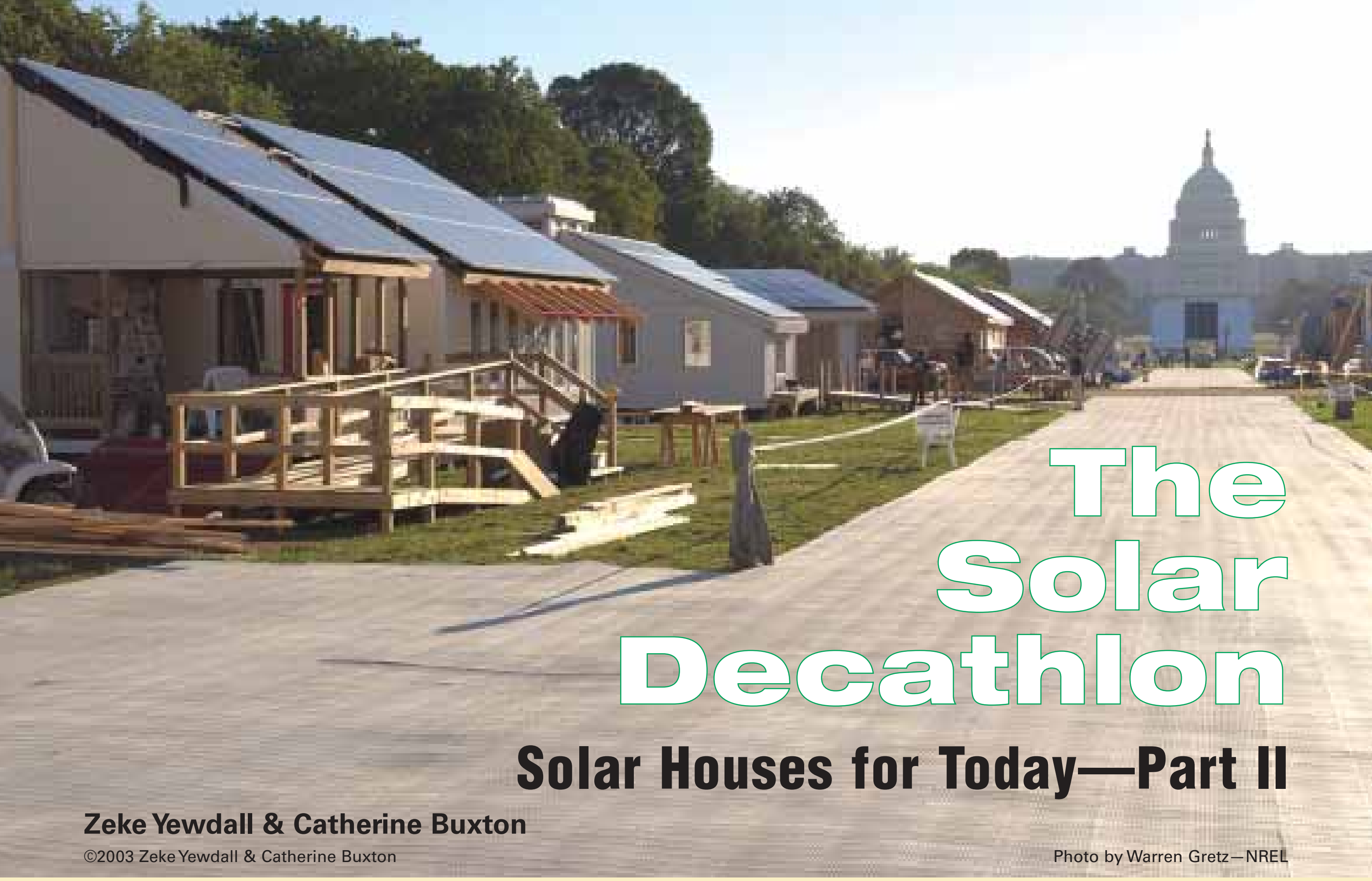

The Solar Decathlon

Solar Houses for Today—Part II

Zeke Yewdall & Catherine Buxton

Photo by Warren Gretz—NREL

Building a solar village at the National Mall.

In *HP94*, we covered the Department of Energy's Solar Decathlon, a competition to design and build the best solar powered house. We summarized the fourteen designs that were exhibited on the National Mall in Washington, D.C. last fall. In this article, we go into more detail on the design choices used in the houses.

Engineering: Theory vs. Practice

Schools had almost two years to prepare for this competition. A lot of design work and simulations of various tradeoffs happened in that time. All of this design work certainly played a part in the results. But when it came down to the wire, the winning houses depended not just on how well they were designed, but on how well the designs were implemented in practice.

For example, Carnegie Mellon and Maryland had very similar hot water systems. Maryland's worked without a hitch and won that contest. Carnegie Mellon's collector piping exploded on the second day, sending a geyser of steam into the sky from the roof. The theory of Carnegie Mellon's system was good, but they used plastic piping that could not withstand the heat.

Similarly, Crowder had the smallest PV array in the village, but placed high in the getting around contest and maintained a positive energy balance. Other schools that had much larger PV arrays were perpetually tinkering with them and never got the full potential from them. This is probably not surprising to professional installers, but for engineering and architecture students, it is a valuable lesson that is not often taught in school. The ability to properly *build* a solar energy system can make or break it, regardless of how good the design is.

Data Collection

The National Renewable Energy Laboratory (NREL) monitored the energy usage and air and hot water temperatures of the houses for the competition. This information was available to the contestants every 15 minutes, and students spent a large amount of time looking at this data. It turned out to be much more fun than anyone had anticipated, trying to plan strategy based on where the nearest competitors in each competition were, and trading off different points—such as energy used to run the air conditioning versus keeping the house cool enough. It was

Students at University of Colorado installing PV. For most of the students, it was their first time.

also fun trying to deduce everyone else's strategy from the most recent data and town gossip—like being a detective.

If you are interested in taking a more in-depth look at this data, an Excel spreadsheet with 15 minute data for all fourteen houses is available. You can download the rather large (13+ MB) Decathlon spreadsheet with all the scoring details from the promised files download area of the *Home Power* Web site (see Access).

Construction: SIPS

More than half of the houses were built with structural insulated panels (SIPs). The most common form of these uses a sheet of white polystyrene foam laminated between two sheets of oriented strand board, although teams used variations with steel frames and other insulations, including waste cotton. SIPs come in precut sheets 4 feet wide by up to 20 feet long (1.2 x 6+ m). Studs occur only every 4 to 8 feet (1.2–2.4 m), and at corners, doors, and windows. The rest of the wall is solid insulation, unbroken by thermal bridges.

Using SIPs gives a very high R-value, compared to traditional, insulated stud walls. This system also results in a very airtight house. (Most of the houses also used heat recovery or energy recovery ventilators to bring fresh air inside.) Because they are precut at the factory, SIPs can be assembled quickly and with little waste at the building site. They have been around for several years, and are beginning to be accepted by the building industry.

Water Heating

Teams used both flat plate and evacuated tube solar hot water systems. The unique feature of the evacuated tube collector is that air is removed from glass tubes, creating a vacuum. This eliminates most heat loss because there is no air to transmit the heat (a low-E coating on the glass reduces radiant losses). As a result, evacuated-tube collectors are more efficient at higher temperature differentials (high fluid temperature and cold or cloudy outdoor conditions) than flat plate collectors.

Most teams using evacuated tubes chose Thermomax collectors, which have small (2 inch by 5 foot; 5 cm x 1.5 m)

Colorado found that building with SIPs was fast and easy—for the most part. Except in this case when the factory sent a panel that was four feet too long.

Thom Johnson helps out with the plumbing of the Suntube evacuated collectors. They are covered in plastic here to keep them cool while working on them.

Warren Gretz—NREL

Crowder College's experimental building integrated PV and solar thermal system. Note the exposed plumbing below the PVs on the roof—insulated hot water transfer tubes run below the PVs and heat-absorbing plate.

tubes that run up and down the roof. The Colorado team chose Suntube collectors, which are much larger—6 inches by 10 feet (15 cm x 3 m). These run horizontally across the roof, and the absorber plates inside can be individually tilted towards the sun, even when the collector assembly is on a flat roof, as theirs was.

Only the Maryland team, which won this contest, used a PV direct circulator pump. PV direct pumping uses only the electricity from a dedicated PV module, which automatically turns the pump on and off with the sun. It can be slightly more expensive due to the photovoltaic module (usually about 20 watts) and the DC pump, but this is offset by not needing a differential controller. (See "Installation Basics for SDHW" in *HP94.*)

All of the other teams used 80 watt AC circulator pumps, which used almost 1 KWH per day for a "solar" water heating system! In a utility-serviced home, this could mean that such a system would use a good deal of nonrenewable energy. The next Decathlon will probably see many more PV direct applications.

Two teams used heat rejected by the air conditioning system to heat water. Although this could not maintain the required 120°F (49°C) temperatures, it supplied a significant portion of the heat needed to raise the incoming water temperature.

Radiant Floor Heating

Many of the houses used radiant floor heating. This is generally more comfortable than forced air heating, and allows lower temperature set points. A high mass radiant heating system can also use lower fluid temperatures, so it's more appropriate to use with solar collectors or heat pumps. Since the Decathlon occurred during a hot, muggy week, heating did not come into play. But if it had, a different set of houses may well have excelled at the comfort zone contest.

Mechanical Conditioning & Ventilating

Most solar homes do not use traditional air conditioning. A number of other methods, such as natural ventilation and evaporative cooling, work well under certain conditions. And indeed, during the first day of the comfort zone competition, all of the winning houses had their air conditioning off and the windows and doors wide open. However, when it is 85°F (29°C) and 75 percent humidity, there is little other than mechanical air conditioners that will work if you are required to keep a home below 78°F (26°C) and 60 percent humidity. Luckily, air conditioning needs frequently correspond to sunny weather, when the PV system is often running an energy surplus.

The Puerto Rico team used an innovative, desiccant-based system to remove humidity from the air instead of condensing moisture on the air conditioner coils. In humid climates, removing humidity can use over half of air conditioning energy. Another version of this system, which was considered by Colorado, is to super-dry the air with the

Solar Decathlon Contests

Contest	Description	Winners	Runners-Up	Judges	Winning Method Factors
Design & livability	Design, innovation, aesthetics, & integration of RE technologies–twice the weight of other contests	Univ. of Virginia	PR & Austin	Architecture	Innovative designs that pushed the envelope
Design presentation & simulation	Drawings & computer simulations of performance	Virginia Tech	Carnegie Mellon & Maryland	Architecture, simulation experts	Appropriate use of different simulation tools, with detailed analysis & drawings
Graphics & communication	Public tours, Web site, & newsletters	Colorado	Auburn & Austin	Communication & PR experts	Design & info in Web sites, newsletters, displays, & presentation boards; effectiveness of tour guides
Comfort zone	Temperature, humidity, & energy use; consumer appeal, innovation, & integration	Colorado	Maryland & Auburn	Engineering	Weather hot & muggy, so cooling was a factor; commercially available split-system air conditioners won; natural ventilation & passive solar design also factors
Refrigeration	Maintaining adequate temps in fridge & freezer; consumer appeal, innovation, & integration	Rolla	Crowder & Auburn	Engineering	Sun Frost with no self-defrost was used by winner
Hot water	Supplying 120°F water for showers, dishwashing, & washing machine; consumer appeal, innovation, & integration	Maryland	Auburn & Rolla	Engineering	Used PV direct pump instead of the 80 W, AC circulation pump most other teams used; variety of evacuated tube & flat plate collectors
Energy balance	Generating as much electrical energy during the week as was consumed	Auburn, Colorado, Crowder, Maryland, & UVA	None, either met criteria or didn't	None	Conservation & proper system install & operation was as important as PV array size
Lighting	Keeping house well lit via electric & daylighting; consumer appeal, innovation, & integration	Crowder	Virginia Tech & Colorado	Engineering	Innovative design, automatic daylight dimming systems, & fluorescent tubes or CFs
Home business	Producing daily newsletters & e-mail via computer & printer; ranked on energy usage, consumer appeal, innovation, & integration	Crowder	Tuskegee & Colorado	Engineering	Flat screen displays, docked laptops, office layout, & daylighting without glare
Getting around	Most miles on identical Th!nk EVs driven around town–top speed 25 mph, & 30 mile range	Virginia Tech	Auburn & Colorado	None	Top teams 200+ miles; winner failed energy balance contest criteria
People's choice*	Based on results of 5,000 ballots	Crowder	PR & Univ. of Virginia	Visiting public	
Overall winner	Based on points from ten contests	Colorado	Univ. of Virginia & Auburn		

* Was not considered in main contest to determine overall winner.

desiccant, and then use evaporative cooling. There are no commercial systems like this, however. (See "Passive Cooling," Parts 1 & 2 *HP82* & *HP83*.)

Ground Source Heat Pumps

Using a ground source heat pump is often the most efficient method of backup heating. They have lower carbon emissions than an efficient natural gas furnace, even when operated from a low efficiency, coal-fired power plant. They require extensive digging (similar to a septic system) or well drilling to function properly.

Although no digging was allowed in the Decathlon, many teams simulated a ground source heat pump with a large water bladder or water tank under the house. A temporary water bladder will only work for so long as a ground source, and is not recommended for longer than a week or two. It

Colorado's power system—two Trace SW5548 inverters, Solar Boost 3048, Trace C40 and Outback MX-60 charge controllers, and Outback power system enclosure.

isn't a big enough thermal mass compared to the real ground. It eventually gets too cold if you are trying to suck heat out of it to heat the house, and too hot if you are trying to dump heat into it to cool the house. People with easy access to small ponds greater than one-half acre (one-fifth hectare) have successfully used them as long-term heat sink sources.

Building-Integrated PV?

Since so many of the houses tried to integrate solar technology into a standard looking house, you might wonder why none of them used Uni-Solar roofing products. This was mainly due to the high electrical loads imposed by the competition rules, and the small roof area, especially when the need to charge an electric car was added. If these designs were changed into two or three bedroom houses, then solar shingles or standing seam metal roofing with thin-film PV may have been a good option.

One school, Crowder College, was an exception to this. They used amorphous PV modules (BP Millennia) that were integrated into solar thermal collectors over part of the roof. The amorphous PV was used because of their tolerance for high temperatures.

This was also the only house to have north-facing PV (Colorado had flat PV on its small north roof section). Simulations predicted that these were roughly 50 percent as efficient over the year as the south-facing ones. Despite having a much smaller array than most of the houses, Crowder still maintained a positive energy balance and placed fourth for distance driven in the electric car. This proved that operating a system effectively can lead to improved output without having a larger system.

A common complaint about putting PV modules on a roof instead of on a rack is that the PV modules are likely to last longer than most roofs. So how do you fix the roof underneath? Most PV mounts also put holes through the roof where they are attached, which may eventually cause leaks.

Colorado came up with an innovative solution to these problems. Their roof is a standing seam metal roof, which is warranted for at least as long as the PVs. The PV mounting system uses clamps from S-5! Solutions that hold onto the seams of the metal roof. Thus the entire PV array is mounted without a single roof penetration.

To MPPT or Not to MPPT

Over half of the entries used maximum power point tracking (MPPT) charge controllers. Most used the Solar Boost controllers (*Things That Work! HP73* & *HP77*), and Colorado used one of the first OutBack MX-60s, a competitor to the high-powered Solar Boost 6024 that was just unveiled. The OutBack controller actually does a current-voltage (IV) sweep to determine the maximum power point, which should be more effective under varying sun and partly sunny conditions than using a fixed offset from open circuit voltage, as the Solar Boosts do.

Did MPPT help? Well, there were too many other factors for it to be a deciding one. But everyone noticed at least a slight boost in current, even on hot muggy days with a hot, roof-mounted PV array, which is when the smallest boost will be seen. A cold winter day definitely gains an advantage. The voltage conversion capability also allowed strings of five modules in series in at least one case, when modules did not fit on the roof in multiples of four for a 48 volt system. It may just be coincidence, but the top performing teams in all the engineering contests were the ones using maximum power point tracking charge controllers.

The Colorado team is now doing side-by-side comparisons of the MX-60, a Solar Boost 3048, and a Xantrex C40 on identical arrays to determine exactly how much boost they are giving, and the conversion efficiency and power point tracking efficiency of the two MPPT options. Stay tuned.

Xantrex Inverters

All fourteen teams used the Xantrex SW series inverters (*Things That Work! HP48* & *HP58*). Most of them used stacked 4048s or 5548s. Why? Primarily because of the large 240 VAC loads. Many of the most efficient split-system air

In Maryland's modular construction, the tech pod was located on the left side of the building, next to the carport.

Colorado's tech pod being hoisted in place. You can see the water storage tanks and hot water tank in the upper section.

conditioners are available in only 240 VAC, and the 3 ton split-system air conditioning units used by at least four teams have a serious starting surge that the SW can handle. The Asko washers and dryers that were donated were only available in 240 VAC, and induction cooktops were hard to find in 120 volt units too.

Also, until relatively late in the design process, it was thought that teams would get a Th!nk City, with a 4 KW, 240 VAC charger, instead of the Neighbor, with its 1 KW, 120 VAC charger. OutBack Power System's new, modular FX series inverter was under consideration by at least two teams, but did not ship in time for the competition.

Tech Pod

The idea of having a separate room or building for all of the systems was used by Maryland and Colorado for their home designs. Instead of sticking something into every closet, they put all of the batteries, inverters, hot water system, etc. in a separate room adjacent to the house. This idea has a couple of advantages.

First, it allows the rest of the house to be more conventional in design. Whether it is grid connected, stand alone, or even if it is just superinsulated with no renewable energy systems, the electrical and water system of each house is exactly the same. Second, it allows building code issues to be dealt with more easily, and will make solar technology more accepted by the masses when it is something that sits out in a service room, just like a well pump, instead of a stack of batteries hiding in a closet.

Window Technology

Most of the houses used high performance windows with R-values between 5 and 10. These are not quite the best technology (experimental, around R-14, which is better than many walls), but are the high end of what is readily available.

Most of the windows were double pane with suspended low-E films and krypton or argon gas fill. These cut down on the weight and cost of triple or quad pane windows, while actually having higher R-values and better light transmittance. Some houses used different windows for different orientations. This idea is gaining popularity on office buildings, especially in Europe, but has not typically been applied to residential design.

Lighting

All of the houses used compact fluorescent bulbs for almost all lighting. A few halogen accent lights and some linear T-5 fluorescents were also used. The continued use of incandescent lightbulbs for most residential lighting in America is an embarrassment.

Why are supermarkets here just starting to stock compact fluorescent bulbs? In a "backwards" country like Mauritania, it is impossible to buy an incandescent bulb. The country has only a few power plants, so it's more obvious that the cost of installing a lightbulb is not just the lightbulb cost, but also the cost of the power plant and its operation. The government couldn't afford to install power plants if everyone installed incandescent bulbs.

PV may be sexy, but if you want to make a difference in your energy impact the cheapest way possible, get together with four of your friends, buy a 20 pack of 15 or 20 watt spiral CF bulbs (about US$3 per bulb) and each replace four of your most used lights. (See *Guerrilla Efficiency* in *HP91, HP92, & HP93.*)

For new construction, indirect lighting with linear T-5 fluorescents is the most effective means of giving overall lighting to a space. They produce 80 to 90 lumens per watt, compared to 60 to 70 lumens per watt for CFLs, and 15 to 20 lumens per watt for incandescents. CFLs are more common because they are smaller and can be used in standard fixtures, whereas T-5s come in 4 foot (1.2 m) long tubes. (Metal halide and sodium lights are more efficient, but not suited to residential lighting.) Although indirect lighting is not as efficient as direct lighting, it provides a much more pleasant lighting environment, so lower light levels can be used.

A number of houses, including most that placed high in the lighting contest, used daylight controls that automatically dimmed the lights in response to the amount of daylight available. Studies have shown that people do not turn on lights if a space has sufficient daylighting. But if they turn on lights in the morning, they will usually forget to turn them off all day, even though daylighting becomes sufficient.

Green Materials

Although environmentally friendly materials and construction were not stated requirements of the competition, most of the teams included them in their designs, along with energy independence. Several houses used bamboo flooring, which performs as well as hardwood, but only takes a few years to grow. Currently it is imported from China, but the right variety of bamboo will also grow in the Pacific Northwest, and efforts are being made to establish an American supply.

Composite fiber cement siding, which is fireproof and can have a 50 year warranty, made its way onto several houses. Reclaimed lumber was used in various applications, from cabinets to flooring to shading louvers. Colorado and Auburn used Parallam laminated beams made from aspens and other fast growing trees as exposed beams, instead of hiding them as is usually done in conventional building.

A variety of recycled products, including Faswall blocks, sunflower seed board and wheat board, recycled poly carpeting, and newsprint countertops were used. Several houses used low VOC (volatile organic compounds) paint, which was noticeably odorless after repainting only one day before opening for tours.

State of the Art vs. State of the Shelf

Some entries went for state of the art technology, such as the translucent aerogel insulation used by Virginia Tech. Others were proud of the fact that everything in their house is commercially available to the average person. Far from being un-innovative, they felt that this was in fact more innovative. After all, one-of-a-kind solar houses have been built for 30 years. A design that can be mass-produced and appeal to the average consumer is something new.

The Cost of a "Green" House

The estimated costs (if all the materials and labor had to be bought at retail values) for most of the houses seemed to fall a little to the high side of US$200,000. Many of the visitors to the Decathlon were surprised by these costs, not that they were so high for a one bedroom house, but that they were so much lower than their impression of what solar technology costs.

Many people seemed to think that a roof covered with PVs would be half a million dollars itself, whereas in reality the most expensive PV system was "only" around US$50,000. And the PV systems are the least cost effective measure found on these houses. Other design features, such as superinsulation and high efficiency air conditioners would pay for themselves in a few years, even on a grid-connected house.

The building industry obviously knows and plays off of people's impression that solar energy and super efficiency is "too expensive." Not a single major home developer was interested in sponsoring the event (although manufactured home companies worked with a few teams).

One developer that touts itself as being especially green and has corporate grants ostensibly dedicated to furthering green building research and public education repeatedly turned down applications for sponsorship. Their thoughts were that just low-E windows, a programmable thermostat, and basic Energy Star compliance on insulation constituted a high efficiency house. For comparison, most of the Decathlon houses, if they had all the PV and solar thermal collectors removed, would use only one-third of the energy of a basic code compliant house the same size, and about half the energy of an Energy Star compliant house.

The housing market at large will only change when people start demanding better. We hope that the Solar Decathlon is a start in showing people that better alternatives exist, and they are a lot further along than what they are being told they can have.

What's Next?

The competition attracted thousands of people—more than even the contest organizers hoped for. It showed the American public the many advances of solar energy since the "solar heyday" of the late 1970s. People saw some of the existing technology that they can use right now, and some new technology that sounds great, but still has some bugs to be worked out.

Several of the houses are on display at their respective university campuses, at least for the next year, and most teams are maintaining their Web sites to further educate the public about solar energy and energy efficient buildings. And a new generation of engineers and architects, now entering the workplace, learned how to implement solar design as a reality, not just as textbook theory.

The next Solar Decathlon competition will be held in 2005. The Department of Energy is in the process of selecting eighteen schools to participate for next time.

Access

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To download the Decathlon scoring spreadsheet, go to www.homepower.com > Magazine > Files & Downloads > Promised Files

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202-586-1693 • Fax: 202-586-8148 • richard.king@ee.doe.gov • www.solardecathlon.org

National Renewable Energy Laboratory (NREL), 1617 Cole Blvd., Golden, CO 80401 • 303-384-6516 • Fax: 303-384-6490 • cecile_warner@nrel.gov • www.eren.doe.gov/solar_decathlon

Structural Insulated Panel Association, PO Box 1699, Gig Harbor, WA 98335 • 253-858-7472 • Fax: 253-858-0272 • staff@sips.org • www.sips.org • Links to all U.S. SIP manufacturers

Thermomax Technologies, 5560 Sterrett Pl., Suite 115, Columbia, MD 21044 • 410-997-0778 • Fax: 410-997-0779 • info@thermomax.com • www.thermomax.com • SHW collectors

Sun Utility Network, 373 West Palmer Ave., Suite A, Glendale, CA 91204 • 800-822-SOLA(R) or 818-244-4919 • Fax: 818-244-4920 • info@sunutility.com • www.sunutility.com • Suntube evacuated tubes

S-5! Solutions, a division of Metal Roof Innovations, Ltd., 8655 Table Butte Rd., Colorado Springs, CO 80908 • 719-495-0518 • Fax: 719-495-0045 • info@s-5solutions.com • www.s-5solutions.com • PV mounts

RV Power Products, 2598 Fortune Way, Suite K, Vista, CA 92083 • 800-493-7877 or 760-597-1642 • Fax: 760-597-1731 • info@rvpowerproducts.com • www.rvpowerproducts.com • MPPT charge controllers

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

Xantrex Technology Inc., Distributed Power Markets, 5916 195th St. NE, Arlington, WA 98223 • 360-435-8826 • Fax: 360-435-2229 • dpm@xantrex.com • www.xantrex.com • Inverters

Efficient Windows Collaborative, Alliance to Save Energy, 1200 18th St. NW, Suite 900, Washington, DC 20036 • 202-530-2231 • Fax: 202-331-9588 • ewc@ase.org • efficientwindows.org • Information on energy efficient windows

Southwall Technologies, 3975 E. Bayshore Rd., Palo Alto, CA 94303 • 800-365-8794 or 650-962-9111 • Fax: 650-967-8713 • bmcclenahan@southwall.com • www.southwall.com • Window technologies

Smartwindow • 888-854-9520 • Fax: 888-854-9552 • smart@smartwindow.com • www.smartwindow.com • Window technologies

Alpen Glass, Alpen Inc., 5400 Spine Rd., Boulder, Colorado 80301• 303-530-1753 or 800-321-1753 • Fax: 303-530-1150 or 800-882-4466 • alpeninc.com • Window technologies

K-X Faswall Corporation, PO Box 88, Windsor, SC 29856 • 800-491-7891 or 803-642-8142 • Fax: 803-642-6361 • faswall@faswall.com • www.faswall.com • Faswall blocks

EcoProducts, 3655 Frontier Ave., Boulder, CO 80301 • 303-449-1876 • Fax: 303-449-1877 • info@ecoproducts.com • www.ecoproducts.com • Recycled carpet, sunflower seed board, cotton insulation, etc.

Phenix Biocomposites, PO Box 609, Mankato, MN 56002 • 800-324-8187 or 507-388-3434 • Fax: 507-388-3434 • sales@phenixllc.com • www.phenixbiocomposites.com • Environmentally friendly panel products

Trus Joist, 2910 E Amity Rd., Boise, ID 83716 • 800-338-0515 or 208-395-2400 • Fax: 208-364-3633 • www.trusjoist.com • Parallam laminated beams

Skywall Translucent Systems, a division of Butler Manuf., PO Box 629, Terrell, TX 75160 • 800-259-7941 or 972-551-6470 • Fax: 972-551-6421 • rcoskery@vistawall.com • www.vistawall.com • Aerogel building materials

Successful Solar Businesses—2004

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

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

Dates: February 20–22, 2004

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

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

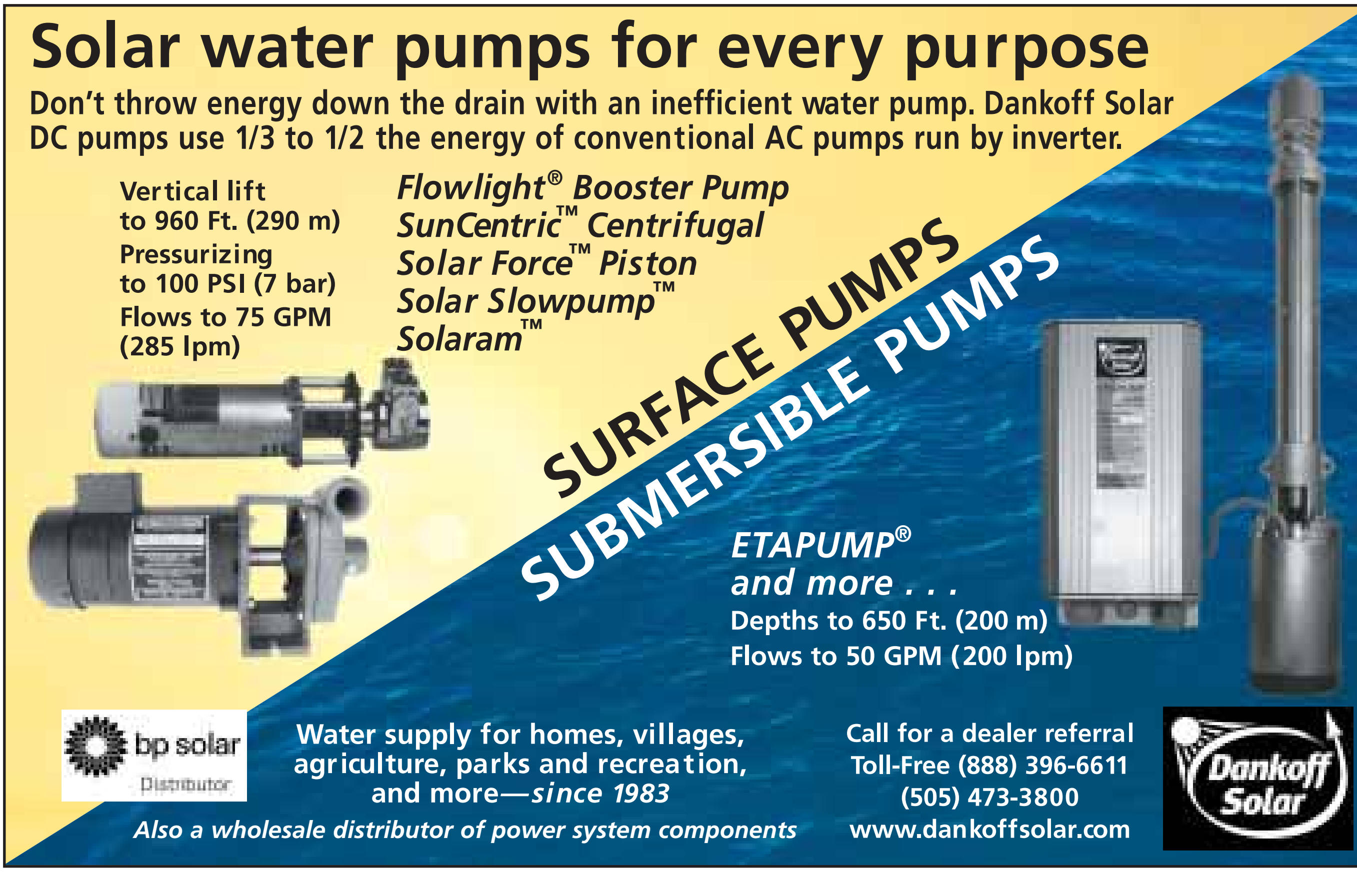
PV Technology Workshop: For those wishing to come up to speed quickly on PV technology, a special one-day workshop, taught by NYSEIA, will be held at the same location

Date: February 19, 2004

Cost for one-day PV workshop: $75

Conference and workshop size is limited, so contact Home Power at 800-707-6585, 541-512-0201, or richard.perez@homepower.com to reserve your place. Interest is very high in this conference, so reserve early if you wish to be sure of a place. Lodging will be available at discounted rates for conference participants.

We hope to see you there, and look forward to helping your solar business prosper.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Adventures with a Solar Powered Lawn Tractor

Christopher Zach

The author's children playing "farmer" on the Elec-Trak lawn tractor (safely turned off, of course).

It all started back in the summer of 2000 when the power line to my work shed shorted out. Replacing the line would have cost well over US$1,000, along with the inconvenience of tearing up my driveway and yard. It was at this point that I thought: "Now would be a great time to try solar electricity!"

So I installed my first solar-electric panel, got a few batteries, ran some wires, threw the disconnect switch, and lit up the shed. At that point, I knew I was hooked.

Making a Difference

One of the things I quickly noticed about solar electricity was its ability to make a difference. Here I was with a single solar-electric panel, two batteries, and an inverter, and I had enough energy to light my shed and use some small power tools as well. Every time I flipped the light switch, I felt a sense of pride in the fact that this was energy I had generated cleanly, and it was truly mine to use.

I began to think about other uses for all that energy coming down from the sky. What I really wanted was to use the solar-electric panels to make the biggest dent possible in my pollution output, while spending a reasonable amount of money, and providing a solution that would clearly display to anyone the benefits of solar energy. While I was pondering this, I went outside and sat down on the biggest, loudest, most pollution-generating device I owned—my Craftsman 16 horsepower lawn tractor.

The Craftsman

Small, gasoline powered yard tools are notorious for the amount of noise and extreme amounts of pollution that they generate. This is partially due to the small sizes of the engines, but mostly to a complete lack of anything resembling pollution control. Garden tool motors typically have single-stage carburetors, so they run very rich. They also have limited (if any) mufflers; and no air injection, fuel injection, or any of the clean air features found on even the most basic automobile engines. The gas tanks are typically vented to open air, and the crankcase fumes aren't reburned.

According to an article from the CNN Web site, lawn mowers in the Los Angeles basin put out more pollution than all the aircraft in that area. In fact, per hour of use, a lawn mower puts out more pollution than 73 automobiles.

Thus, my choice was clear. The gasoline powered lawn tractor was the biggest polluter I owned. But I use it a lot. It mows the lawn, it lugs around loads, and it's a very useful tool to have. What could I possibly replace it with?

The Elec-Trak

In browsing past issues of *Home Power* magazine, I read about the General Electric Elec-Trak line of lawn tractors in *HP70*. These units were built in the early 1970s, and instead of using a gasoline engine, they were powered by electric motors run from six golf cart batteries.

The solar-electric charging system hooks up to the Elec-Trak's 36 volt accessory port.

My first thought was, "Wow, I've got to get one of those." I could plug it into the wall and get rid of the tractor. Then the second thought hit me: "Why not take this idea to the limit and run an Elec-Trak on solar electricity?"

The idea of mowing a lawn with solar electricity is not quite a new one. At least one manufacturer makes a tiny solar powered lawn mower. But the Elec-Trak isn't a little plastic contraption. It's a 900 pound (408 kg) steel tractor with a 42 inch (107 cm) cutting deck—a difference in scale to be sure. My next steps were to find an Elec-Trak, and then figure out a way to run it on solar electricity.

Buying an Elec-Trak was actually not too difficult. General Electric made a lot of them, and they were built extremely well, so many still survive. I checked on eBay for a few weeks, and found an E20 model (the biggest they made) for the low price of US$520. The batteries were shot, and it had some surface rust, but the basic mechanics were solid. I rented a small pickup truck, drove from my home in Maryland up to New Jersey, and hauled it back.

It took a bit of work to get it running, but thanks to lots of help from the Elec-Trak Web site (www.elec-trak.org) and a very helpful e-mail list, I was able to find local people who could help me bring it back to operation. So now that I had the tractor, it was time to build a solar powered charger.

The Solar Charging System

The first step in designing any solar-electric system is to answer these three questions:

1. How much do your loads draw?
2. How much time do your loads run?
3. How good is your solar resource?

The first question was answered with a bit of basic research: I estimated that the Elec-Trak would draw approximately 60 amps at 36 volts while cutting my lawn.

The second question was the key to designing this system. My 1 acre lawn takes about an hour to mow. So the electrical load would be 60 amps at 36 volts for one hour, or about 2,160 watt-hours. I mow my lawn about once a week. In the hot summer months, I might only need to mow the lawn every other week. The rest of the time, the tractor sits idle. So the solar-electric array for my electric tractor needed to provide 2,160 watt-hours once every week or two weeks.

The third question has to do with the environment the system is installed in. I live in Maryland, on the south side of a nice hill, and have a heavily wooded backyard around my shed. During the summer, when I use the tractor most, I can typically get only about four useful hours of sun per day because of the number of the trees in my backyard. Due to clouds, I can count on about five days of sun a week, or about twenty hours of peak sun per week.

When I take into account the decrease of PV output as temperature increases, the losses inherent in charging batteries, and the losses in the wiring, I figure that about 80 percent of the PV array's rated output is available for charging the tractor's batteries.

Fill 'er up! The tractor getting topped off with solar electricity.

Given these assumptions, I made the following calculations: A solar-electric array that is rated at 180 watts can probably charge the batteries at about 80 percent or 144 watts. Multiplying this by an average of four peak sun hours a day, I have about 575 watt-hours (WH) of daily energy production.

So in five sunny days, I can expect 2,880 WH of energy production. If I get a full week's worth of sun (all seven days) I'll get more than 4,000 WH. A 180 W rated solar-electric array would provide more than enough energy to mow my lawn every other week, and might provide just enough to mow my lawn every week (depending on the amount of sun).

A great deal of assistance in the design process was provided by Kirk Mulligan from Atlantic Solar Products. In addition to providing the equipment, he was quite helpful in determining the right products to use and answering my questions.

Building the Solar Charger

Building the solar-electric system was not as complicated as I anticipated. I mounted the panels to my shed's roof with zinc plated steel girders. The girders are mounted to the panels with standard 5/16 inch (8 mm) bolts, and screwed into the shed's roof. The roof of my shed consists of 1 by 12 lumber planking, nailed to 2 by 4s, and covered with 20 year shingles, so I am rather confident that the rack will not come apart in a windstorm.

I first used one BP Solarex MSX120 panel configured for 24 volts, series connected to an MSX60 panel configured for 12 volts. (These PVs are field configurable for 6, 12, or 24 volts.) This provides a combined output voltage of 36 volts at 180 W rated, which matches the power requirements of the tractor. The outputs of the panels are connected via #10 (5 mm^2) wires to a junction box, which is connected via conduit to a weatherproof Cutler-Hammer 30 amp disconnect.

The disconnect serves two functions. First, it allows me to turn off the panels when I want to work on the downstream wiring. I make it a personal policy to ensure that all connections from a solar-electric panel can be disconnected with the simple throw of a switch.

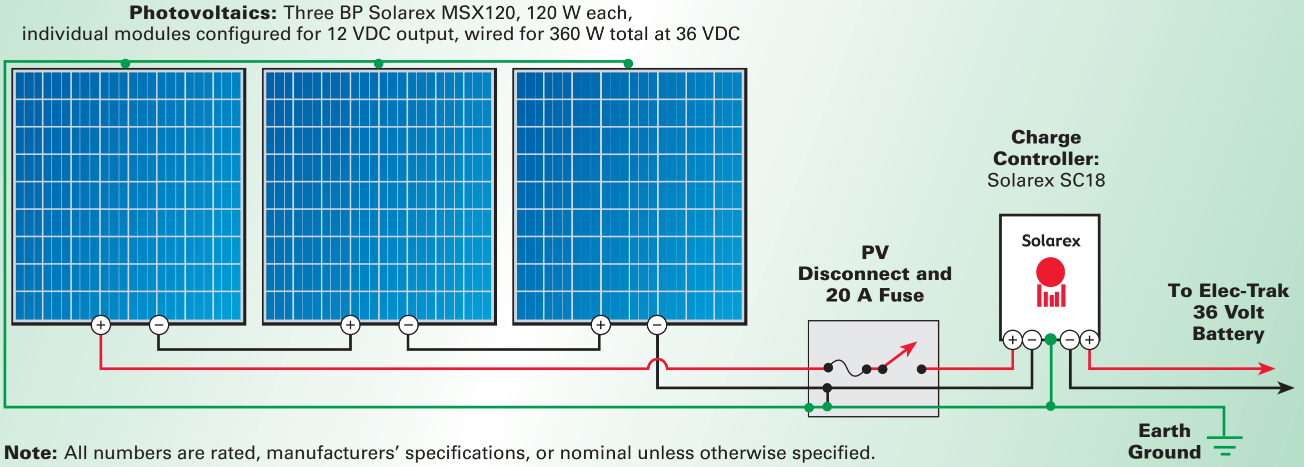
Boost the Power

The 180 W rated solution I installed was working well. But I wanted to decrease the time it took to fully charge the tractor battery, so I could mow my lawn weekly, and have power to spare to drive my tractor around. So I went out to Atlantic Solar and picked up two more 120 watt panels. Installing them on the roof was a simple matter of building a mount and wiring them in.

For the 360 watt solution, I configured the three BP Solarex MSX120 panels to output 12 volts nominal. Then I wired the three modules in series. This gave me a 360 watt output at 36 volts. The original MSX60 is now being used to charge spare batteries.

The three MSX120s are providing the tractor with more than 7.5 amps of charge at 36 volts nominal. With this much solar electricity, I can run the batteries down and bring them up in three days. It turns out that this is more than I need, so I'm starting to reconfigure my system again so I can sell some of the surplus to the utility.

360 Watt, 36 Volt Charging System



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

Second, it serves as the carrier for my 20 amp RK5 fuse. I use DC-rated fuses, which have an interrupt rating of 10,000 amps. I cannot stress enough the importance of properly fusing your solar-electric panels. If your panels or wiring were ever to short, the current from the Elec-Trak's batteries could destroy your panels and possibly set fire to your dwelling. Always remember to use DC-rated fuses; common fuses are typically not rated for DC circuits.

From the disconnect, the wires run in 3/4 inch conduit to my Solarex SC18 charge controller. Finding a charge controller was a bit of a challenge, since most are designed to work on 12, 24, or 48 volt systems. The Elec-Trak uses a 36 volt power supply, so you need to ensure that your charge controller can support 36 volts. I found the Solarex SC18 controller on eBay from for about US$100. Oddly enough they are normally only sold in Australia, though I've recently heard that B.Z. Products in Missouri makes a 36 volt controller.

The SC18 is a rather simple controller. It will charge the batteries to one of two set points based on the battery voltage. If the batteries are slightly discharged (above 37 volts but below 41), it will float charge them up to 42.3 volts. If the batteries are deeply discharged (below 36.9 volts), it will automatically charge the batteries to 45 volts.

The output of the SC18 is fed to a 25 foot (7.6 m) extension cord that plugs into the Elec-Trak's accessory port. This accessory port was originally designed to power things like chain saws, hedge trimmers, and other DC powered tools. It's connected to the battery, and is protected from overload by the tractor's internal disconnect and a circuit breaker. This makes it a perfect point to attach the solar-electric array.

I used a Hubbell (HBL7102C) twist-lock plug to connect to this port; this can be ordered at most electrical supply houses. When hooking up the twist-lock plug, make sure that you get the polarity right. Positive on the Elec-Trak *must* go to positive on the charge controller. Verify this with your voltmeter *before* connecting the charge controller to the Elec-Trak.

Grounding is important, even on a small system like this. The system is grounded with #6 (13 mm^2), bare, solid wire connecting the panels, the mounts, the disconnect boxes, and the negative side of all wiring to an 8 foot (2.4 m), 5/8 inch (16 mm) grounding rod hammered straight into the

Estimated Costs for Two Charging Scenarios

Item	Cost (US$) 180 W	360 W
2 Solarex MSX120, 120 W modules	-	$1,000
Solarex MSX120, 120 W module	$500	500
Solarex MSX60, 60 W module	280	-
Solarex SC18 charge controller	100	100
Conduit, fittings, & misc. parts	100	100
Cutler-Hammer 30 A disconnect	40	40
Totals	$1,020	$1,740

ground. Always use proper grounding to protect your equipment against lightning strikes and the possibility of electrical shorts.

Putting It All Together

Installing the panels and wiring the boxes took most of a weekend. The hardest part was ensuring that I had enough of the small things that go into a project like this. Items like nuts, bolts, and waterproof connectors always seem to be in short supply, and can keep you going back to the hardware store. I am fortunate to have a very nice hardware store a mile from my house. They carry just about everything, and have an extremely knowledgeable staff.

At each stage of the wiring, I checked my connections for proper polarity with my trusty voltmeter. It's actually pretty easy to make a mistake and wire a panel backwards, so it's very important to check that the output voltages and currents match what you anticipate.

When all the wires were run, and all the connections had been tested, I installed the fuses, hooked up the tractor, and threw the big disconnect switch. Thunk!

I was rewarded with a green charging light on the SC18, indicating that the tractor was being charged. A quick check at the Elec-Trak with my digital multimeter showed a voltage of 40 volts and a current of 3 amps, indicating a good solid charge.

Harness the Sun

After three days of charging, the controller's light went off. Checking the batteries showed a voltage of 41.5 volts, which indicated a full charge. I unplugged the charge cable and drove off.

I had fun that afternoon. There's no feeling quite like reaping the rewards of solar energy. I gave my two children rides around the yard, and later as I used my trailer to haul wood around, I realized that I had truly harnessed the power of the sun!

Amaze Your Friends

I love driving the Elec-Trak around. It's easily more powerful than the Craftsman tractor, due to the exceptional low-end torque of the electric motor. And the 900 pounds (408 kg) of weight provides plenty of traction. The larger tires are easier on the grass, and the mower works quite well.

Friends and neighbors are amazed when they stop to take a look at the Elec-Trak. It's different, and it's quiet. And when I tell them it's 100 percent powered by the sun, I can almost see their minds begin to expand. For most people, solar energy is abstract—it's what runs a little calculator, or maybe a child's solar powered toy.

Watching a 900 pound tractor powered by the sun allows them to see things in a new and different light. Green power from the sun isn't abstract; it can power big tools and do very visible tasks. Solar energy can make a difference.

But the thing that amazes me most is the quiet. A low whirr is all I can hear when it's running. No noise on a Sunday afternoon, no refueling, no gas cans, no pollution. I can listen to the birds while mowing the lawn, and can do it all with the knowledge that I am no longer a part of the problem—I'm a part of the solution.

Access

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www.crystel.com

Atlantic Solar Products, Kirk Mulligan, PO Box 70060, Baltimore, MD 21237 • 410-686-2500 • Fax: 410-686-6221 • mail@atlanticsolar.com • www.atlanticsolar.com

BP Solar, Inc., 2300 N. Watney Way, Fairfield, CA 94533 • 888-274-7652 or 707-428-7800 • Fax: 707-428-7878 • solarusa@bp.com • www.bpsolarex.com

The Last Place You Looked.com, PO Box 925, Lynnfield, MA 01940 • Fax: 978-532-3151 • sales@thelastplaceyoulooked.com • www.thelastplaceyoulooked.com • SC18 controller

"The Elec-Trak Rides Again; Reviving G.E.'s Electric Lawn Tractors," Mike Bryce, *HP70*. Available in print or on the Solar4 CD.

Elec-Trak Owners Club• don.barry@kmtc.com • www.elec-trak.org

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Lawn mower pollution articles:
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www.pscleanair.org/whatcan/airchoice.shtml

Xantrex Prosine 2.0

Inverter/Charger

Joe Schwartz

Application: I installed a Prosine 2.0 inverter/charger in an off-grid, residential system at *Home Power* Central. It powers standard, 120 VAC household loads including lighting, audio and video equipment, a refrigerator, circulation pumps for a solar hot water system, and small power tools. During the winter months, it's frequently used in conjunction with an engine generator to recharge the battery bank during extended cloudy periods.

System: The system is located in southern Oregon. Major components include a 1.4 KW (rated) PV array, four Surrette 6-CS-25PS flooded lead-acid batteries (1,640 AH at 12 VDC), and a Honda ES6500 (6,500 watt) gasoline generator.

The Xantrex Prosine 2.0 is a great 12 volt sine wave inverter for boat, RV, or small residential systems. Its integrated AC charger is perfect for shore power or generator backup.

The Prosine 2.0 was designed for mobile and marine inverter applications, but it's also suitable for small off-grid systems that aren't rolling down the road, and for utility backup systems.

Whether your home is in motion or not, there are three major inverter design characteristics that you'll want in most cases: high quality AC output, an efficient battery charger, and the ability to install the inverter in a safe, code-compliant fashion. The Prosine 2.0 has all three of these characteristics covered.

Waveform

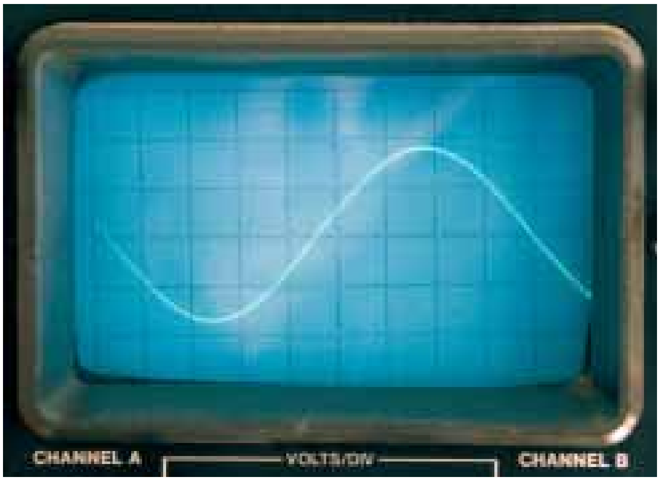
In virtually all new residential installations, modified square wave inverters are a thing of the past. Their less-than-ideal AC output waveform often results in noise on audio and video equipment, hot and inefficient motor operation, unsatisfactory operation of tools with variable speed controls, and damage to some AC appliances.

On the other end of the spectrum are high quality sine wave inverters, like the Prosine 2.0. The AC power quality of the Prosine is excellent. In fact, its output has higher power quality than the utility grid in most cases.

Battery Charger

Most off-grid systems have an engine generator to charge the battery bank during extended cloudy periods. Anyone who has spent time living with a generator knows that they are expensive to run and maintain, and that not much detracts more from the great outdoors than a roaring generator. When you do need to use the generator, high quality chargers will minimize the run time and get you through the charging process as quickly, painlessly, and inexpensively as possible.

The Prosine 2.0 has an efficient battery charger with a high power factor (1.0 throughout our testing). Power factor is a ratio of the AC power actually used by a load (real power, the battery charger in this case) compared to the total power delivered (apparent power). With high power factor devices, the load uses most or all of the power delivered by the source. Low power factor appliances reflect some of the delivered power back at the source. The higher the power



The Prosine's AC waveform is cleaner than most utility power.

Test Equipment & Setup

Inverter test data was collected while adding incremental AC resistive loads to the inverter. Charger data was collected over a complete charge cycle. Battery voltage, battery current (via a 50 mV/500 A shunt), and peak and rms AC voltage were measured using three Fluke 87 digital multimeters. AC amperage was measured with a Brand Electronics model 20-1850 power meter and a Fluke 43B AC Power Quality Analyzer. The Fluke 43B was also used to measure total harmonic distortion and power factor. The battery temperature during testing was 70.9°F (21.6°C). The inverter setting for AC breaker size was set at 20 A.

Prosine 2.0 Inverter Test

	AC Out				DC In			
Load Watts	Volts (Peak)	Volts (rms)	Amps	THD*	Watts	Volts	Amps	Efficiency
Search	NA	NA	NA	NA	1.3	12.99	0.1	NA
Idle	164.8	117.8	0.0	1.1%	22.0	12.97	1.7	NA
21.2	164.8	117.8	0.2	1.0%	47.2	12.75	3.7	44.9%
42.4	164.8	117.8	0.4	1.0%	71.4	12.75	5.6	59.4%
63.6	164.8	117.8	0.5	1.0%	96.8	12.74	7.6	65.7%
86.0	165.2	117.8	0.7	1.2%	119.7	12.73	9.4	71.9%
168.3	165.2	117.7	1.4	1.1%	207.3	12.72	16.3	81.2%
255.0	164.4	117.5	2.2	1.0%	300.3	12.67	23.7	84.9%
338.1	164.4	117.4	2.9	1.0%	391.2	12.62	31.0	86.4%
493.4	164.4	117.2	4.2	1.0%	562.3	12.58	44.7	87.7%
579.6	164.0	117.1	5.0	1.1%	656.3	12.50	52.5	88.3%
663.4	163.6	117.0	5.7	1.1%	748.9	12.44	60.2	88.6%
748.2	163.6	116.9	6.4	1.1%	843.2	12.40	68.0	88.7%
819.9	163.6	116.8	7.0	1.0%	935.2	12.37	75.6	87.7%
981.8	163.6	116.6	8.4	1.1%	1,110.8	12.37	89.8	88.4%
1,230.5	162.8	116.3	10.6	1.1%	1,387.9	12.25	113.3	88.7%
1,365.3	163.2	116.1	11.8	1.1%	1,544.5	12.19	126.7	88.4%
1,601.5	162.0	115.8	13.8	1.1%	1,802.9	12.10	149.0	88.8%
1,846.4	162.0	115.4	16.0	1.1%	2,080.0	12.03	172.9	88.8%
2,101.7	160.8	115.1	18.3	1.1%	2,364.5	11.96	197.7	88.9%

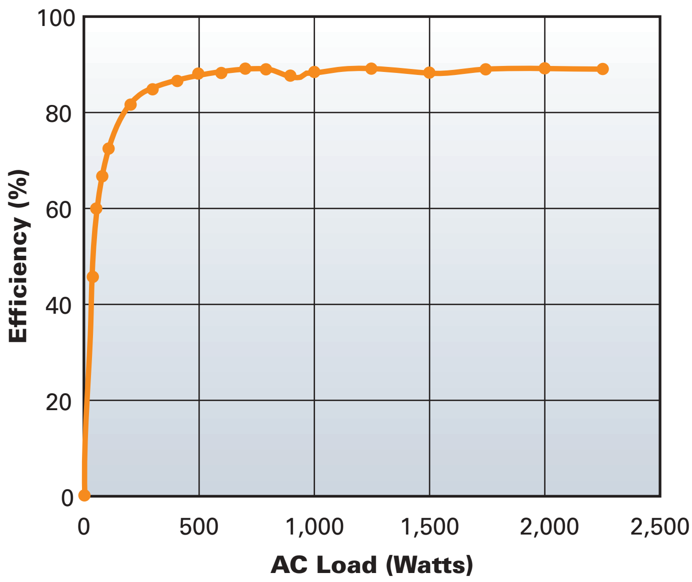
*Total harmonic distortion

factor, the better. A unity power factor, represented numerically as 1.0, means that all the power supplied to the appliance is used by the appliance to do work, and none is reflected back to the source. The result is more efficient operation of the AC source, and in this case, less generator run time.

Installation

Inverters should be installed in cool, dry locations. Because the Prosine 2.0 was designed for mobile and marine markets, it's not available in a preassembled power panel that includes AC and DC enclosures and disconnects. But if you purchase an optional DC conduit box from the manufacturer, the inverter can easily be installed to meet all the requirements of the *National Electrical Code (NEC)*. The inverter is straightforward to install and relatively easy to program. The 164 page installation and operation manual will guide you through the process if you're installing the inverter on your own.

Prosine 2.0 Inverter Efficiency



Applications

The Prosine 2.0 is well suited for a variety of applications—some more so than others. Here are some of my quick observations about this equipment's adaptability.

Boats and RVs. If you're a boater or RVer, the Prosine 2.0 is a great choice. Built for these markets, the inverter is designed to operate seamlessly between stand-alone and shore-powered use.

In a residential application, the neutral wiring system is routinely bonded or connected to the equipment ground wiring system by placing a jumper between the ground and neutral bus bars located inside the main load center or breaker panel. The neutral system should only be bonded or connected to the equipment ground system in one place. This reduces the shock hazard by creating a single electrical path to ground.

In mobile applications, AC power from a marina or RV park (sometimes referred to as "shore power") is often used to supplement the vehicle or boat's onboard power system. The shore power system's neutral conductor is already bonded to the stationary equipment ground system. Connecting to this system creates a secondary neutral bond if the vehicle's onboard power system already has a fixed neutral-to-ground bond inside a breaker panel.

To eliminate this problem, the Prosine 2.0's transfer relay opens (disconnects) an internal neutral-to-ground bond when it's connected to shore power. In stand-alone use, the transfer relay closes (connects) this internal neutral-to-ground bond, effectively connecting the inverter's neutral output conductor to the vehicle's equipment ground system. If you're planning to use the inverter in a stationary residential application, you can easily disable this automatic neutral-to-ground bond feature by relocating a small bonding screw in the inverter's AC wiring compartment, and make a permanent neutral-to-ground bond in the AC mains panel. The manual explains this process thoroughly.

Utility backup. The Prosine 2.0 is also well suited for grid backup power systems. The inverter is not designed

Features

High Points:

- Excellent power quality (< 2% THD)
- DC charger with 1.0 power factor
- User-friendly control panel that can be remote mounted
- 16 VDC high battery voltage input limit
- Auto restart after error conditions end
- Detailed installation and user's manual
- Quiet operation

Low Points:

- 30 A transfer switch limits battery charging under some conditions
- Tight AC wiring compartment
- No off-the-shelf, power panel mounted options

List Price: US$2,199

Warranty: 2 years

Other:

- Two units can be series stacked for 120/240 VAC output
- 15 amp GFCI receptacle option for AC output in mobile applications

Prosine 2.0 Charger Test

DC Out			AC In (from Generator)						
Volts	Amps	Watts	Volts (Peak)	Volts (rms)	Amps	Watts	Freq. (Hz)	Load* (Watts)	Efficiency
13.67	106.3	1,453.1	170.0	120.7	14.04	1,694.6	60.4	None	85.7%
14.14	105.0	1,484.7	170.8	120.9	14.32	1,731.3	60.9	None	85.8%
14.62	82.0	1,198.8	169.2	122.5	11.47	1,405.1	62.4	None	85.3%
14.75	63.0	929.3	169.2	123.3	8.83	1,088.7	61.7	None	85.4%
13.57	74.1	1,005.5	170.0	120.9	14.63	1,768.8	60.4	583	84.8%
13.49	59.3	800.0	169.2	120.8	14.88	1,797.5	60.4	861	85.4%
13.33	26.3	350.6	168.4	120.3	15.39	1,851.4	60.0	1,424	82.0%

*Additional resistive load

Tech Specs

Inverter

- Continuous output power: 2 KW at 40°C (104°F)
- Surge rating (5 second): 4.5 KW
- True sine wave AC output: <2 percent THD typical
- Efficiency (full load): 87 percent
- Peak efficiency: 89 percent
- No load power draw (inverting): <25 W
- No load power draw (search mode, 3 sec. interval): <2 W
- Input DC voltage range: 10 to 16 VDC
- Transfer time (backup AC to inverter and inverter to backup AC): 16 milliseconds typical

Charger

- 100 A DC continuous output current
- Three-stage DC charge control with manual equalize
- Temperature compensated charging via remote battery sensor
- Average efficiency 81 percent
- AC input power factor 0.99
- Input AC voltage range 90 to 135 VAC

Physical Size: 17 3/4 by 11 3/8 by 5 3/4 inches (45 x 29 x 15 cm)

Weight: 24 pounds (11 kg)

Note: All specifications supplied by manufacturer.

to sell electricity to the utility, but it does have an internal transfer switch that allows it to automatically power select loads in the event of a utility failure. The transfer time between grid and inverter power is 16 milliseconds. This may or may not be fast enough to keep computers from crashing. Make sure to contact the manufacturer of your computer and double-check the required transfer time before purchasing any inverter for this use.

Residential. The Prosine 2.0 is not the most versatile inverter for use in off-grid systems, since only one input voltage is available—12 VDC. Twelve volt systems are standard in the RV market because the vehicle's alternator is often used to charge the coach batteries while you're rolling down the road. But modern off-grid power systems typically operate at 24 or 48 VDC nominal. Higher voltage systems allow for smaller wiring between the DC charging sources and the batteries, and allow these charging sources to be farther away from the batteries.

High Quality Inverter

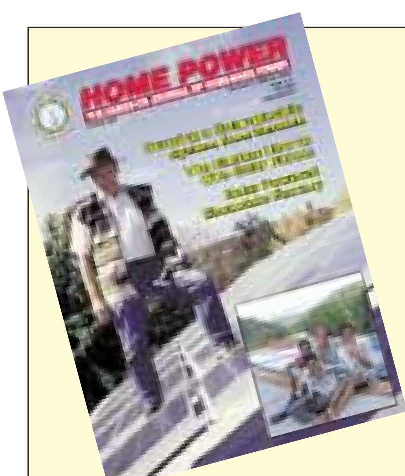
Twelve volts can be a great choice for small systems running some DC appliances, but 24 or 48 VDC nominal systems are far more common these days. That said, the inverter installed in our test system has performed flawlessly, and has definitely met my expectations.

You can choose from several high quality, battery-based inverters in the 1 to 2 kilowatt range. The Prosine 2.0 is definitely one of them. It is well suited for use in RVs, boats, and small off-grid systems.

Access

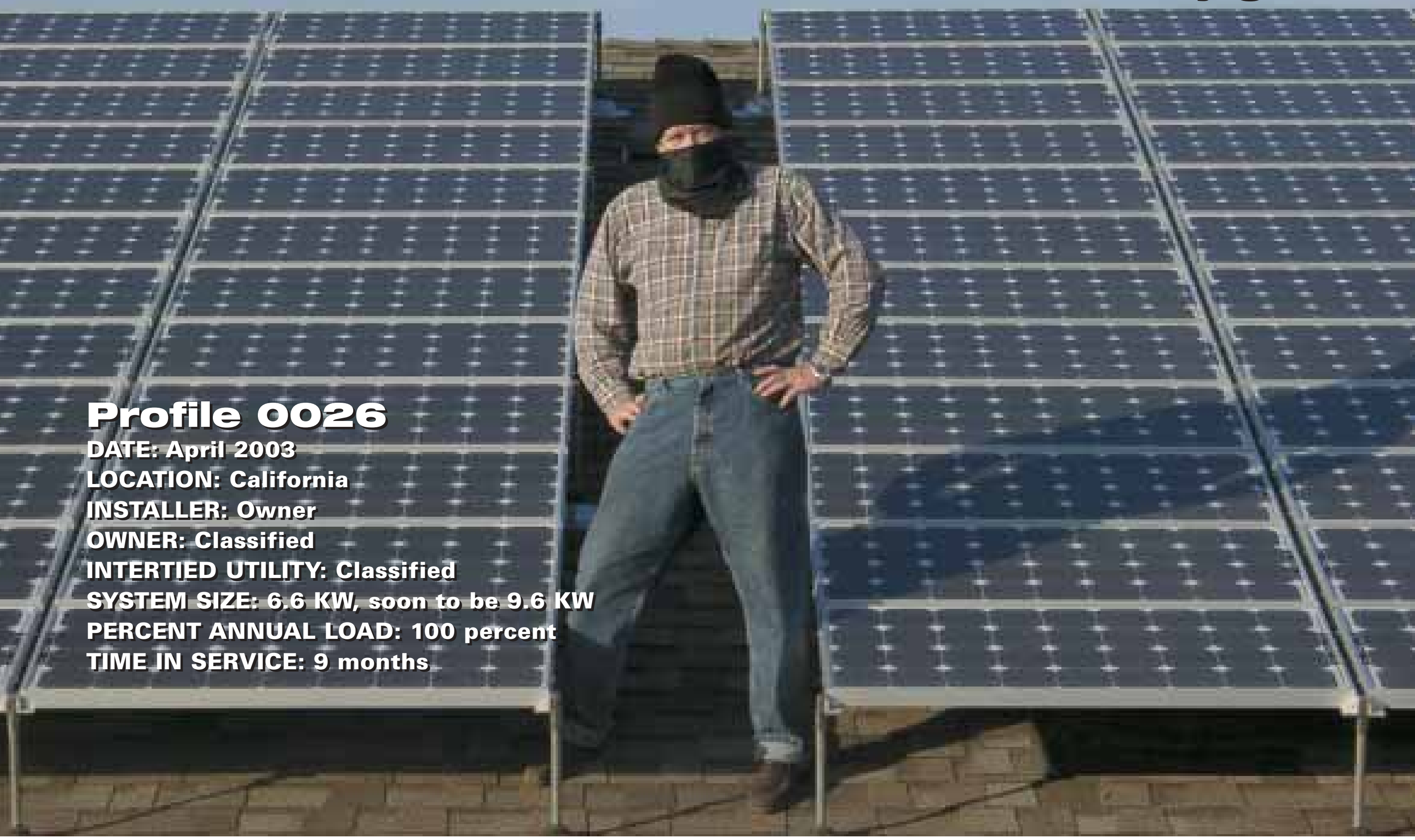
Joe Schwartz, PO Box 520, Ashland, OR, 97520 • 541-944-0780 • joe.schwartz@homepower.com

Xantrex Technology Inc., 5916 195th St. NE, Arlington, WA 98223 • 360-435-8826 • Fax: 360-435-3547 • info@xantrex.com • www.xantrex.com • Prosine 2.0 inverter



guerrilla solar

the unauthorized placement of renewable energy on a utility grid



Profile 0026
DATE: April 2003
LOCATION: California
INSTALLER: Owner
OWNER: Classified
INTERTIED UTILITY: Classified
SYSTEM SIZE: 6.6 KW, soon to be 9.6 KW
PERCENT ANNUAL LOAD: 100 percent
TIME IN SERVICE: 9 months

My wife and I recently moved to an area where the maximum daytime temperatures during the summer are generally in the mid to high 90s, with frequent trips over the century mark. To conserve energy, we planned to use a whole-house fan to cool the house at night and attic fans to help cool the attic during the day. Despite these efforts, we knew that we would be forced to run our air conditioners in the summer. The electricity market was in an upheaval and it looked like energy costs could spiral, so our plans included the installation of a PV system.

Air Conditioning—Costly Load

As the next summer approached, temperatures started to rise. For a while, the whole-house fan did the trick. But when temperatures hit the mid to high 90s, this was not enough. When temperatures hit the century mark, we could not keep the house below 85°F (29°C) without the use of the air conditioners. The air conditioners draw about 9 KW. With utility bills going up with every degree, I knew I had to get the PV system up and running, and the sooner the better.

Our utility rates are tiered, with baseline rates at 11.6 cents per KWH. When the summer's high temperatures arrived, we reached the fourth tier, which is 22.8 cents per KWH, and were rapidly approaching the fifth tier, which is 25 cents per KWH. This was a lot higher than it had been the year before when we lived in the mountains, where we only occasionally needed to run the air conditioning.

PVs & Mounting

Using PV, it appeared that a 9 to 10 KW system could supply 100 percent of our annual needs. I decided to start with 120, 75 W, BP275 panels. I was naive enough to think that PV panels would put out close to their rated output.

What I overlooked is just how hot the panels get, and how much this reduces their actual output.

We mounted the panels on our roof using a custom rack that I designed. It allowed all of the supports to be placed directly over the roof trusses. With the panels 14 inches (36 cm) above the roof surface, there's ample working room below them, and good air circulation.

The racks are made from aluminum angle supported by 1/2 inch diameter pipe nipples, which are flashed for weather protection. The nipples are attached to the roof with floor flanges, and the aluminum angle is connected to the nipples using custom-machined, stainless steel pipe caps.

Close-up of PV rack support, with hot water collectors in background.

Battery Backup

I work out of my home, so a system with a battery backup that would allow me to keep working was important. I used to live in an area where the grid went down two or more times a year, sometimes for more than two days. I knew that with a private well, a grid outage means no water unless you have a generator or a battery-based system capable of operating the pump. Since my generator uses a rope starter, I was ready for something more convenient.

Equipment installation with covers off.

With eight Trojan T-105s, there is enough energy to keep our computers, lights, and TV running for more than 10 hours. Four Trace C40 charge controllers will regulate the PV array in the event of a grid failure, assuring that the batteries aren't damaged due to overcharging.

Inverters & Panel

To obtain a capacity of 10 KW, I used two Trace SW5548 inverters. To simplify the installation, I decided to mount the inverters on an OutBack Power Systems PSMP mounting plate, along with OutBack PSAC and PSDC boxes.

No sooner had I placed my inverter order than the infamous SW islanding problem arose. Although it has not been observed in practice, under certain laboratory conditions, the SW inverters did not disconnect themselves from the grid within the allowable time period. Failure to disconnect would mean that the inverter could continue to power a small local portion of the grid, hence the term "islanding."

I looked at other inverters, but at the time, nothing else available would work as well. It was fall and temperatures were mild, so I decided to wait. The wait was short, but then to meet the anti-islanding requirement, I had to add a Trace Grid-Tie Interface (GTI) to each inverter. Fortunately, there was enough room for the GTIs next to the OutBack PSPV combiner boxes I had selected.

Step by Step

Remembering the saying that every little bit helps, I decided to install the inverters and associated equipment first.

Installing the first PV module.

Then I would be able to use the energy from each PV string as soon as it was connected to its combiner box. Of course, at some point in this process, the system would be producing more than I was using, and the excess would be fed to the grid.

Since it is impossible the get the utility's approval until the system has passed inspection by the local building department, and the local building department would not inspect and approve the system until after the installation was complete, the utility would be fed electricity without their approval. Not deterred by this dilemma and not about to let that energy go to waste, I became a solar guerrilla.

As each string was installed and connected, I checked the utility's meter to see if it was running backwards. At first, there was no noticeable effect. When I finally noted an effect, it was less than I had expected. What I learned is that PV panels produce their maximum output only when they are cold, and the panels' dark color causes them to get quite hot, especially in July.

Progress

Once I got the first 24 panels connected, I turned off the refrigerator (briefly) and the utility's meter ran backwards for the first time. I was making progress, and was on my way to energy independence. However, my joy was short lived when, for no apparent reason, the meter started running forward. We are on a private well, and my wife had turned on the water. That 1.5 hp pump drew more than those first 24 panels could supply. Having solved the mystery, I went back to work installing panels.

After about half of the panels had been connected, I was watching the meter turning backwards and contemplating the end of electric utility bills, when I heard one of the air conditioners start. The meter began going forward as fast if not faster than it had been going backwards. It was clear that I needed more PVs, so back to work I went.

Ultimately, all 120 panels on the roof were connected. As far as I could tell by reading the meters on the inverters, the system was peaking at about 6.6 KW, or 55 W per panel. The high temperatures in late July were not helping. It would be nice if someone could come up with an economical method of cooling PV panels to increase their performance when ambient temperatures are high.

Billing Irregularities

By keeping the thermostat set near 85°F (29°C), our utility meter read slightly less at the end of August than it had at the end of July. I expected the utility to knock on my door once they read the meter and discovered that the PV system was in operation. Instead, and to my surprise, they apparently assumed that they had misread the meter in June, and reduced my June bill by almost two-thirds. Being a solar guerrilla was having some unexpected benefits.

At the end of the billing cycle in September, the meter was about 300 KWH below what it had been in August, and I still did not have the utility's approval of my application for net metering. When the September bill arrived, I was curious to see how they had dealt with the even lower meter reading. Would there be a note about tampering with their meter or unauthorized connection of a PV system to their grid? When I opened the bill, I discovered that they had estimated the meter reading and were billing me for approximately 500 KWH. Of course, this was more than 800 KWH above what the meter read.

Knowing that there was no way the utility could justify their estimated reading, I called to complain about the bill. The lady who answered the phone stated that they had noted their earlier "error" and had "corrected" my bill. When I pointed out that I was not complaining about the adjustment to my July bill, but the estimated reading on the September bill, she excused herself.

Faced with a meter reading that was 300 KWH lower than it had been the month before, she was obviously not ready to deal with a meter that was running backwards, and needed a powwow with her coworkers or a supervisor. Several minutes later, she came back on the phone and coyly asked if I had a PV system. When I responded yes, she said that I had to talk to the person who handled customers with PV systems, and I was given his telephone number.

Solar Rebel

I called, and was asked for my account number. When I provided it, I was told that I was not in the system, and I had to talk to the regular customer service representatives. Of course, this sounded like a runaround to me, so I explained that I had already spoken to them and they said I had to talk to him. He was not deterred, so I explained that I had a PV system. He asked if it had been approved and I replied, "No." I added that I had filled out an application for net metering and was still waiting for approval.

He then stated that I had an "unauthorized" connection to the grid and that I had to disconnect the system until it was approved. Knowing that the system had been inspected and passed by the local building department and was safe, I stated that I did not intend to disconnect it. I thought about mentioning the contributions that solar guerrillas make, but decided not to, because he was probably a company man and obviously did not appreciate the fact that I was providing energy to the grid that they were selling to someone else.

Having let the proverbial cat out of the bag and unsure of just what effect my conversation might have, I decided that I needed to check on the progress of my net metering application. I called a number I had been given by my PV system supplier and left a message asking what progress had been made on my application. To my surprise, I received a telephone call a couple of hours later informing me that my application had been approved and that I would be receiving a call to set up an appointment for the utility's inspection of my system.

Utility Inspection

The next day, the utility called and asked if the system had been inspected by the local building department. I responded that it had, and that a copy of the building department's approval had been attached to my application for net metering. I was then asked if the required disconnect was located within 10 feet (3 m) of the meter. I responded that it was less than 2 feet (0.6 m), and that a photograph showing its location next to the meter had also been attached to my application for net metering.

They said that they would be out the next day to replace my existing meter with a bidirectional meter. Of course, the meter I had was bidirectional; it just did not have a sticker on the side saying so.

The utility's installer arrived on time and was very pleasant. It only took a few minutes to swap meters, after which he verified that the inverters had disconnected from the grid when he swapped meters.

During our conversation, he mentioned that the lower reading had caused a report to the utility's revenue agents, the people who investigate electricity theft, and that they had been to the house. Of course, I had not tampered with their meter, but had only used it to measure the energy my PV system was delivering to the grid.

System Performance

This story would be incomplete without some mention of the performance aspects of the system. With my air conditioning thermostat set at 85°F (29°C), the PV system was able to generate approximately 8 to 9 KWH per day more than I was using. Now that fall is here, the system's output has dropped. The decrease has been partially offset by milder weather and lower temperatures, and I am still a net energy producer.

It does not appear that the present system could produce enough energy on an annual basis to run my air

The technology just works! For a while, this large solar-electric system sold electricity back to the grid without the utility's permission.

conditioners for the three to four hours per day it will take to keep the temperature inside the house at or below 78°F (26°C) when it hits 95°F+ (35°C+) outside. To overcome this problem, I am installing 40 additional BP275 panels on Wattsun dual-axis trackers.

Since 160 panels will exceed the capacity of the four Trace C40 charge controllers I am using, I will be switching to OutBack MX60 MPPT charge controllers as soon as they are delivered. The combination of the MPPT charge controllers and 40 additional tracked panels should put peak system output between 8.8 and 10 KW. Since GTI-enabled SW5548s are limited to 40 A or 4.8 KW output, I will have to wait to see if the inverters hit their limit. A possible solution, should this occur, would be to replace the SW5548s with four OutBack FX2548s.

Guerrilla Action Works!

Now that the connection of our PV system to the grid has been authorized, my short career as a solar guerrilla has come to an end. But it seemed to put some fire under the bureaucracy, while making the best and most timely use of my investment in photovoltaics.

Guerrilla Solar Defined

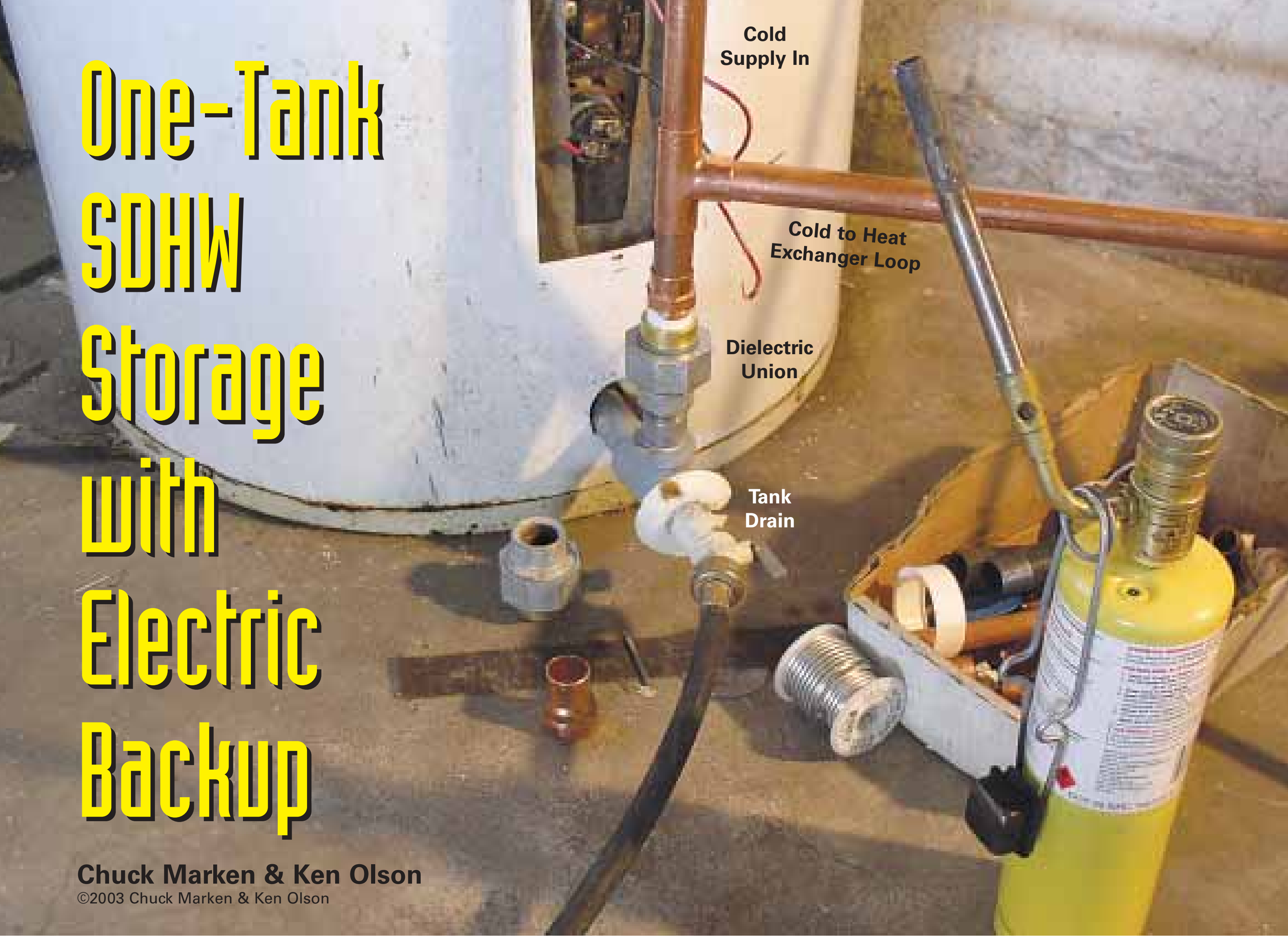
Energy is freely and democratically provided by Nature. This century's monopolization of energy by utilities both public and private threatens the health of our environment. Solar guerrillas believe that clean renewable energy should be welcomed by utilities. But utilities and governments continue to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

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

Send us your GE or GS text and photos. If your story is published, we'll send you a free one-year subscription to HP *and a T-shirt.*

One-Tank SDHW Storage with Electric Backup

Chuck Marken & Ken Olson



Simple modifications to an electric water heater can save space and money in your SDHW system.

One of the first challenges, when installing a solar domestic hot water (SDHW) system, is where to put the solar storage tank. Many homes just don't have the space for an extra tank. For households installing a SDHW system with an external heat exchanger and 100 square feet (9.3 m^2) of collector or less, using a single tank may be the solution. Here is how you can retrofit an oversized electric water heater to accommodate both solar hot water storage and electric backup in one tidy package.

The one-tank strategy may cost you some efficiency if solar storage volume is undersized for the collector area. Insufficient storage volume causes collectors to operate at higher temperatures, which increases heat loss and lowers efficiency. The system may also shut off earlier in the day as the tank reaches its temperature limit. Stay within the generally accepted guidelines in the storage volume table.

An 80 gallon (303 l) electric tank will give you about 55 gallons (208 l) of solar storage and 25 gallons (95 l) of electric backup. That corresponds to approximately two, 3 by 8 foot (2.3 m^2) collectors in the Midwest or a single 3 by 8 in the Southwest. The largest single tank readily available has a 120 gallon (454 l) capacity, which will give you approximately 80 gallons of solar storage and 40 gallons (151 l) of backup. However, a 120 gallon tank will typically cost more than two smaller tanks.

The Retrofit Strategy

When you turn on a hot water tap in your house, hot water comes from the top of the tank and cold water enters the bottom of the tank from the supply line. A standard electric water heater has two 4,500 watt heating elements,

Storage Volume Recommendations

Region	Gallons per ft.^{2} of Collector Area
South & Southwest States	2.00
Southeast & Mountain States	1.50
Midwest & Atlantic States	1.00
Northeast & Northwest States	0.75

one at the bottom and one approximately one-third of the way down from the top. These elements only operate one at a time. The upper heating element has the first priority. It heats the upper third of the tank for quick recovery. Once the upper thermostat is satisfied, the lower element turns on to bring the lower part of the tank up to temperature.

In a SDHW system, it is important to keep solar heated water separate from water heated by your back up system. To pass electrically heated water through your collectors would defeat the function of the solar water heating system. Therefore, the tank is modified to take advantage of natural temperature stratification within the tank. Just as hot air rises and cool air falls, the hottest water, heated by the electric element, remains at the top of the tank. The cooler water being heated by the solar collectors remains low in the tank. You do not want the two to mix. Once you have finished modifying the tank, solar heated water will be stored in the lower two-thirds of the tank. Water in the upper third of the tank will be heated as required by the tank's electric element unless it is hot enough already from the solar system. This strategy won't work with a gas tank because because they are heated from the bottom.

The Procedure

If you are retrofitting an already installed water heater, shut off the water supply, drain the tank, and while you're at it, disconnect the cold water supply from the tank so you can plumb in some detours. *Make sure the power is off* at the circuit breaker before you open the access panel to the upper heating element. Check it with a voltage tester to be sure it is off! Electric distribution panels are not always labeled accurately.

Once inside the tank's access panel, identify the wires that run to the lower heating element from the upper thermostat. Disconnect them at the upper thermostat and cover the ends with wire nuts. Be careful not to disconnect the wrong element from the terminal block in the top opening.

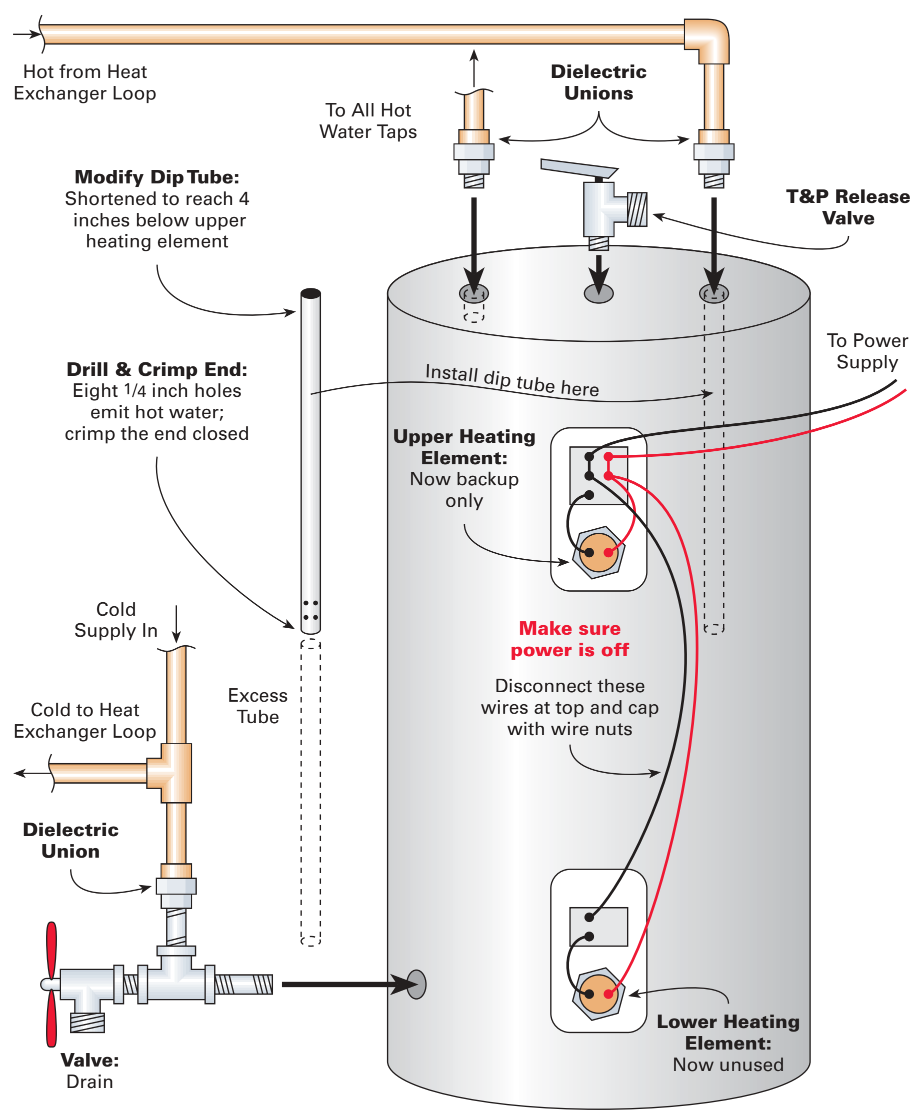
Next, you are going to modify the plumbing so that cold water circulated to the heat exchanger is drawn from the bottom of the tank and returned to just below the upper electric heating element. You want to avoid disturbing the hottest water at the top of the tank. Therefore, you will modify both the drain port at the bottom of the tank and the cold-water dip tube at the top of the tank. See the diagram.

Modifying the Drain Port

The drain port at the bottom of the tank will be modified to handle three functions:

- Cold water inlet
- Cold water supply to the heat exchanger
- Tank drain

Modifying an Electric Water Heater for SDHW



Remove the drain valve from the bottom of the tank and replace it with a threaded, galvanized pipe about 3 inches (7.6 cm) long that has a galvanized tee on the end. The galvanized pipe should be long enough to clear the insulated water jacket that you will install. The other openings of the tee will have the water heater drain (the original or a boiler drain valve) and a dielectric union. Align the drain valve in such a way that you will have free access to attach a hose to the drain valve. Use pipe dope sealant or Teflon tape on all threaded connections.

A dielectric union is used to make connections between copper and steel pipe. The nonconductive seal between the copper and steel sides of the union prevents galvanic corrosion, which would otherwise erode dissimilar metals in contact with one another. On the copper side of the dielectric union, install a copper T-fitting. Solder the modified incoming cold water supply to one tee opening. The other tee opening handles outgoing water pumped to the potable water side of the heat exchanger.

Modifying the Cold Inlet Dip Tube

The cold inlet port of a standard water heater has a plastic dip tube that extends close to the bottom of the tank. That is how the cold water gets to the bottom without disturbing the hot water at the top. You are going to alter the dip tube so it delivers solar heated water just below the upper heating element without destroying the temperature stratification you want to maintain.

At the point where the cold water is usually connected to the tank, stick your finger into the cold port and pull the plastic dip tube out. You may have to grit your teeth or bite your tongue or whatever it is you do when you can barely get something that is in an awkward place. Once you have the dip tube out, mark it for cutting. You can see where the upper heating element is by removing the upper access panel on the side of the water heater. Cut the tube at 4 inches (10 cm) below the heating element.

Drill two 1/4 inch (6 mm) holes all the way through the tube at 2 inches (5 cm) from the lower end of the tube. Then drill two more 1/4 inch holes all the way through the tube at 1 inch (2.5 cm) from the end. Close the bottom of the tube by carefully heating it with a torch and pinching it closed. Pinching the tube closed and drilling the holes reduces turbulence, which helps to keep the warmer water stratified—near the top of the tank. Reinstall the modified dip tube in the cold inlet port of your tank. It will now deliver solar heated water to the tank without disturbing the natural temperature stratification you want to maintain. You're done with the tank modification. Now you can get on with the rest of the installation of solar components.

One Tank vs. Two

Don't kid yourself—a one-tank solar storage/water heater setup is not as efficient as a two-tank system (solar storage and water heater as two separate tanks). The advantages of a two-tank system are:

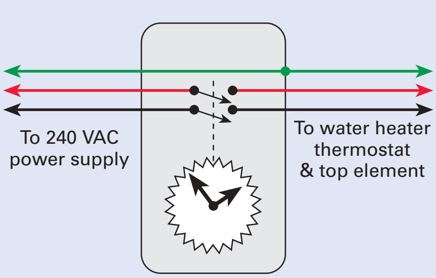
- The initial cost of two 40 gallon (150 l) tanks is less than the cost of a single 80 gallon (300 l) tank.
- A two-tank system will always outperform a one-tank system by 10 to 30 percent.

Wiring Modification to Enhance Efficiency

A few simple wiring modifications can enhance the operation of a one-tank combination solar storage tank/ electric water heater.

Using a Timer

Standard water heater timers with contacts rated for the higher electrical current are readily available in the U.S. Set your timer to be off when the solar heater will normally be heating the water.

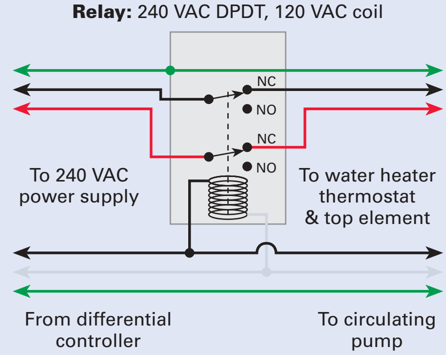


Timer: 240 VAC

Using a Relay

Use a double pole, double throw (DPDT), 240 VAC input/output, relay with a minimum 20 amp rating. The coil terminals of the relay are wired in parallel with the output wiring from the differential control. The wires from the breaker of the water heater are wired to the common terminals of the relay, and the wires to the water heater top element are connected to the normally closed (NC) terminals of the relay. When the solar pump(s) come on, the relay will open the circuit to the water heater element. You may also use a DPST normally open relay, but they are harder to find. There are also other methods to interrupt the 240 volt circuit when the differential control is on.

Relay: 240 VAC DPDT, 120 VAC coil



Caution: 240 volt wiring can be extremely dangerous.If you have any doubt about this wiring, hire or consult with a qualified electrician.

Why use a one-tank system? One reason only—space limitations. If you don't have room for two tanks, the only good solution may be a single, modified tank.

Stretch Your Efficiency

If hot water is not normally used during the day, you can increase the efficiency of a one tank system by switching the electric heating element off at the breaker in the morning. Turn it back on in the evening if you need it. If you are inclined to automate this strategy, you can use a water heater timer, or a relay controlled by the system's differential control (see sidebar).

Combining solar storage and backup in one tank is normally used only in situations without sufficient space for a separate solar storage tank. But if you have a small system and you're short on space, this strategy will allow you to fit a solar hot water system into your life.

Access

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Don't Go There

EV Conversion Mistakes to Avoid

Mike Brown & Shari Prange

You're all fired up about electric cars, and you're ready to make the big leap. You're going to convert one yourself. Already, your mind is bubbling with ideas for it.

Before you make any serious commitments—like spending large amounts of money or taking your car apart—let's look at some of the common mistakes electric vehicle (EV) beginners make, so you can avoid them and build your car like a pro.

Donor Vehicles

Choosing the correct donor vehicle is one of the most important parts of the conversion process. Picking the wrong car could result in an EV that will not meet your requirements for range, passenger and cargo capacity, or suitability for your terrain and climate conditions.

No Heavy Metal. The weight of the donor vehicle has a direct effect on the range of the finished conversion. The more an EV weighs, the more power or torque is required to accelerate it and keep it moving. More motor torque means higher amperage drawn from the battery pack, and reduced range. Using a big vehicle with room for more batteries doesn't work because more batteries equal more weight, which requires higher amperage, etc.

Continuous, high-amp draws can also damage components like the motor and speed controller. For these reasons, we don't advise considering any vehicle with a curb weight of more than 3,000 pounds (1,360 kg) for conversion. Light pickups, such as the Ford Ranger or Chevy S10, can be good candidates for conversion. But stay away from larger 3/4 ton or 1 ton rated pickups, and SUVs and minivans.

Size Matters. So if a heavy, large vehicle is out of the question, is the lightest, smallest car the best choice for a conversion? In a word, maybe. The small size of an Austin Mini, Honda 600, or MG Midget leaves little room for batteries. An on-road conversion EV needs at least a 96 volt battery pack because voltage equals speed. A 96 volt system with enough capacity to give decent range requires sixteen, large, heavy, 6 volt golf cart batteries. The total weight of this battery pack is nearly equal to the total weight of a Mini, and has about the same footprint.

Eight, 12 volt batteries would give us our 96 volt system with much less weight, and would take up much less space. However, because pounds of lead equal miles of range, the 12 volt EV's range would be much less than a 6 volt powered conversion. You must decide if there is enough room in the vehicle for the number and type of batteries needed for the range you want. The lack of space for batteries also eliminates many fiberglass kit cars, even though they are physically bigger than the little cars we have been discussing.

Choosing a donor vehicle is kind of a Goldilocks thing—not too large and not too small, but just right.

Parts Supply

The expense and work of doing the conversion makes owning the EV a long-term commitment. So the vehicle you pick should be a popular make and model. This ensures an available supply of affordable replacement parts like brake and chassis pieces. Some vehicles weren't built and sold in large enough numbers to make it profitable for the aftermarket industry to manufacture and stock parts for them. The dealership is often the only source for these parts.

If there is no longer any dealer presence for your donor car, you may be forced to pay inflated prices to a specialty parts house to keep your conversion on the road. So if Auntie Em has a Fiat that she will give you for your conversion project, try to remember the last time you saw a Fiat dealership.

Shifting Gears

A conversion EV with a series-wound DC motor (the most commonly used type) needs a transmission. Direct drive is only suitable for small, lightweight, built-from-scratch vehicles. Even those cars have to compromise when selecting their drive gear. One gear ratio will give good

Compact cars and light pickups are good vehicle choices. Don't use tiny cars or large trucks or vans

acceleration but a low top speed. If you gear for high speed, it takes a while to get there, and is less efficient at lower speeds. The best way to get speed, acceleration, and efficiency is with the torque and speed multiplication of a transmission.

So our conversion needs a transmission, but which kind—automatic or manual? Unfortunately, most automatic transmissions don't work well for several reasons. The first problem is the lower efficiency inherent in an automatic transmission, which has a bad effect on the range of the EV. The second problem is with the shift points. These will not be set to match the needs of an EV, and can be particularly bad on hills. Finally, an automatic is designed to work with an engine that idles at stops. Electric motors don't—they simply stop. This leads to a delayed throttle response when the stoplight turns green again. For these reasons, automatics are rarely used. They can be made to work, but this isn't really a project for an EV novice.

Clutch or No Clutch?

One of the oldest controversies in the conversion EV world is whether or not a clutch is necessary. A gas or diesel engine needs a clutch to prevent stalling when the vehicle comes to a stop. Disengaging the clutch also makes shifting gears easier.

Some people feel that since the electric motor freewheels when the electricity is shut off, a clutch is not necessary. Another perceived benefit is the weight saved by eliminating the flywheel and clutch assembly.

Like the majority of other EV builders, we believe that a clutch should be used. While it is not necessary when coming to a stop, a clutch makes starting off a much smoother process. Smooth gearshifts in a clutchless EV are possible after much practice, and upshifts are easier than downshifts. The amount of practice and the occasional missed shift might keep some people from driving the conversion on a daily basis, or at all.

The main reason for retaining the clutch is safety. A slow jerky start or a missed shift in traffic could lead to a rear end collision. Missing a downshift while attempting to accelerate out of harm's way could also be dangerous. Being able to disconnect the motor from the rest of the drivetrain in case of a motor or controller failure is a necessity. Most people who are familiar with a manual transmission would want a clutch. Eliminating it doesn't save that much weight. Leave it in.

Components

People get themselves into trouble several ways when choosing their conversion components. Usually, they are either trying to save money or increase performance. If you're a novice with EVs, you're safest to stick toward the well-traveled middle of the road in your conversion. The more you stray and improvise and experiment, the more knowledge you need to do it safely and successfully. The components you choose should be:

- Appropriately rated for use in a car
- Compatible with each other
- Not homebuilt
- Not obsolete or out of production
- Not experimental or preproduction prototypes

Let's look at each of these criteria, and see why they are important.

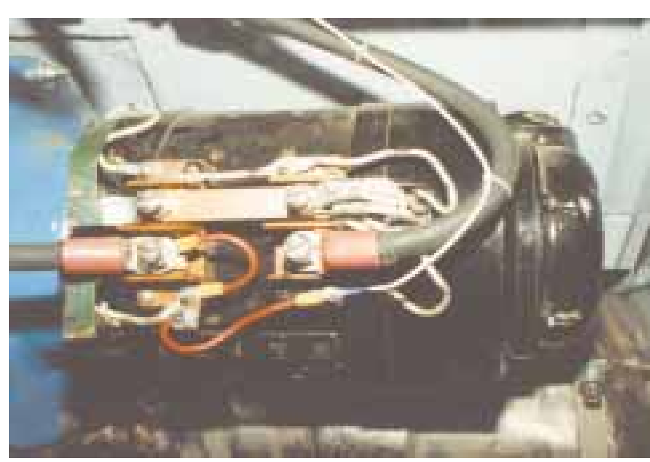
Appropriate Ratings. This is usually a problem when people are bargain hunting. They find a "great deal" on a surplus aircraft starter/generator or a forklift motor. The problem is that these units were designed for an entirely different kind of duty cycle. For example, the aircraft starter/generator is designed to be a starter or a generator, not a traction motor. Its voltage rating is too low for a car because it's keyed to the battery voltage of an aircraft.

The forklift motor *is* designed to move a vehicle, but not very fast. It's designed to use low voltage for low speeds and high current for lots of torque. Unless you want to pull stumps, this motor is not for you.

The same principles apply if you try to use a household AC circuit breaker instead of a DC breaker, or ordinary automotive starting batteries instead of traction batteries. Make sure your car has the right stuff.

Don't try to save bucks with an obsolete control system like this.

Aircraft starters and generators belong in aircraft, not in cars.



Homebrew electronics with inappropriately rated components can be very costly in the end.

Compatibility. This is another issue that comes up due to bargain hunting, especially when people are searching out used parts from multiple sources. You may find a good deal on a motor here, a controller there, and a charger somewhere else. They might all be perfectly valid components to use in a conversion—but not the same conversion.

Different motor types require different controller types. Also, many components only operate within specified voltage ranges. A 72 volt charger is no good with a 96 to 120 volt controller. Shopping used and piecemeal can be done, but you need to be fully informed to make the right choices.

Homebuilt. Some people also think that they can save some money (and have a little fun) building a few of their own components. Usually, this means the speed controller, the charger, or the motor-to-transmission adaptor. Or they may come across a "great deal" on someone else's homebuilt components.

Homebuilt controllers and chargers are often pretty crude compared to manufactured pieces. In the case of a charger, this can damage your batteries and end up costing you more money. More important, they usually lack many fail-safe features and safety redundancies. With the level of voltage and current involved, this is no place to skimp on safety.

The motor-to-transmission adaptor is also more subtle and complex than people realize. This piece is carrying a large amount of torque, at high rpm, from the motor to the transmission. Even small errors in measurements, design, or fabrication can lead to stresses that will cause failures. Any adaptor failure will be a major hassle, and possibly expensive if it damages the motor. This is a precision piece of design and machine work that should be built by someone with experience. Your local machinist buddy may have the tools, and the skills to operate them—but not the knowledge of electric cars to do the design.

Obsolete or Out-of-Production Components. Obsolete components probably will not provide the same level of performance as current models. If your needs are modest, this may not matter much to you, but you also need to beware of the compatibility issues mentioned earlier.

Some out-of-production units, such as Prestolite motors, are still perfectly valid for many vehicles. The main problem here is the lack of factory support. If you have a problem with a component that is out of production, you may not be able to find the pieces or services needed to fix it. If you then have to redesign your car for a different component, this can be an expensive and frustrating experience. While some of these components can be quite good, you need to make an informed decision about whether you feel comfortable with that level of risk.

Experimental or Preproduction Prototypes. The opposite of obsolete and out of production units is experimental or preproduction prototypes. These components may offer improved performance. The problem is that they are not fully developed yet. You will be essentially volunteering your services as a guinea pig for testing and debugging these units.

If there are problems, you may have some vehicle downtime while the inventor tries to identify the cause and repair it. There won't be any quick factory exchange for a working unit. This is another situation where you have to make an informed decision about risk levels. As a novice, you might want to stick to safer territory. Even an experienced EVer shouldn't combine too many risks in one vehicle.

Use batteries like these that are appropriate for powering a vehicle. Don't use starting, marine, or RV batteries.

Batteries

Batteries deserve some attention all by themselves. First, let me repeat what I said above about getting the right components for the job. This is especially true with batteries. Many novices get suckered by "great deals" (there's that phrase again!) involving very cheap or free batteries. They think, "If the batteries don't last very long, who cares? They were cheap."

But cheap batteries can have other problems, some of which are expensive. For one thing, they may not have the energy density to give you the range you need. If your vehicle isn't usable, what good is it to you? And if you want to switch to a more appropriate battery later, you may have to completely redesign and rebuild your rack and box system. Remember—bargain batteries aren't.

The other common battery issues are more a matter of oversight than economics. The first is that people don't always stop to think about battery maintenance. Battery tops need to be easily accessible. If you can't easily reach the batteries to check and refill the water, you won't do it, and the batteries will die very young. This is often an issue with kit cars.

The second issue is battery containment. The battery pack represents a *lot* of weight. In the event of a collision, it will try to keep moving while the chassis is crashing to an abrupt stop. If this battery monster is sitting behind you, a collision could be very deadly.

Take the time to do some serious study on battery containment. You need to secure them against movement in all directions—front-to-rear, side-to-side, and up-and-down in case of rollover. Even a 30 mph (48 kph) collision involves significant G-forces. (For more info on proper battery containment, see *HP78*, *HP79*, and *HP80*.)

Finally, don't run out and buy your batteries first. Buy them last. If they sit in your garage for six months while you build the car, they will be in the way, and will self-discharge and sulfate if they are not being regularly charged.

Hybrids—Don't Try This at Home

Gas or diesel range extenders for EVs have always held a lot of interest. The common scheme involves carrying a small generator in the back of the vehicle. The problem with this idea is that a commercial genset with enough capacity to do the job would end up being nearly as big as the engine you removed. The biggest drawbacks of the "genset in the back" plan are the noise, vibration, and air pollution.

Another hybrid scheme involves leaving the existing drivetrain of a front-wheel drive car in place for long-range trips and adding an electric drive to the rear wheels for around town driving. The major drawback of this plan is fitting two complete drive systems—with a fuel tank for one and a battery pack for the other—in a small car, as well as a clutch system for engaging and disengaging them. We saw it done once and it wasn't pretty.

The Sun, the Wind, & the Rolling Wheel

Solar-electric panels and electric vehicles seem to be a natural match. If an EV with the roof covered by solar-electric panels is sitting in the sun at work for eight hours, the batteries should get back most of the energy it used getting there, right?

Wrong. The output of a solar-electric system the size of a car's roof is so low that all it does is trickle charge the batteries. I was involved with a Voltsrabbit with a PV array on the roof, and after a full day of sitting in the sun, its range was only increased by 5 miles (8 km). A large, stationary PV array at home *can* be used to charge a car, but the panels you can fit on the car itself just aren't enough to be effective.

Another idea that we hear from time to time is putting a wind generator on the roof of the vehicle. The theory goes that the air passing by the car, while you're driving, turns the wind generator, which in turn charges the batteries. The reality is that the air drag produced by the wind generator eats up more energy than it produces.

Hooking an alternator to the nondrive wheels is another idea that would work if it didn't take mechanical energy to produce electrical energy. The only way this would work at all is if there was a clutch between the alternator and the wheels that was engaged only when the power to the motor was turned off. This would be a kind of regenerative braking that would produce more braking action than electricity. Finding a source for the alternator, clutch, and control system might be difficult. It has been done, but the results are not impressive.

Off to a Good Start

You now know how to avoid electric vehicle conversion mistakes that have cost some novices considerable time, money, and disappointment. You're already ahead of the game. With a little homework and realistic expectations, you can build an electric conversion that will be a solid, reliable workhorse for you, as well as carefree and fun to drive.

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Making Connections

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

PV systems often use components that cannot be easily connected to other equipment. Making electrical connections that meet code requirements can be problematic if the installer is not experienced. This column will look at some of the techniques, hardware, and components used to make electrical connections in a PV system.

Twist-On Wire Connectors— Bad Rap from the Past

Many PV installers think (and are being taught) that twist-on wire connectors (aka Wire Nuts) are not suitable for use in the DC circuits of PV systems. This information is derived from the early, improper use of twist-on wire connectors in PV systems. Before about ten years ago, twist-on wire connectors were listed only for use in dry, interior locations. Early PV installations saw them installed in outdoor junction boxes that were sometimes filled with water. Some connectors were installed in exposed outdoor locations to connect module wires together. Both of these types of installations resulted in early failure of the connectors and in a very bad reputation that has persisted until present times.

Twist-on wire connectors, now made by several manufacturers, are listed and fully suitable for use in dry locations, damp locations, wet locations (indoor and outdoor), or direct burial service. As with any other piece of electrical equipment, the installer must read and heed the instructions for each type of connector. These instructions will generally include the following:

- Service location—dry, damp, wet, or underground
- Temperature rating—75°C, 90°C, or 105°C
- Voltage rating—may vary with application (fixture or nonfixture)
- Conductor stripping length
- Combinations and size of conductors that can be inserted
- Insertion of solid or stranded conductor first
- Pretwisting conductors
- Twisting insulation so many turns outside the connector or not
- Other limitations such as once-only use, or not suitable for aluminum conductors

Implied in these instructions and also in the *NEC* , these twist-on wire connectors provide only the electrical connection and the insulation for that connection. They do not provide the splice with the mechanical strength of the

Twist-on wire connectors make for code compliant connections if used properly.

Use specialty connectors in specialty situations.

unspliced conductor. This indicates that these connectors should be installed in pull or junction boxes where the attached conduit provides the strain relief or where cord grips are used on exposed conductors entering the J-box. Direct burial cables are provided with strain relief by the surrounding soil.

Split Bolts—Heavy Duty Connections

Spilt bolts are available in a number of sizes, from the tiny units used to splice #20 (0.5 mm^2) conductors to monster-sized units for 500 kcmil (254 mm^2) and larger cables. They clamp the two conductors firmly together, are tightened with a wrench (to the manufacturer's specified torque), and provide both a mechanical and electrical connection. Usually they are designed and listed to splice only two conductors.

Because they are bare metal (copper, tinned copper, or tinned aluminum), they must be insulated, and the insulation must be equal to the insulation on the unspliced conductor. This means that just a couple of layers of 1,500 volt rated, PVC electrical tape may not be sufficient. In many "warm" PV installations, the tape will soften and the sharp points on the split bolt will penetrate the tape with possibly disastrous results. The insulation applied to a split bolt must equal the insulation of the unspliced conductor, plus you must take into account the sharp points on these devices. Several layers of fabric tape and rubber tape can be used to properly insulate and mechanically protect a split-bolt splice. Rigid and flexible plastic covers are available to provide insulation on these devices. The conductors are bolted together with the split bolt, and the cover snaps on to complete the installation.

Various types of split bolts are available and may be used for copper-to-copper, copper-to-aluminum, or aluminum-to-aluminum connections depending on the design and materials. Each device is marked with the allowable conductor types.

Split bolts provide both mechanical and electrical connection, and come in sizes for most gauges of wire.

Double Lugging— A Common Code Violation

For some reason, PV systems designers and the equipment designers often seem to want to make more electrical connections to a single point than there are terminals for that point. The uninformed PV installer may need to connect two conductors to a single point, and the terminal or lug appears to be large enough to hold the two conductors. In they go, they appear to fit, and the terminal bolt or screw seems to tighten properly. (You did use a torque wrench or torque screwdriver, didn't you?) This is called double lugging, and it is a code violation in many cases. If the terminal is listed for use with only a single conductor, it may not be used with more than one conductor, no matter how many will fit.

Most commercial electrical equipment has a sufficient number of terminals for each wiring point, but even in those installations, it is sometimes necessary to connect multiple conductors to a single point. For example, how can we connect two #2/0 (67 mm^2) conductors in parallel to the single box lug on a Heinemann 250 amp circuit breaker in a Xantrex DC 250 enclosure? Sure, two #2/0 conductors will fit in the box lug on the circuit breaker that is sized to accept up to a single, 250 kcmil (127 mm^2) conductor, but that doesn't make it right or code compliant. Just because Xantrex, in the factory, can remove the box lug, use a longer bolt, and connect a second wire under the box lug on the breaker doesn't mean we can do it in the field. The factory manufactured item has been listed for the second attached wire. How can we meet code and get the job done?

We can do it in several ways. First, if there is room, the two conductors could be connected to an appropriate split bolt where one conductor is terminated and the second conductor continued through the split bolt to the circuit breaker box lug. No ampacity problems should result, because the ampacity of conductors in enclosures is based on the free air ampacity (*NEC* 310.17) and the conductor is bare (uninsulated) for the less than $^1/_2$ inch (13 mm) between the split bolt and the box lug.

A caution is in order with this type of connection. The split bolt, after taping, may contact the front of the enclosure that houses the circuit breaker. If the taped insulation is not adequate, it may wear (or melt) through, causing the conductor to fault to ground through the grounded enclosure. Depending on where the overcurrent device is located with respect to the current sources, this can get pretty exciting as the front panel melts.

NSi Industries, Inc. makes a series of multiple conductor connectors (their Polaris line) that are fully insulated and accept a wide range of conductor sizes. They are ideal for splicing larger conductors together, and the insulation precludes problems even when they touch grounded surfaces. The photo on the next page shows one being used. It parallels two #2/0 conductors, connecting the pair to a 250 amp circuit breaker and also providing a third lead for a feeder to another circuit. A smaller Polaris connector can be used to make the multiple connections required in an inverter bypass switch using a Square D QO load center and

Multiple conductor connectors by NSi Industries provide pre-insulated connection for various sizes of wire.

QO circuit breakers. These connectors are available at many electrical supply houses.

Power Blocks

Power combining and terminal blocks are handy for connecting two or many conductors together. Numerous sizes and configurations are available from various large electrical parts suppliers. Only fully listed products should be used in field installations or in equipment that is not fully listed. Get the specifications before you buy. In the photo below, the two power blocks/terminal strips on the right are only UL "recognized," not fully listed (see sidebar). They are therefore unsuitable for installation in code-compliant PV systems. The terminal block on the left is fully listed. Markings on the device will indicate the listing or recognition category. Beware, many devices purchased through electronics suppliers are neither recognized nor listed.

A UL-listed power block alongside two "recognized" power blocks. The latter are unsuitable as installer supplied components in code compliant RE systems.

UL Recognized

A UL-recognized component (signified by a UR symbol that is backwards) is a component that has been evaluated by UL against a set of specifications established by the *manufacturer.* It has not been fully evaluated against a set of specifications found in a *UL standard.*

The recognized component may be used by an original equipment manufacturer (OEM) inside a product that is further evaluated as an entire product against a UL standard. The evaluation of the entire product results in a listing and the product is said to be UL listed. Other laboratories like ETL and CSA can also list products against UL standards. Only UL has a component recognition program.

Recognized components by themselves can never be assembled in the field during the installation of a code-compliant electrical system. For example, the UL-recognized power blocks shown on the right in the photo below cannot be used by PV installers or homeowners in the assembly of combining boxes. However, Xantrex or Outback may use the same device in the factory assembly of a listed combiner box because that listed box has been fully evaluated for the safe use of that recognized component. Unfortunately, several of the larger PV equipment distributors sell UL-recognized components to the uninformed buyer.

UL listed **UL recognized**

Soldering, a Time-Honored Solution

Contrary to common belief, soldering conductor splices is allowed by the *NEC* (see Section 110.14(B)). But note that the two conductors must have an electrically and mechanically secure connection before the splice is soldered. After the soldering, insulation must be added so that the splice is insulated as well as the unspliced conductor.

Soldering is somewhat of a lost art. High levels of heat are needed, along with the use of noncorrosive electrical-grade solder. High-heat soldering guns and irons should be used rather than the low-heat soldering pencils used to solder electronics circuits. Listed, heavy duty, heat shrink tubing with internal meltable sealant, installed with a heat gun, provides sufficient insulation for most installations.

Good Connections

Connections are one of the weak links in the electrical circuit chain. When made properly, using listed equipment and tools and following the requirements of the splicing device manufacturer and the *NEC*, they should last as long as the conductors themselves.

Use an appropriately sized soldering gun (right) to match your job. A heat gun (left) is used to apply heat shrink tubing to the connection.

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write. Visit the SWTDI Web site for more details on PV and the code, and to see all past *Code Corner* columns. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work was supported by the United States Department of Energy under Contract DE-FC04-00AL66794. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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

NSi Industries, Inc., 9730 Northcross Center Ct., Huntersville, NC 28078 • 800-321-5847 or 704-439-2420 • Fax: 800-841-5566 or 704-439-2424 • nsi@nsipolaris.com • www.nsipolaris.com • Connectors for multiple conductors


the [new] equation:

The Party's Over

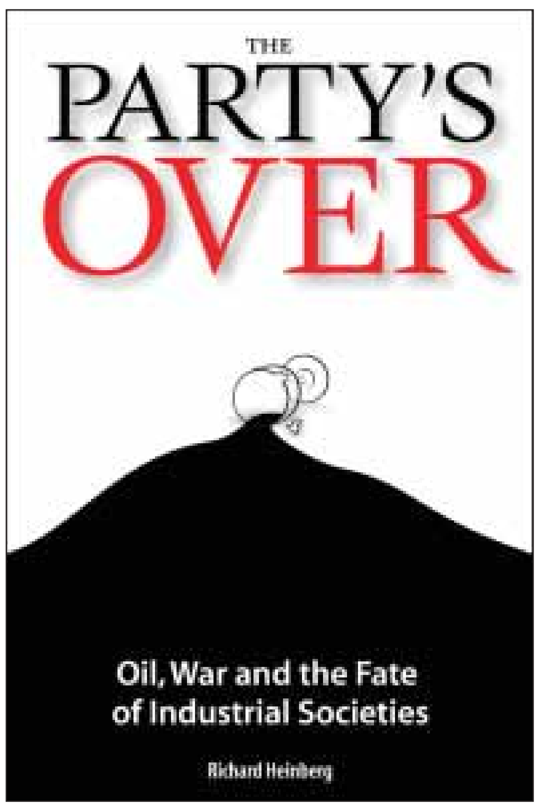
Don Loweburg

Black tape covered over the word "No" on a visitor's protest button, leaving the message "Blood For Oil." Our eyes met and I said, "That's the deal isn't it?" "Yup," he answered.

Even before the invasion of Iraq, I had no illusions about our national purpose. In fact, one of my favorite bumper stickers reads, "It's About Oil—Go Solar." Now, post-invasion and no weapons of mass destruction in sight, it is increasingly difficult not to be cynical. I cannot accept the mass hypnosis passing for "news" telling us that we have freed Iraq.

Our Use of Energy

Nor would Richard Heinberg. His latest book, *The Party's Over—Oil, War and the Fate of Industrial Societies*, places the Iraqi invasion in a different context. Written in 2002, Heinberg, in fact, predicted the invasion. However, this book is not about U.S. military policy per se. Rather, it examines civilizations and their relationship to and use of energy—historically and globally.



The Party's Over is not about fault or blame. Written in a tone that is compassionate, at times whimsical and humorous, Heinberg's approach is scientific. Central to his hypothesis is that modern industrial societies are dependent on extracted hydrocarbons as their primary energy source. These resources are finite and eventually will be depleted. Few would dispute these facts. What many may wish to dispute is the timing of the onset of that depletion and its consequences. Heinberg's message is that the party is over—not sometime in the future, but essentially now!

Petroleum is the most energy dense of the hydrocarbons. Its crucial role in modern transportation has made it the most used and economically most important of the hydrocarbons. So it will be the first to be depleted. The early work done quantifying oil depletion was done by oil geologist M. Hubbert in the 1950s. His estimates have been modified by other oil geologists in the ensuing years, but only slightly. What Hubbert did was to plot actual and projected oil production over time. The plots indicate a peak in global oil production somewhere between 2006 and 2015. Heinberg is clear that this is not undisputed, but argues convincingly for Hubbert, et al.

Some might say, "So what? The peak in petroleum production does not mean the end of the world. We have hundreds of years of coal left. We have renewables, conservation, and efficiency improvements." These facts are discussed in detail in Heinberg's book. However, he argues that they will not alter the fact that once the peak or "rollover" occurs, the global economy will experience a significant discontinuity. He develops two additional precepts that, when coupled with the rollover, support this conclusion.

The first is the concept of "net energy" or energy returned on energy invested. Think of the early oil gushers—very little energy was invested and there was lots in return. Later, as that same field is depleted, the oil must be pumped from greater and greater depths. The net energy return is less. The peak of the global Hubbert curve tells us that the era of easy oil (easy energy) is over. We have high-graded the reserves and can expect what's left to cost more (less net energy). Since historically, oil has had the highest net energy of all sources, switching to any other source (nonrenewable or renewable) will also yield less net energy. Energy returned on energy invested in the future will be less than in the past!

The second fact is the structure of the global economic system and money itself. Money basically represents debt. Borrowing and lending are based on compound interest. Compound interest is mathematically described by an exponential function. In the physical world, an exponential system cannot persist indefinitely. Though money itself is an abstraction, it must be somewhat coupled to the physical world. In this case, the exponential growth of the global economy and population coincides with the exponential increase in available global net energy. Look at the graph of the Hubbert curve and notice, first the leading edge (exponential), and then where we are now on the time line.

Eons on RE

Heinberg structures his book like the Hubbert curve itself. We start slowly at the beginning. In chapter 1, "Energy, Nature and Society," the author builds, as a background, the understanding that all biological systems are energy machines. As an extension, so are populations, communities, families, clans, and nations. He points out that humans have existed on the earth for eons, most of that time living on what we now call renewable energy sources.

Chapter 2, "Party Time," documents the rise in global energy consumption from the Middle Ages to the present. Because of the depletion of European forests due to the demands of metallurgy and population growth, the need for another energy source created the transition to coal, and along with it, the beginning of the modern industrial era. The steam engine, powered by coal, furthered accelerated the growth of modern industry.

The relatively quick transition from coal to oil was not based on depletion, but rather on the increased energy density of oil and its use for lighting and lubrication. Later, early in this century, oil's role in transportation, as fuel for the internal combustion engine, made petroleum the number one global energy source. This chapter also has a section on the development of electricity and the modern distribution grid. Peppered with the big names in industrial history—Rockefeller, Edison, Tesla, Westinghouse, Nobel, J.P. Morgan—this is not the high school tale that so often passes as modern history. Nor are the final sections dealing with warfare, geopolitics, and global economy. Heinberg's tale places cheap energy in the captain's chair as the driver of history, rather than personalities and political concepts.

Cornucopians & Cassandrans

"Lights Out," chapter 3, details the book's central premise that world petroleum production is at a peak and about to start its decline. This premise is disputed by some, and the author devotes considerable text to the opposition. Heinberg characterizes two groups, the Cornucopians, who oppose his premise, and the Cassandrans, who support it.

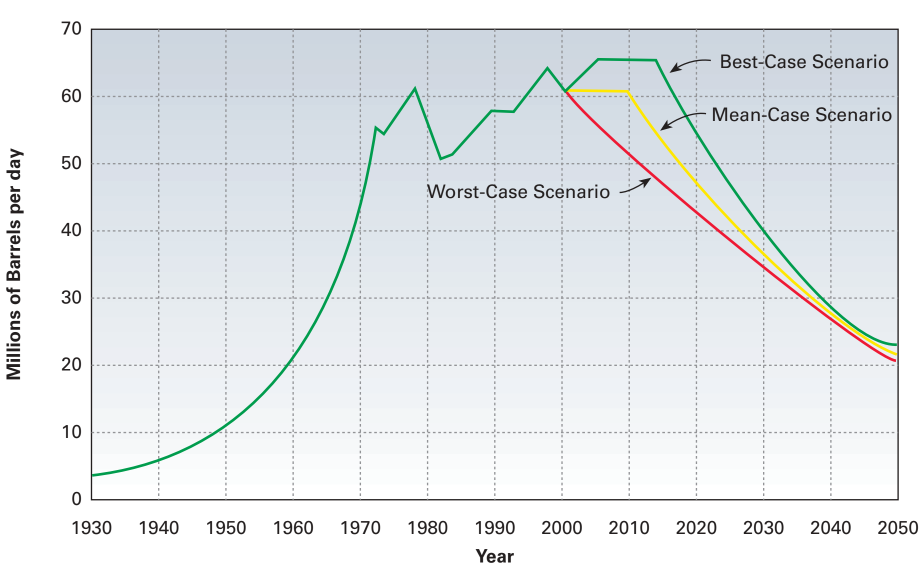
The view of the Cornucopians (many of whom are economists) might be summarized as the belief that human enterprise, imagination, and free markets can create the resources necessary to solve any problem. To paraphrase, "Humans don't use energy, they create it." The Cassandrans, primarily physical scientists (many ex-oil company geologists), argue that physical resources are constrained and ultimately put limits on human activities and numbers. The degree of disparity between these two camps is well stated by Mr. Hubbert when he refers to "two universal, overlapping, and incompatible intellectual systems."

The rest of the book deals with the downside of the Hubbert curve. Chapter 4 examines nonpetroleum energy sources. The analysis of other energy sources uses "net energy" as the definitive tool. Renewables are presented as significant and desirable energy resources. However, because they have less net energy than historical petroleum resources, they will not be able to avert future energy shortages.

Efficiency and conservation also yield huge benefits, but will not avert a global drop in available energy. Shifting to fuel cells running on hydrogen will not be a solution. Though beneficial with respect to pollution, Heinberg points out that hydrogen must be manufactured and hence is an energy sink (net energy less than one) rather than a source of energy.

What are some of the political and economic scenarios possible as the global economy moves towards less net energy? These are the questions posed in chapter 5, "A Banquet of Consequences." Regardless of the form of government or political philosophy, Heinberg asserts that no nation or group is equipped to deal with coming events.

World Oil Production: 1930–2050



Source: C.J. Campbell / adapted from *The Party's Over*

A Book Worth Reading

Having read this much of the review, you must now read the book for the finale. I will not give away the end of this tale, though I can say that many readers of *Home Power* magazine may recognize themselves in the last chapter, "Managing the Collapse."

A book is worth reading if you recognize yourself in the cast of characters, and experience a shift in perception. On both counts, *The Party's Over* makes the cut. In the introduction, the author identifies four "voices" addressing questions about the future of energy. I found myself among the environmentalists. I have long held that we couldn't use up petroleum fast enough. I feared that undeclared reserves would extend the era of oil, possibly indefinitely, with increasingly dire climatic changes and pollution. I had believed that oil could be better used to manufacture carbon fiber bodies for fuel cell powered "hypercars," and we all could be happy and prosperous zipping around in a Lovinsesque future. Now I see that we missed our turn-off thirty years ago and the sign for the last off ramp ahead reads "hard times," or if we continue on down the main road, "dismal failure." There is no white knight. Have a nice day!

Access

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The Party's Over: Oil, War and the Fate of Industrial Societies, Richard Heinberg, paperback, 288 pages, ISBN: 0-86571-482-7 • US$17.95 from New Society Publishers, PO Box 189, Gabriola Island, BC V0R 1X0, Canada • 800-567-6772 or 250-247-9737 • Fax: 250-247-7471 • info@newsociety.com • www.newsociety.com

My First Corporate Junket

Michael Welch

Since 1978, I have been involved with Redwood Alliance and its efforts to dismantle the defunct Humboldt Bay Nuclear Power Plant near Eureka, California. A few years back, the utility established a citizen advisory board (CAB) to encourage input from the community, and I was chosen to participate.

As a member of the CAB, I was invited on a May tour of the Yucca Mountain nuclear waste repository experimental facilities in Nevada. The trip was ostensibly to demonstrate to us that it needed to be opened, and that it would be a safe place to receive and then store nuclear waste for hundreds of thousands of years. But based on what I knew already and things that I was shown during the tour, I really doubt if humans are capable of pulling something like this off.

Human Technological Error

The PG&E corporate plane that flew us to Nevada was forced to land with only one of two engines in Las Vegas. This was pretty scary, and it made me wonder about the ability of the nuclear industry to evaluate and run such a high-tech facility as this repository, especially without any practical experience to back it up.

What really gets me is how much faith these folks put into their belief that there will always be an engineering or technical fix for any problem that might pop up. For example, early in the Yucca Mountain facility's development, it was discovered that water, earthquakes, and heat could harm the long-term security of the facility. The possible end result would be leakage into the outside environment—the thing that no repository should do. So instead of biting the bullet and admitting that it wouldn't work, they set about hiring engineers and scientists to prove that they could make it work.

We were promised a facility that would last forever. That has been changed—now it is supposed to last 10,000 years. Did they forget that the half-life of plutonium is 240,000 years, which means we can count on lots of radioactivity for more than a million years?

Junket or Tour?

Once we arrived at the Luxor Hotel, we had a brief CAB meeting to give us the scoop on our tour the next day. Then we were wined and dined by PG&E, and went up the strip to the New York New York hotel and casino for rides on the biggest roller coaster I have ever seen. Truly, this was a junket, and if I ever find out that California's ratepayers picked up the tab for this trip instead of corporate shareholders, I am going to feel guilty.

The forces of nature created the beauty of Nevada's Yucca Mountain, and the forces of nature make it a bad place to store nuclear waste.

The next morning had us on a bus at 6 AM. Our first stop was the DOE's Yucca Mountain Visitor Center, where we were told what to expect on the tour, signed in for our badges, and given the appropriate security clearances. I can hardly believe they let me in, after years of radical anti-nuclear activism and several arrests for civil disobedience at nuclear facilities. We also took on board a couple of tour guides for the bus trip; smiling faces would give us the nuclear industry's version of the facts at Yucca Mountain.

Two and a half hours north of Las Vegas, we arrived at the Nevada Test Site, within which lies the Yucca Mountain repository. The tour guides started in on their rote spiel. We were informed that there was nothing, absolutely nothing, wrong with using Yucca Mountain as our nation's long-term nuclear waste repository. In spite of all its shortcomings, folks in the industry still call this place "perfect."

Nevada Site of Testing Really Bad Ideas

At the test site entrance, heavily armed guards made sure that only the right people (like me?) came in. That is not just because of Yucca Mountain, but because the Nevada Test Site holds many of our nation's nuclear secrets. Now the guards keep out terrorists. Thirty years ago they kept out communists. Fifty years ago they kept out anarchists. I wonder which "-ists" will be next?

I prefer to call this place the Nevada Site of Testing Really Bad Ideas. The best known of these bad ideas was the aboveground testing of nuclear weapons. Las Vegas residents became used to hearing and seeing the nuke detonations with their mushroom clouds, even though they were behind mountains and 100 miles away.

The most impressive of these bad ideas was what appeared at first to be a nearby, common radio tower. But distances are deceiving in the desert, and it turned out to be quite far away and 1,527 feet (465 m) tall—55 feet (17 m) taller than New York City's Empire State Building. This thing was used in something called the Bare Reactor Experiment—Nevada (BREN) to approximate the radiation effects experienced by the victims of the Hiroshima and Nagasaki nuclear bombings at the end of World War II. The idea was to haul an open (no shielding or containment), operating nuclear reactor up this tower, which simulated the altitude of the explosions over Japan. Then they took radiation measurements at ground level to see how much radiation we laid on the citizens of Nagasaki and Hiroshima.

Soon after leaving the BREN tower at our backs, the bus came upon the next really bad idea: facilities designed to build and test nuclear rocket propulsion systems. It turns out that the U.S. Army and Air Force were quite jealous of the Navy's nuclear powered submarines and ships. While the nuclear Navy used reactors in much the same way as civilian reactors, complete with containment and precautions against environmental exposure, the Army and Air Force wanted to use a sustained nuclear reaction as a propellant for airplane flight. The idea and experimentation moved forward for thirteen years, until somebody finally noticed (Duh!) that these airplanes would spew high-level radioactivity wherever they flew.

Up the road a piece was a horizontal test stand for those nuclear rockets, the site of this area's next really bad idea. Here, but quite a while ago, scientists purposely scattered plutonium to study its effects. Now, this area is used by other scientists to figure out ways of extracting plutonium from soil. Gee, nuclear scientists are strange folks.

Of course, billions of dollars were spent on these experiments, so maybe they were looking for nothing more than getting on the government dole. I guess everybody needs a job. The really weird thing is that all these things were presented to us with a sense of pride, as if they were a bunch of good ideas, instead of harmful, destructive playthings of the powerful.

The business end of the boring machine breaks out of solid rock at the South Portal.

The Tunnel

Our main destination, of course, was Yucca Mountain. The Exploratory Studies area is pretty much a huge, horseshoe-shaped hole that was bored into the side of the mountain as if by a gigantic, mutant gopher. The hole starts at what is known as the North Portal, going straight in and downward for a bit more than a mile. It then heads due south for almost 2 miles as the Main Tunnel, which is about 980 feet (300 m) below the surface at the peak of the mountain ridge. Finally, the bore turns and goes another 0.8 miles to exit at the South Portal, on the same side of the mountain as the entrance. It's a pretty big hole, complete with huge piles of tailings at one end.

At the South Portal stands the most interesting human-made thing on Yucca Mountain, the boring machine. Nicknamed the Yucca Mucker, this thing has a rotating head on the front that bores a round, 25 foot (7.6 m) hole through rock. As it slowly moved through the mountain, it also built the tunnel supports to prevent collapse, installed the rail tracks that it moves on, and built a conveyor system to remove the tailings out the North Portal behind it. Similar machines bore train and highway tunnels through mountains, and bored the tubes for the subway under the English Channel. For most folks, the boring machine is the highlight of the tour since it is so monumental, and was obviously a technological success.

This exploratory tunnel was not bored to receive the nuclear waste. It was intended to be used to research the

A small-scale model of a nuclear waste storage cask—sure, it looks high tech, but can we trust it for millions of years?

mountain, and to be the entry point for the smaller storage tunnels yet to be bored. Once the project receives all final approvals and more funding, the storage tunnels will be drilled. Nuclear waste will begin arriving from all over the nation. It will be transferred to permanent casks in handling buildings, and moved by robots into the tunnels, where it will supposedly rest undisturbed.

Our group got off the bus at the North Portal and went into the only large building on the site, where we were given instructions for being inside the tunnel, and issued hard hats and safety goggles. We were then led a few hundred feet into the North Portal. There we went up a side tunnel that had been hewed out of the rock without the benefit of the boring machine. At the end of this grotto were chairs, and we were given a lecture on the science surrounding the facility and its exploration. We heard about how geologically stable the place really was, in spite of finding both unexpected corrosive water and the potential for seismic activity.

The presenter had an answer for everything. The storage tunnels would be reinforced with engineered barriers to maintain the integrity of the tunnel shape and keep out intruding water. After nuclear waste is moved in robotically, it will be constantly monitored until the facility is closed and sealed. That could happen any time Congress wants, but the design allows for up to 300 years before sealing. At some point after each of the storage tunnels is full and before sealing, robots will install extra shields over the waste containers, as a further engineered effort to keep them dry.

It's Not a Problem

Every problem has a solution, or it is declared to not be a problem. In the minds of these folks, there are no problems that cannot be dealt with by engineers. Faith in human ability to control every circumstance is rampant. Nothing shakes this faith, not even a failing airplane engine—after all, we landed safely on the other engine.

On the bus trip to the Test Site and at the Visitor Center, we had received other "answers" for the transportation issues that so many activists and communities on the haul routes to Yucca Mountain are concerned about—don't worry, everything is safe. Shipping accidents will not happen, but if they do, the casks' integrity cannot be breached. But if they are breached, the communities are being trained to deal with the spills. But if they can't deal with them, don't worry because the waste isn't really as bad as folks think anyway…

Back in the tunnel's side grotto, we heard about heat experiments. Much of the high level waste is very hot. Scientists had no idea of how the mountain would react to this temperature, so they drilled a tunnel into the proposed waste storage area for testing. They drilled hundreds of holes from above to surround the experiment area, and installed moisture, heat, and seismic sensors.

They put huge electric heaters in the tunnel, powered by 14 KV lines, and sealed it tight. Then they brought the tunnel up to 400°F (204°C) and kept it there for about four years. They felt that would be long enough to test what the long-term effects of all that heat would be on the surrounding rock and the moisture that exists in the rock. Yucca Mountain scientists found that the results were similar to what they had modeled by computer before the experiment. In their minds, the four-year test verifies the computer modeling, even on the long term of 10,000 years, which is the Congressional-mandated design lifetime for the project.

A Very Bad Idea

Even after the folks at PG&E and Yucca Mountain gave it everything they had, I still see no good reason to justify storing all our nation's high level nuclear waste there. And when you add in the risks of thousands of cross-country shipments of the waste, the prospect becomes even less acceptable. There is nothing a junket of wining and dining can do to change the fact that the Yucca Mountain repository is merely another very bad idea.

Access

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Magnetism

Ian Woofenden

Derivation: From Greek magnes (lithos) *literally "stone of Magnesia," an ancient city in Asia Minor where lodestones were found.*

Magnetism is critical if you're trying to make a generator or motor, design electronic devices, or get things to stick on your refrigerator. Magnets do a surprising amount of work in our technological society. They're also a lot of fun.

Where does magnetism come from? All magnetism comes from the movement of charges. When charges flow through a wire, a magnetic field is generated around the wire.

You've tried holding two magnets together north pole to north pole, right? They try to push each other away. Hold the south pole next to the north pole and they snap together. These repelling and attracting forces of magnetic fields are key to motor and generator function. A motor is essentially one set of magnets rotating inside or beside another. Depending on the type of motor, these can be "permanent magnets," materials that hold their magnetism, or "electromagnets," coils of wire that generate a magnetic field when there is a current through them.

In a motor, electrons flow through the electromagnetic coils, causing a magnetic force. The force is enhanced by providing steel pathways for the magnetism, and manipulated by the structure of the motor to attract or repel the magnets in the other set, causing a rotating motion that drives the motor. So an electric current is used to create a spinning motor shaft. Electricity in; mechanical energy out.

With a generator, the exact opposite happens. We drive the spinning shaft with an engine, a hydro runner, blades in the wind, pedals, or some other source of rotating motion. The motion spins the magnets past the coils, causing an electrical current in the wires of the coils. Mechanical energy in; electricity out. Without magnetism, we'd have to dream up a whole new way to design motors and generators.

The earth is like a big magnet. Scientists theorize that the motion of liquid metal in the earth's molten core is the source of the earth's magnetic field. Just like the currents in wires, the currents in the earth's core—billions of amperes—have a magnetic field.

People have been aware of some effects of the earth's magnetic field for hundreds of years. Early transoceanic explorers used bits of metal suspended or floating to guide their ships. These ferromagnetic ("ferrous" means "iron") compass needles aligned themselves with the earth's magnetic field, pointing north/south. Nowadays we know that the earth's magnetic pole is not exactly aligned with the earth's rotational pole. So we have what is called "magnetic declination," the difference between "true north" and "magnetic north."

Magnets and magnetism are used in a surprising variety of tools and toys that we use every day. Motors, sensors, medical diagnostic equipment, relays, latches, audio and videotape—the list goes on and on. Once you're aware of how they are used, you notice every day how dependent we are on magnets.

Magnets are also fascinating and fun. I recently hosted Hugh Piggott's Homebuilt Wind Generators workshop here in the Pacific Northwest for SEI. We spent a week building wind generators from scratch, including winding the coils for the alternator stators and casting the magnet rotors. We got to see firsthand the effects of magnetism as we pinched our fingers between neodymium (rare earth) magnets and learned why not to use steel tools around them. At the end of the workshop, we saw their more practical effects, generating electricity from the wind generators we'd built.

Close-up of students casting magnets in resin during SEI's Homebuilt Wind Generators workshop.

There is a magnet below this dish full of ferrofluid—what we're "seeing" is the magnet's field.

One highlight of the week was an evening presentation by Dan Bartmann and Dan Fink from Wondermagnet.com (authors of an article in *HP88*.) The Dans showed us lots of neat tricks with magnets. Try dropping a neodymium magnet down a heavy-wall copper tube. The copper acts as an electric brake, slowing the fall of the magnet. We also got to see "ferrofluid" in action. This is an oily substance with magnetic material ground into it. It lets you "see" a magnetic field in three dimensions. We poured some in a Petri dish and put a magnet underneath the dish. The fluid is attracted to the magnet, and shows the lines of magnetic force with little spikes—it's wild!

I'm drawn to the idea of ending my column with a magnet joke, but that would probably just repel you. The discovery and use of magnetism is one of the unsung heroes of human history. We acknowledge the contributions of fire, the wheel, and the computer chip, among others. But we too often overlook the contribution magnetism makes. Electricity, fun tricks, and spelling words on the fridge—what more can we ask?

Access

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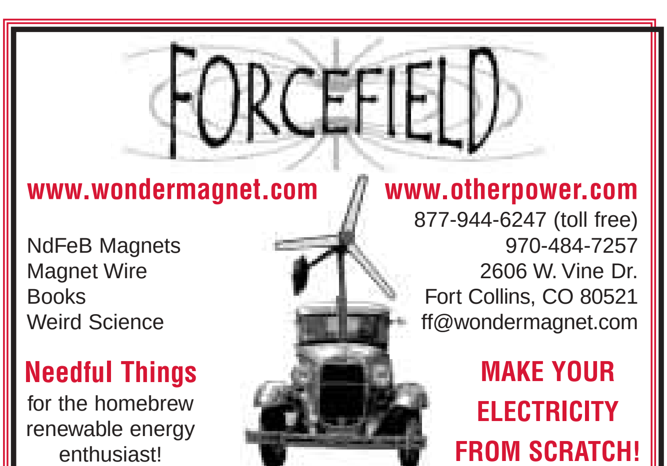
ForceField, 614 South Mason St., Fort Collins, CO 80524 • 877-944-6247 or 970-484-7257 • Fax: 970-493-7243 • ff@wondermagnet.com • www.wondermagnet.com • Lots of neodymium magnets and other fun stuff

Driving Force: The Natural Magic of Magnets, James D. Livingston, ISBN 0-674-21645-8, paper, 311 pages, 1996. US$16.95 from Harvard University Press, 79 Garden St., Cambridge, MA 02138 • 800-405-1619 or 401-531-2800 • Fax: 800-406-9145 or 401-531-2801 • Contact_HUP@harvard.edu • www.hup.harvard.edu • Good overview of magnetism and magnets



Salmon River Rescue

Part 1

Kathleen Jarschke-Schultze

Sometimes the events of your life take you for a wild ride. I've found that when bad things happen, you need to keep your sense of humor and wait to see the next chapter of the mystery of life. Sometimes, when the worst happens, it turns out for the best.

Betchawannaland

After the fires of 1987 on the Salmon River, Bob-O was working with his partner, Pat, falling trees on a fire salvage job. It was way to hell and gone up McNeil Creek. The route was all dirt roads and took about an hour to get there. The area was locally known as "Betchawannaland" because of the distance, ruggedness of the road, and desolation. Once you were there, the next sure bet was, "Betcha wanna come home."

When on a falling job, Bob-O would get up at 4:00 in the morning. I would feed him a big breakfast. It was hard for him to eat that early in the morning, but later on the job, he would need the fuel. As he ate, I would pack his lunch and fill his gallon canteen. I always put a little grated ginger root into his water. When he stopped to drink, he would pound down a lot of water at once and the ginger root made it easier on his stomach. Since Bob-O's work was so hard, every small comfort helped.

Falling Out

After Bob-O left, I would go back to bed until I needed to get up and send Allen off to meet the school bus. On this particular day, after Allen had left, I put the finishing touches on a small dollhouse I had made for a young friend of ours who had broken a femur bone. She had been on a packing trip in the Marble Mountains with her family when a mule rolled on her. They packed her out in the night, and she was still in a body cast at home.

It was probably about noon when I left Starveout to go downriver to visit my friend. Her family lived over a small footbridge on the other side of the Salmon. They did not have a CB radio in their cabin, so for a couple of hours I was unreachable.

Tuning In

When I got back to my rig and turned on the radio, there was a lot of chatter going on for the road channel. I was able to make out that a rescue was in progress. Then, to my shock and dismay, I figured out that Bob-O was the person being rescued. I interrupted the talk on the radio. "Hey!" I said, "This is Kathleen. What's going on?"

A recent photo of Bob-O using his radio under less stressful circumstances.

Betty Ann called back, "Where have you been? We've been trying to reach you." She filled me in, and we made plans to meet at the old school where the rescue equipment was stored. I drove on downriver to Forks of Salmon.

Falling Over

Although I got bits and pieces of the story then, here is what happened. It was near the end of the workday for Bob-O. He was falling his last tree. He had an escape route planned. He cut the tree, it started falling, and he ran out his escape route. The tree twisted and the top part fell onto other standing trees, which acted as a fulcrum and lifted up the butt end. The butt end of the tree then fell on top of the stump, and using it as a guide, slid back about 20 feet.

Unfortunately, it slid up Bob-O's escape route and caught him as he was running away. The tree butt hit him right at his boot line. It broke the tibia and fibula—both of the bones in his lower right leg—and poked them through the skin.

Bob-O told me later that he remembered being hit and being pushed to the ground. He lifted up on his elbows and looked around. "Boy, that was close," he thought. Looking down, he could see his lower leg and foot sitting at a right angle to his leg. "That's gonna hurt," was his next thought. He reached for the whistle all fallers wear around their necks. He waited a few minutes until he heard his falling partner Pat shut down his saw, and blew as hard as he could.

Triage

Pat came running. He uttered some choice words. Bob-O sent him to his pack for a handheld two-meter radio. This hooked him into our phone/radio system. He phoned in his own rescue. Bob-O and I were in the middle of taking an EMT course and beginning a fledgling river rescue group. He was able to describe his own injury with medical accuracy and set the wheels in motion for his own rescue.

He tried to call me first, but I wasn't home. Next he called Betty Ann. She wasn't at home, but he reached her at Forks School where she was the secretary. She called Nixie, the only EMT on the river at that time and got her going up to Bob-O with her kit. A general call for help on the CB got several different people headed up to Betchawannaland.

After one attempt to move, Bob-O realized that if he didn't move, it didn't hurt. So he stayed still. He knew it would be a long time before anyone could get there. He had Pat bring some leftover lunch from his pack and he lay there and ate it. There wasn't much to be done with his leg except cover it to keep any dirt from falling on it. Pat cannot stand the sight of blood, and luckily it wasn't bleeding much at all. After Bob-O assured Pat that he was going to be okay, Pat climbed the mountain up to the road where the crummy was parked to wait and guide the rescuers to Bob-O.

The Rescue

Bob-O was located about a quarter-mile down a very steep side hill. The felled trees and brush provided added obstacles. In a little under an hour the cavalry began arriving. Some people had been called on; others came because they weren't too far away and heard the call on the CB.

They all gathered at the crummy at about the same time. Pat led them down the side hill to Bob-O. Nixie, being the only EMT, was in charge. She gingerly straightened out Bob-O's leg. She covered the compound fracture with a sterile bandage and splinted the leg. That made Bob-O's leg start hurting and bleeding.

A Forest Service guy had responded and had a backboard with him. After Nixie was done with her first aid, they loaded Bob-O onto the backboard and six men began the long climb up the mountain. Bob-O is not a little guy. They had to stop about every ten steps and rest. Pat, who couldn't look at Bob-O's bleeding leg, would turn his back on him during the rests, but would turn back and heft the backboard up the torturous slope when the rest break was over. Nixie kept track of Bob-O's vital signs. It took a half-hour or more to carry Bob-O to the crummy.

The Plan

Meanwhile Betty Ann and I had gotten egg crate foam mattresses from the equipment room and, by putting the back seat down in my Volvo station wagon, made a transport bed. The plan was that I would wait for Bob-O to be brought down to the pavement where McNeil Creek Road and the Salmon River Road meet. He would be transferred to my rig, and I would drive him to the hospital three hours away.

Sometimes having a plan doesn't mean that things will go as planned. What I mean to say is, this plan didn't. As Betty Ann and I drove to the McNeil Creek turn-off, a helicopter, which had been working on another salvage sale, flew overhead towards Bob-O. All our plans were about to change. Find out what happened next in Part 2 in *HP97.*

Access

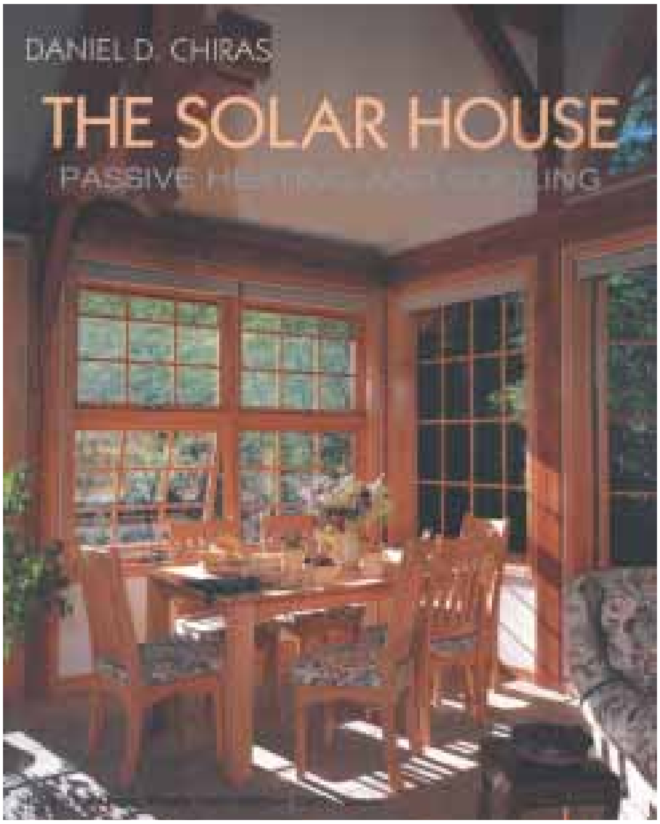
Kathleen Jarschke-Schultze is turning 50 and is okay with that fact at her home in Northernmost California. c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 • kathleen.jarschke-schultze@homepower.com

The Solar House:

Passive Heating and Cooling

By Daniel D. Chiras
Reviewed by Rachel Ware & Johnny Weiss

How do you design and build the ideal solar home? Clearly, your site selection, building design, materials choice, and lifestyle must all figure into the process. The choice to integrate passive solar strategies into a home design costs relatively little. Your heating and cooling requirements can be drastically reduced, saving money and increasing comfort.



Incorporating passive solar features is better than a "free lunch." It's more like the "lunch you're paid to eat!" —Johnny Weiss

The Solar House: Passive Heating and Cooling, by Daniel D. Chiras brings passive solar design out of the experimental 1970s and into modern residential design. It is comprehensive and up-to-date. No longer are we building "solar cookers" and roasting the occupants in discomfort. We are now able to integrate south-facing windows into a much larger system of passive solar techniques. Chiras calls it "natural conditioning."

The reasons for naturally conditioning your home with sunshine include comfort, economics, and sustainability. Chiras makes a strong case for passive solar design for each of these reasons. For the experienced building professional or the owner-builder, Chiras provides the design tools and building techniques to avoid common solar mistakes.

He wisely avoids prescribing one correct solar design. There are, however, certain strategies that every builder should pay close attention to, such as reducing air leakage. Dramatically reducing air drafts is as fundamental to good passive solar design as energy efficiency is to sensible PV system design. Chiras stresses that a quality building envelope, tight and super-insulated, is critical. After reading this 375 page resource, designers and builders will be familiar with many of the different materials and technical solutions readily available to consumers.

Have you ever wondered how to optimize passive solar heating features so that they also promote passive solar cooling? Chiras' holistic approach does not separate these two comfort requirements. Heating and cooling needs are not competitive. Designing to insulate from the cold also reduces unwanted heat gain. The author says, "With foresight, careful planning, knowledge, and common sense, we can achieve comfort in virtually any climate, naturally, using sunlight, shading, earth sheltering, insulation, and natural daylight."

Chiras also recognizes the importance of how heat moves and how thermal mass contributes to occupant comfort. However, a more in-depth discussion of heat transfer (conduction, convection, radiation, and evaporation) would be helpful. Likewise, greater discussion of the relationship between thermal mass and mean radiant temperature would further help readers to appreciate the subtleties of building science and human comfort.

While we agree with the principles and fundamentals of Chiras' solar site analysis section, we occasionally use different terminology. For example, we refer to azimuth angles from true south, while he discusses bearing angles in reference to true north. This may confuse people. On the other hand, we feel the frank discussion of "lessons learned" from historic passive solar building is especially valuable.

Chiras lives in a successful solar home he designed and built, and is a wealth of firsthand information. We hope his enthusiasm will inspire you to create the sustainable nest of your dreams. This is the fundamental up-to-date solar house book we've wanted to use as SEI's Solar Home Design workshop textbook for more than a decade.

Access

Solar House: Passive Heating and Cooling, by Daniel K. Chiras, 2002, paperback, 288 pages, ISBN 1-931498-12-1, US$29.95 from Chelsea Green Publishing Company, PO Box 428, White River Junction, VT 05001 • 800-639-4099 or 802-295-6300 • Fax: 802-295-6444 • info@chelseagreen.com • www.chelseagreen.com

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Green Empowerment finances microhydro & other RE projects in Nicaragua, the Philippines, & Borneo. Volunteers needed • www.greenempowerment.org

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

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

CANADA

Aug. 18–20, '03; SESCI 2003: 28th Annual Conf. of the Solar Energy Society of Canada; Queen's University, Kingston, ON. Info: SESCI 2003, Solar Calorimetry Lab, McLaughlin Hall, Queen's Univ., Kingston, ON, K7L 3N6 • 613-533-2591 • sesci03@me.queensu.ca • www.solarenergysociety.ca/sesci03

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

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

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. Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

ENGLAND

Sep.22–23, '03; RE Finance Forum, Marriott Grosvenor Hotel, London. Info: www.euromoneyenergy.com

GERMANY

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

NICARAGUA

Aug. 5–15, '03 (again Jan. 6–16, '04); Solar/Cultural Course. Managua. Lectures, field experience, & eco-tourism. Taught in English by Richard Komp & Susan Kinne. Info: Barbara Atkinson • 215-942-0184 • lightstream@igc.org • www.grupofenix-solar.org

SINGAPORE

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

U.S.A.

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

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

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

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

Energy Efficiency & RE Clearinghouse (EREC): Insulation Basics (FS142), Financing an Energy Efficient or RE Home (FS104), PV: Basic Design Principles & Components (FS231), Cooling Your Home Naturally (FS186), & Small Wind Energy Systems for the Homeowner (FS135). EREC, PO Box 3048, Merrifield, VA 22116 • 800-363-3732 • TTY: 800-273-2957 • energyinfo@delphi.com • www.eren.doe.gov

Ask an Energy Expert: online questions to specialists. Energy Efficiency & RE Network (EREN) • 800-363-3732 • www.eren.doe.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

Aug. 8–10, '03; SW RE Fair. Flagstaff, AZ. Exhibitors, workshops, & speakers on solar, wind, biomass, green building, & alternative vehicles. Greater Flagstaff Economic Council • 928-526-9317 or 800-925-0583 • swref@gfec.org • www.gfec.org/swref

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

Aug. 2–3, '03; So. CA RE Expo; LA County Fairgrounds, Pomona, CA. Solar, wind, hydro, fuel cells, hybrid autos, green building, solar cooking, solar pumping, alternative building materials, solar hot water, energy efficiency, EVs, straw bale construction, biodiesel, net metering, becoming a solar dealer, & more. Solatron, 888-647-6527 • www.socalenergyexpo.com

PV and Microhydro Design & Installation workshop; Indian Canyon, near Hollister. Info: Vivian Gratton, 831-459-8942 • vgratton@cruzio.com • www.indiancanyon.org • www.solarenergy.org.

Aug. 23–24, '03; Solfest RE & Sustainability Fair; Exhibits, workshops, music, speakers; Hopland, CA. Info: 707-744-2017 • www.solfest.org

Oct. 1–3, '03; Sustainable Energy Expo & Conf.; LA Convention Center. Business conf. & trade show. John Mikstay • 646-432-1102 • www.sustainableexpo.com

Oct. 4, '03; National Tour of Solar Homes participant, Arcata, CA. Info: Redwood Alliance, PO Box 293, Arcata, CA 95518 • 707-822-7884 • info@redwoodalliance.org • www.redwoodalliance.org

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

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

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

Solar Living Institute workshops. Advanced PV Design & Installation for Off-grid Systems, Bio-intensive Food Production, Composting Toilets & Greywater Systems, EVs, Grid-tied Solar Electric Systems & Money Saving Rebates, Hybrid Adobe, Hydrogen–the Emerging Fuel Source, Intro to Permaculture, Intro to PV, Natural Building Workshop, Solar Installer Training, Straw Bale Construction, & The Green Householder. Info: Solar Living Institute, PO Box 836, Hopland, CA 95449 • 707-744-2017 • sli@solarliving.org • www.solarliving.org

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

Aug. 4–8, '03; RE Youth Camp; Paonia, CO. Ages 15–19. See below for SEI contact info.

Sep. 13–14, '03; Rocky Mountain Sustainable Living Fair; Ft. Collins, CO. RE & other sustainable living topics. Workshops, keynotes, demos, vendors, music, kids' activities, food, more. Info: Rocky Mountain Sustainable Living Assoc. • 9860 Poudre Canyon Rd., Bellvue, CO 80512 • 970-224-2209 • kellie@poudre.com • www.sustainablelivingfair.org

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

ILLINOIS

Aug. 9–10, '03; Illinois RE Fair; Ogle County Fairgrounds, Oregon, IL. Info: 815-732-7332 • sonia@essex1.com • www.illinoisrenew.org

IOWA

Sept. 6–7, '03; Iowa Energy Expo, Prairiewoods Franciscan Center, Hiawatha, IA. Info: IRENEW, 563-875-8772 • www.irenew.org

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 electric, solar hot water, gardening, sustainable forestry, more. ASPI • 50 Lair St., Mt. Vernon, KY 40456 • 606-256-0077 • solar@a-spi.org • www.a-spi.org

MASSACHUSETTS

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

MICHIGAN

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

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

MINNESOTA

'03 St. Paul MREA Workshops. Basic PV & Site Audit: Sep. 18–19, Intermediate PV: Sep. 20–21, PV Install: Oct. 14–18. Info: see MREA listing in WISCONSIN

MISSOURI

Sep. 1, '03; Energy & Affordable Housing Fair, New Bloomfield, MO. Wind generators, dome homes, straw bale & cordwood construction, earth home, solar cooking, biodiesel, solar electricity & hot water demos, EVs, solar car, & electricity from a solar chimney. Free. Info & site: Mid America RE Center, 9810 State Rd. AE, New Bloomfield, MO 65063 • 800-228-5284 • www.moreenergy.org.

MONTANA

Aug. 18–22, '03; Biodiesel Fuel; Missoula, MT. Make biodiesel & a biodiesel processor. Vehicle conversion & straight vegetable oil covered. Info: see SEI in COLORADO listings. Local Coordinator: David Max • zenfuel@yahoo.com

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

NEW MEXICO

Aug. 17–Oct. 25, '03; Certificate for Earth-based Vocations. Santa Fe, NM. 10 wk. internship for professionals about systems approaches for designing human environments, including RE. Ecoversity, 2639 Agua Fria, Santa Fe, NM 87501 • 505-424-9797 • apilling@ecoversity.org • www.ecoversity.org

Sep. 20–21, '03; Solar Fiesta energy fair. Indian Pueblo Cultural Center, Albuquerque. RE, energy efficiency, passive solar design, green building, sustainable living, Kid's Korner, solar financing, wind energy, fuel cells, solar pumping, PV, EVs, straw bale building, & energy careers. Info: NMSEA • 505-246-0400 • www.nmsea.org

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

NEW YORK

Sep. 12–13, '03; ReCharge Energy Expo & Conf.; Bear Mt., NY. Displays, demos, & discussions on RE & efficiency. Info: Pace Energy Project • 914-422-4415 • mgolden@law.pace.edu • www.rechargeexpo.com

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

Aug. 22–24, '03; Southern Energy & Environment Expo, Asheville/Fletcher, NC. Exhibits, displays, workshops, alt. vehicles, campground, kids programs, more. Info: SEE Expo, PO Box 1562, Etowah, NC 28729 • info@seeexpo.com • www.seeexpo.com

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

OHIO

Wind & Solar Workshops; Aug. 23, '03, Stow Safety Bldg., Stow, OH (near Akron); Nov. 15, '03, Dublin Community Center & Glacier Ridge Metro Park, Dublin, OH (near Columbus). Info: Green Energy Ohio, 7870 Olentangy River Rd. #209, Columbus, OH 43235 • 866-473-3664 • christina@greenenergyohio.org • www.greenenergyohio.org

OREGON

Sep. 13, '03; Solar Cookery Class, Potluck & Picnic at Morning Hill Forest Farm, Seneca, OR. See EORenew below for contact info.

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

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

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

PENNSYLVANIA

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

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

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

RHODE ISLAND

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

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

TENNESSEE

Summertown, TN. Kids to the Country: nature study program for at-risk urban TN children. Sponsors & volunteers welcome. KTC • PO Box 51, Summertown, TN 38483 • plenty1@usit.net • www.plenty.org/KTC.htm

TEXAS

Sept. 26–28, '03; RE Roundup & Green Living Fair, Fredericksburg, TX. Info: 877-376-8638 • www.theroundup.org

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

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

VERMONT

Aug. 9, '03; RE for Your Home; Fairfield, VT. Hands-on workshop, incl. off-grid solar, wind, & hydro. Tour a PV system, theory, & practical help. Info: Flack Family Farm • 5455 Duffy Hill Rd., Enosburg Falls, VT 05450 • 802-933-6965 • sarahf@globalnetisp.net • www.flackfamilyfarm.com

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

Sep. 18–21, '03; NW RE Festival; Whitman College, Walla Walla, WA. Keynote Christopher Flavin, tours of Stateline Wind Energy Center, & RE & efficient homes. Sessions, workshops, kids' activities, exhibits, & music. Info: PO Box 1501, Walla Walla, WA 99362 • 509-525-8479 • info@nwrefest.org • www.nwrefest.org

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

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

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

WISCONSIN

MREA workshops. Straw Bale Construction: Sep. 5–7 or 12–14 in Sarona; Intro to RE: Sep. 13 in LaCrosse; Community Micro-Grid Wind Install: Sep. 14–20 in Amherst; Solar Water & Space Heating: Oct. 11 in Custer; Intro to Masonry Heaters: Nov. 8 in Custer. Also Wind System Install, PV Install, Straw Bale, Sustainable Living, & others. MREA, 7558 Deer Rd., Custer, WI 54423 • 715-592-6595 • mreainfo@wi-net.com • www.the-mrea.org

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

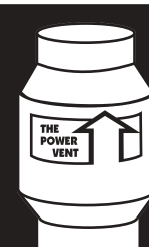
Dark Energy

Recently, astronomers and cosmologists have found convincing evidence of the existence of dark energy. Dark energy, also called quintessence, is an energy field considered to pervade all space. It is thought that this energy is responsible for the accelerated expansion of the physical universe. New data has seemingly confirmed that the expansion rate of the universe is indeed increasing.

The indication of the existence of dark energy may allow for the development of devices to tap into this energy source. It is quite possible that such devices may be able to produce more energy than is used to run them. It would be like putting a pipe into a sea of energy—the only input would be like the energy needed to run a pump or open a valve.

The gravitational properties of dark energy are already known and understood. To begin to tap this energy, the electro-magnetic properties need to be uncovered, as well as any gravito-electric or gravito-magnetic interactions.

At last, mainstream science may have confirmed what free energy enthusiasts have been saying for years. Space is not an empty vacuum. It is pervaded everywhere by a real energy field. Maybe now they are ready to listen to those who say that this field could possibly be a virtually inexhaustible supply of energy for the Earth and beyond.



Whisper Tower Kit Recall

It is very important that all customers who have purchased any height Whisper Tower Kit for use with a Whisper H80 contact Southwest Windpower or their local dealer for a tower kit replacement. Machines installed on this tower kit must be turned off. We will continue to upgrade existing kits until August 30, 2003 only. This only affects Whisper H80 installations.

Any dealer with Whisper tower kits in stock should contact us for replacement kits. Southwest Windpower will replace the kits at no charge and cover all freight costs. We regret any inconvenience this may have caused and thank you for your prompt attention to this matter. Andrew Kruse, Southwest Windpower, 2131 North First St., Flagstaff, AZ 86004 • 866-807-9463 or 928-779-9463 • Fax: 928-779-1485 • www.windenergy.com

White House Solar Thermal Credit

Richard, In the interest of giving credit where credit is due, I'd like to make a small correction to the description of the thermal systems installed at the White House ("Solar Energy at the White House?" in *HP94*, page 138). You are correct that the cabana pool heater was made using SunEarth products. However the DHW system on the maintenance building uses a single 4 x 10 foot collector made by Alternate Energy Technologies of Jacksonville, Florida. These folks deserve a nod, too. Dan Lunceford, Daystar Energy Services, Silver Spring, Maryland

Chasing the Elusive Power Factor

Dear *Home Power*, I'm writing to defend Carol Montheim (*HP92*, page 48), who had it exactly right until the power-factor nitpickers descended upon her with such a clatter that she was forced to recant half of her evidence for the virtue of compact fluorescent lightbulbs (CFLs).

The nitpickers were right to say that power companies supply power in volt-amperes (VA). And they were right to say that most CFLs have a power factor rating of about 0.5, which means that a 25 watt CFL takes 50 VA to run (25 watts divided by 0.5). But it is *not* true that utilities must therefore burn twice as much coal or cook twice as many atoms in order to supply twice as much energy to run Carol's CFLs. Power factor does not affect the energy consumption of homes either on or off the grid.

Volt-amperes are a measure of apparent power (as in false and tricky). Watts are a measure of true power (as in honest and upright, like Carol). When AC power hits reactive loads like CFLs or TVs or air conditioners or surge protectors or computers, electrical current and voltage tend to get jostled out of phase with each other, causing volt-amperes (sneaky false power) to rise above watts (foursquare honest power).

So our reactive 25 watt CFL still uses an honest 25 watts, even though amps and volts go out of phase and the sneaky VA rise to 50, making energy consumption appear to double. The extra 25 volt-amperes is not lost or consumed, just stored or borrowed. It goes to work somewhere else. It may offset the power factor of another appliance or it may go back out to the utility line where industrial capacitors tweak it back into phase. Utility meters may not read the extra volt-amperes that CFLs suck into the house, but neither do they read the extra volt-amperes that blow back into the grid from Carol's house. Everything gets canceled out, and the only thing actually consumed is the 25 watts.

Inductors (which cause current to lag voltage) and capacitors (which cause current to lead voltage) store or borrow volt-amperes that are not consumed as watts. They return those unused volt-amperes to the circuit later. For example, pure inductance does not consume energy; it stores it as a magnetic field. When that magnetic field collapses, the energy is returned to the circuit.

Utilities like the power factor of loads to be close to 1.0 (unity) because that makes it cheapest to distribute energy. These companies constantly adjust loads to bring current and voltage back into phase without using significant extra power. Commercial fluorescent lights usually have power factors of 0.9 or higher. Utilities lobbied to get residential CFLs to have similar power factors, but bulb manufacturers revolted because high power factor bulbs are more expensive to make. But the issue was power management, not energy consumption.

To prove this point, I set up an experiment with CFLs vs. incandescent lights (resistive loads with a power factor of 1.0), and measured watts and volt-amperes delivered by my inverter. Then I measured the amps from my power source, a bank of L-16 batteries, which are DC sources wise to the tricks of reactive power.

A 75 watt incandescent bulb measured 70 watts and 70 volt-amperes out of the inverter, which is what you would expect with a power factor of 1.0. The TriMetric meter measuring true power from the batteries measured 71.8 watts (volts times amps). The slightly higher wattage was due to inefficiency in converting 12 volt DC to 120 volt AC.

Then I lit a 25 watt CFL. It measured 25 watts and 52 volt-amperes out of the inverter, which indicated a power factor of about 0.5. The TriMetric, however, showed the true power needed by the batteries was 26.5 watts. The low power factor did not require the batteries (or the utility) to produce any extra energy.

This is not to say that volt-amperes are not important. Household wiring must be sized for the highest volt-ampere load it will carry, not for the highest watt load. Inverters, too, must be able to handle the highest volt-ampere load thrown at them, not the highest watt load.

Nonetheless, CFLs save as much energy as Carol said in her first story. With our nation's leadership in full attack mode on the environment, let's not make Carol's job any harder. My hat's off to you, Carol. Josey Paul, Joyce, Washington

Hello Josey, Thanks for your great letter. The figures in Carol's spreadsheet, Sylvania's power factor info sheet, and my response to Carol regarding power factor were misleading and way too high, as you point out. Unfortunately, the affect of power factor on energy consumption isn't quite as clear-cut as you describe.

One point that definitely shouldn't be overlooked regarding power factor is that all current causes losses in electrical distribution systems. This is true whether the system is the electrical wiring in a given building, or major utility transmission lines. The degree of loss is what's hard to quantify.

Here's an example to illustrate the effects of line loss in relation to power factor. Say a given pump has a power factor of 0.60. To do 1,000 W of useful work requires 1,667 VA of apparent electrical power. At 240 VAC, the electric current demand is 6.9 A. Replacing the pump with one that has a power factor of 0.95, would reduce the amount of apparent power to about 1,052 W, and reduce the circuit's current to 4.4 amps. This amounts to a 36 percent reduction in the level of current. In almost all cases, this will mean less power loss. How much depends on the length of the wire runs and the gauge or size of the wire in the circuit.

A second way that power factor affects an RE system's consumption is inverter efficiency. Inverters operate less efficiently when low power factor loads are being powered. Sandia National Labs runs reactive load tests on inverters. Their data shows that Trace SW5548 inverters powering loads with a 1.0 power factor run 4 percent more efficiently than a 1,000 watt load with a 0.5 power factor. That means more amps out of the battery. At 3,000 watts, the efficiency difference is 7 percent. It's important to note that different combinations of loads and inverter technologies may result in higher or lower efficiency figures. But the bottom line is that low power factor loads decrease inverter conversion efficiency.

We have some comprehensive experiments planned to quantify the affect of low power factor loads on overall energy consumption. I'd be very interested to hear from RE or utility folks regarding this, since it's a complex and often misunderstood electrical concept. Joe Schwartz • joe.schwartz@homepower.com

Vending Machine Energy Use

A long time ago, I read that soda vending machines are tremendous energy hogs, especially when located outside in the sun. I recently did a quick search on the Web and found the following excerpts:

Refrigerated vending machines operate 24 hours a day, seven days a week. In addition to consuming 2,500 to 4,400 kilowatt-hours (KWH) of energy per year, they add to cooling loads in the spaces they occupy. At average electricity costs of about US$0.08 per KWH, that amounts to US$200 to US$350 per year in operating costs. Source: www.ladwp.com/energyadvisor/PA_50.html and www.bchydro.com/business/guides/guide3684.html

The average soft drink machine uses two fluorescent bulbs, which total 80 watts. Add to this the energy required to operate the ballast, a component required to alter the electricity when using fluorescent bulbs. Using a very conservative estimate of only 2 KWH per day usage, a soda machine uses an annual 730 KWH just for lights. At an average rate of US$0.10 per KWH, this amounts to US$73 per year for just one machine. Source: www.window.state.tx.us/tspr/drippingsprings/ch05d.htm

The island nation of Japan is home to nearly 5.4 million vending machines—one for every 23 people. These machines dispense a wide variety of consumer products including coffee, sodas, and even cut flowers. A vast majority of them must be left running 24 hours a day to light and power the machines, as well as heat and cool the products. The result? While vending machines are a convenience for consumers, nearly 3.7 percent of the electricity consumed in Japan can be attributed to vending machines. Drink dispensers alone use an estimated 5.7 billion kilowatt-hours annually at a cost of US$1.1 billion. Source: www.electricconsumers.org/News/Newsletters/0399news.htm. Anonymous reader

Well, I can no longer say that I have not seen the stats—5.7 billion KWH per year for Japanese drink dispensers, and just so we can have a cold soda whenever we feel like it! Michael Welch • michael.welch@homepower.com

Fencing the Horse

Good evening, *Home Power*, I've just about finished building your "time machine" electric fencing unit (see *HP21*)—the horse model. But because I didn't buy any 4.7 k-ohm resistors (I series connected two 2.2 k-ohm instead), it gave me bad timing. It is a bit too fast for the fence, I think; lowest speed is about 6 Hz. I will visit my local electronic parts store and make it better.

Thanks a lot for sharing the schematics and the article. Soon the horse will have his own working device for the small (about 6 x 6 m) fence needed when he is taken to a competition (in the past, we've borrowed a 12 V fence from friends). I was thinking about buying one, but it is way more enjoyable to build my own. The one in the picture probably does not thank you! His relatives are from Iceland. Thanks a lot and goodnight. Lars Andersson • larsanderss@brevet.nu

Great work, Lars! The correct resistor should take care of your timing problems. If not, keep changing that resistor string (or the capacitor that is fed by this string) until you get exactly the pulse

frequency you want. The circuit is very solid and can be easily modified to give you the timing values you want. Over the years, I have purchased three commercial 12 VDC electric fencers and none of them works as well, is as energy efficient, or has lasted anywhere near as long as this homebrew. I'm sure it will serve you well. And thanks for the picture of your equine buddy—he's sure a fuzzy fellow. Richard Perez • richard.perez@homepower.com

Coming Back to HP

I began reading *Home Power* in the early 1990s on the advice of a friend. I am deeply committed to low impact living and want to implement the projects and lifestyle changes. I am not an engineer, however, and many projects in the early issues of *HP* were directed to engineers. I haven't read the magazine for a decade so it may have changed. I am hoping that you gear some articles to the handyperson who isn't an engineer. It's still a great resource. There's nothing I "don't like" about it. Thank you. • lakwete@auburn.edu

Thanks for your kind words via our Web site. Home Power *endeavors to publish information for both handypeople and engineers, and I think you'll be pleasantly surprised to see where we've come in the last ten years. As part of our recent redesign, we are trying to move some of the heavy technical info out of the article text and into sidebars. That way, techies can find it easily, and folks who are less interested in the tech info can breeze on by. I hope you enjoy it. Ian Woofenden • ian.woofenden @homepower.com*

Enlightening

Your magazine has a hallowed place in our home library. I love the electrical system diagrams and common sense format that greatly assists me in absorbing all the technical data you have to offer. I am aghast when I talk with other people concerned about renewable energy who are unaware of your great magazine. I do my utmost to correct that ignorance as quickly as possible! Keep up the great work! Thanks for all your awesome effort in putting out this enlightening publication. (The pun was intended!) oakspring@hotmail.com

Phantom Loads

Dear *Home Power*, This letter is in response to the letter "Phantom Loads Not Welcome" in *HP94*. The presidential executive order requiring federal agencies to make low standby purchases has indeed led to a large number of electric appliances being tested for standby power. The Department of Energy, in conjunction with Lawrence Berkeley National Lab, maintains a Web site (http://oahu.lbl.gov) that provides lists of low-standby office equipment (such as computers and printers) and consumer electronics (including televisions, stereo receivers and DVD players).

This Web site is primarily intended for government buyers, but we encourage interested members of the public to use these lists as they make their own decisions about buying low-standby load appliances. The information on the site is kept up-to-date by the manufacturers themselves, who are seeing the benefits of making their products competitive in the area of low standby power. Emily Bartholomew, Lawrence Berkeley National Laboratory • esbartholomew@lbl.gov

CFL Questions

Hello *HP* , You have had several articles in the past about compact fluorescent lightbulbs (CFLs). These articles inspired me to change my incandescents to CFLs. In doing so, I reduced my total lighting wattage use by about 78 percent.

I found it cheaper to change my dimmer switch to a regular switch and buy four regular 7 W CFLs than to buy four dimmable 15 W CFLs. I went from using a total of 160 W of incandescents to a total of 28 W of CFLs in this dining room fixture. It is every bit as bright while using 82 percent less energy. The dimmable 15 W CFL would have been too bright, and would have used more than double the wattage of 7 W, non-dimmable CFLs.

I do have some concerns about the disposal if every household were to switch over to CFLs. The mercury in the CFL makes it a hazardous waste, as all fluorescent tubes are. How can we feel good about buying a product that will have to be disposed of in a hazardous waste dump? We should be trying to reduce hazardous waste by *not* creating products with it in the first place. In my area, each household has to bring any hazardous waste to a drop off site. I will, but I think the average person is too lazy to do that, unfortunately. How will each city enforce it? This could be a health, safety, and environmental nightmare. I would feel better if all the lighting manufacturers would take back all of the CFLs at the end of their life, and recover and recycle the mercury into new CF lightbulbs. This way, the mercury would not be going into the landfills to leach out into our environment.

I have heard that some CFLs have no mercury in them. If so, why are they not advertised and mass produced instead? It is not enough to reduce CO_2. We need alternatives to toxic metals in the products we buy. Sincerely, Sue Drouillard LaSalle, Ontario, Canada

Hi Sue. You make a great point, and we thank you for becoming more energy-efficient. We need to work on reduction of toxics, as well as reducing electricity usage. Getting folks to start disposing of this stuff properly is not easy, just as getting folks to recycle is not easy. I think you will see more and more educational campaigns and disposal and recycling opportunities coming up. Right now the really big, yet similar, problem is with electronic devices, especially computers and monitors. They are chock full of things that should not be in landfills, many of which can be recycled.

Keep in mind that using less electricity means less toxics (including mercury) in the environment, which helps offset the problem you point out. Every type of boiler that produces electricity concentrates toxic waste in the boiler. Every now and then, power plants go into them and clean out the metals and minerals, concentrate them, and barrel them up for shipping to *toxic waste dumps. Then there are always the toxics and other pollution problems with stack emissions from these plants. So the big question is, which ends up with more toxics and pollution—using a CF, or using power plants that produce the electricity that CFLs save?*

The bottom line is that watts produced create environmental damage, whether from a coal-fired, centralized power plant, or from rooftop PV; and that every watt-hour consumed creates more environmental damage, like from manufacturing and disposing of the TVs or computers people use. Of course, I look forward to those mercury-free CFLs, since every little bit counts.

See HP93, page 62 for more info about recycling CFs. For a list of U.S. fluorescent bulb recyclers, see: www.gelighting.com /na/specoem/lamp_recyclers.html Michael Welch • michael.welch @homepower.com

Solar Pool Error

Dear *Home Power* In *HP95*, you featured the second article on solar pool heating. On page 63, under the heading "Piping Installation," you state that the piping is to be added "after the filter and the chlorinator." Installing the collectors after a chlorinating device will void the panel warranty with some manufacturers. Even adding chlorine or acid directly to the skimmer while the pump and solar collector are operational may void the panel warranty. Chlorinators should be mounted after the solar collectors and heater to avoid damage.

In addition, on page 64, you state that two-hole pipe clamps should be used on pipe to prevent sagging. PVC expands and contracts, so it is important not to clamp the pipe so it cannot slide in and out of the clamp. On Spanish tile roofs, place piping in the valleys (where possible), since a hot pipe will usually stay in the valley. Hey, maybe I should write a book! Keep up the great work. Joel Helleso, Nevada Solar Energy (Aquatherm master dealer), Las Vegas, Nevada

Joel, Thanks for pointing out the error of our ways. The mistake on page 63 was an error introduced during editing that was not caught. Tom's book does explain the piping placement correctly in relation to the chlorinator. Linda Pinkham • linda.pinkham@homepower.com

Biodiesel Emissions Reduction

Dear *HP*, I read with interest Gary Liess's claims about the environmental benefits of soy and veggie diesel fuel in *HP95*, "My Car Runs on Vegetable Oil." In the section on "Pollution," he stated that biodiesel results in no SO_4 emissions, since vegetable and soy oil contain no sulfur. He also stated that biodiesel doesn't contribute to global warming, since it's CO_2 neutral. Both of these claims make sense.

However, he also says that soot and particulates are reduced by 40 to 60 percent by using soy or veggie diesel. In the same issue, Scott Durkee responds to a letter from Richard Engle, about biodiesel pollution. In the response, Scott said that "...everything I've read supports the idea that pollution levels at the tailpipe drop dramatically once biodiesel is introduced."

Could someone please expound on why soot and particulate emissions are less with biodiesel fuels than with petroleum fuels? Don't be afraid to use some chemistry. When we make such claims to the general public, it's usually met with raised, skeptical eyebrows. Our understanding of why this is so, and our ability to explain why to skeptics, will only enhance the renewable community's credibility on the subject. Thanks for your consideration. Mick Sagrillo • msagrillo@itol.com

Dear Mick, Thanks for your letter and for expressing your concerns about biodiesel emissions. Though I am not a chemist or an air quality expert, I do run my car on 100 percent biodiesel and feel like that helps to reduce the acute pollution problem in the Seattle area. I got this idea not just from the smell of the exhaust coming from my old Mercedes, but from Josh Tickell's book, From the Fryer to the Fuel Tank.

On page 38, Josh writes: ''Biodiesel emissions are substantially lower than petroleum diesel emissions. Biodiesel tailpipe emissions are similar to gasoline emissions. However, compared to gasoline, biodiesel produces no sulfur dioxide, no net carbon dioxide, up to 20 times less carbon monoxide, and more free oxygen."

Josh states that biodiesel has the following emissions characteristics when compared to petroleum diesel fuel:

- *Reduction of net carbon dioxide emissions by 100 percent*
- *Reduction of sulfur dioxide emissions by 100 percent*
- *Reduction of soot emissions by 40 to 60 percent*
- *Reduction of carbon monoxide emissions by 10 to 50 percent*
- *Reduction of hydrocarbon emissions by 10 to 50 percent*
- *Reduction of all polycyclic aromatic hydrocarbons (PHA) and specifically the reduction of the following carcinogenic PHAs:*
- *Reduction of phenanthren by 97 percent*
- *Reduction of benzofloroanthen by 56 percent*
- *Reduction of benzapyren by 71 percent*
- *Reduction of aldehydes and aromatic compounds by 13 percent*

(These figures came from a paper titled ''The Technical, Energy and Environmental Properties of Biodiesel" written by Korbitz Consulting, Vienna Austria, 1993, which Josh footnoted.)

The only element in biodiesel exhaust that rises is nitrous oxide, which can increase by 5 to 10 percent, though this can be mitigated by either installing a catalytic converter or by retarding the timing of the engine by one to three degrees.

Another source of information concerning the emissions from both diesel and biodiesel is the report written by the National Renewable Energy Laboratory in Golden, Colorado called ''Biodiesel Handling and Use Guidelines." Written in 2001, it compares the emissions of 100 percent biodiesel and B20 (20 percent biodiesel mixed with 80 percent petroleum diesel).

On page 7, this report states that "blends of 35 percent, 50 percent, and higher can provide significant emission reduction benefits for carbon monoxide, particulates, soot, and hydrocarbons (Table 5). Higher blend levels of biodiesel significantly reduce polycyclic aromatic hydrocarbons and other toxic or carcinogenic compounds found in diesel exhaust. Higher blend levels also provide significant reductions in greenhouse gas emissions, and increase the renewable content of the fuel."

I hope that this information answers some of your questions, Mick. And I hope that you will join us in helping to both alleviate some of the pollution caused by transportation and to encourage the use of renewable sources of energy.

Oh, and one more thing. For the past few weeks, I've been adding biodiesel to my 1967 VW truck and my 1976 BMW motorcycle—both equipped with gasoline engines. I've added between 5 and 10 percent biodiesel (B-5 to B-10), and so far I haven't noticed any drop in performance or any other problems. It feels like both engines are running smoother and cleaner. Biodiesel contains more oxygen, which creates a better environment for combustion and has a very high lubricity, which I figure couldn't help but make the engine run more easily. And yes, the exhaust now smells a bit like fried chicken! Good luck to those of you who are willing to work out on the cutting edge. Scott Durkee, Vashon Island, Washington • renewable_energy@earthlink.net

Risks & Rewards

A solar-electric panel costing US$4 per watt takes 22 years to pay for itself if utility generated electricity is delivered at US$0.10 per kilowatt-hour. In other words, 400,000 cents (US$4 per watt times one kilowatt times 100 cents) divided by 10 cents yields 40,000 hours of power generation, this divided by 5 hours per day (average daily exposure for a solar-electric panel in North America) is 8,000 days, which divided by 365.25 is 22 years. Accounting for power controllers and other costs, actual payback approaches 30 years.

On Wall Street, "price/earnings ratio" means the number of years it takes to repay an investment at current dividend (or interest rate) yields. The market overall is at a P/E of 28, meaning that for every $28 invested now, $1 of earnings will be produced each year. The historical norm is closer to 14, and value stocks are considered to be lower than 7.

There is a certain risk of encountering a dry hole when exploring for natural gas; this risk is currently about 33 percent, or one well out of three. In comparison, there is about 0 percent risk of erecting a wind turbine that would not pay for itself if properly chosen, sited, installed, and maintained, presuming electricity prices remain at current levels. If the gas well is drilled to supply a power plant, investors are faced with even more uncertainties. First, gas wells are drilled, which has to continue indefinitely since they play out. Then pipelines are laid from the wells to the power plant, and then the plant is built and operated before electricity is generated and distributed via the grid. Bringing a well into production is only the beginning. Other actors have to play their part—ethically and honestly.

The investors who put money in dry holes have impaired their wealth, which is quite probably all out of proportion to their personal energy use. If drilling a gas well costs US$1 million, there are typically no more than 30 investors due to subchapter-S tax issues. This means an individual share is no less than US$30,000. What kind of RE system could most investors get for US$30,000?

In short, anyone who has enough surplus wealth to invest in the more traditional energy markets should first cover their bets with an RE system. The financial volatility of RE is substantially lower than any petroleum derivative. It's like buying bonds—boring, reliable, and relatively fixed yield, but relatively little downside.

Historically, low interest rates favor higher risk investments, since safe investments take ages to pay back. Warren Buffet suggests that it will take more than a decade for the stock market to return to the peak we reached in 2000. A payback of 30 years isn't all that unreasonable, considering the lack of alternative options. Meredith Poor, San Antonio, Texas • mnpoor@txdirect.net

Batteries for Cordless Devices—

Keep 'Em Running!

Richard Perez

In this modern world, many of the devices we buy and use are available in cordless, battery powered versions. It's hard to deny that these cordless devices are easy to use, portable, and allow us to work and play far from the wall socket. This column is a short guide to selecting the right kind of cordless battery technology, how to break the battery in, and how to make it perform well and last long.

Selecting the Device

A happy cordless experience begins when you select your cordless device. This information applies to all battery powered devices—laptop computers, cell phones, digital cameras, camcorders, cordless power tools, portable stereos and TVs, flashlights, radios, and any device powered by its own internal battery.

When buying a device, it is easy to become focused on the device itself and what it does. When you choose a cordless device, be sure to investigate what type of battery technology is used to power it. An antiquated battery technology can easily make the device an expensive pain to use.

In many instances, the battery is specifically made and sized to fit within the device. Examples of this are laptop computers and cell phones. Here you are stuck with the battery that the manufacturer has built into the device. If it comes with a proprietary battery, there's little you can do to choose what battery technology is employed. If you are comparing devices, make the battery technology employed a prime criteria.

Other devices use standard removable and rechargeable cells, such as the common AAA, AA, C, or D sized cells. If the device you own or plan to buy uses standard removable cells, you can easily use the battery technology of your choice.

Battery Types

Three types of rechargeable batteries are now commonly employed in portable devices—lithium ion (Li-Ion), nickel-metal hydride (NiMH), and nickel-cadmium (NiCd). Each of these technologies has distinct characteristics.

Lithium ion. Li-Ion technology is the new kid on the block. The use of this technology in consumer devices is less than four years old. Li-Ion cells are not yet found in standard flashlight battery sizes. The reason for this is two-fold—cost and battery voltage (around 3.6 VDC per cell, making it unsuitable for most devices employing flashlight-sized cells). Li-Ion, however, has found its way into proprietary batteries powering laptop computers, cell phones, and camcorders.

Of all the current rechargeable battery technologies, Li-Ion is the one to choose if you have the choice. Li-Ion has the highest energy-to-weight and energy-to-size ratios—your device will run longer, weigh less, and be smaller in size. Li-Ion has only minimal "memory effect." Memory effect is the tendency of a battery to lose its capacity to store energy if it is routinely shallow cycled. Li-Ion technology also doesn't use any heavy metals and is environmentally friendly.

Nickel-metal hydride. NiMH technology is now common and has been used in consumer devices for more than five years. NiMH cells have a voltage of 1.2 VDC and are found not only in proprietary battery packs, but also in standard flashlight cell sizes. NiMH cells are energy dense, about double the capacity of similarly sized NiCd cells, but not as energy dense as Li-Ion cells. NiMH cells have only a slight memory effect, and employ no heavy metals.

Nickel-cadmium. Many cordless power tools still come with factory supplied NiCd batteries. Avoid them. These cells have three major deficiencies. First, NiCd has the lowest energy density of any rechargeable battery technology employed in portable devices. Second, it has a radical and profound memory effect. Third, it employs cadmium, which is a heavy metal that is dangerous to our environment and must be specially disposed of or recycled.

When you're shopping for cordless tools, spend the extra money on a NiMH battery, which is sometimes an option. Soon, most tools will at least have NiMH as an optional replacement battery. Within a couple of years, most tools will come with NiMH as standard.

Breaking in a New Battery

How you cycle your cordless device when you first use it has a large effect on its battery's performance and longevity. New batteries need to undergo a "forming" process—breaking in. This applies to all the battery technologies—Li-Ion, NiMH, and NiCd. When first using the device, make sure to deeply cycle the battery for at least five cycles. Deep cycle here means to operate the device until the device ceases to function normally. This will assure that the battery is "formed" for its maximum capacity. Failure to do this will result in a battery with less effective energy capacity and a shorter lifetime.

Routine Cycling

With devices using Li-Ion and NiMH batteries, it is prudent to fully discharge the battery every thirty shallow cycles, or every month or so. While these technologies are touted by the manufacturers as having no memory effect, experience has shown that they do have a slight memory effect. Deep cycling the battery every month or so will keep them working at peak capacity.

NiCd batteries should be deep cycled every three to five cycles or they will lose their capacity to store energy. It is sufficient to use the device until it ceases to provide normal functionality. The practice of operating the device until the battery is totally dead will reduce battery capacity and longevity.

For example, when a flashlight becomes dim, it's time to recharge the battery. Don't wait until the lightbulb goes totally dark. Don't place a rubber band around the trigger of your cordless tool and run it until it stops rotating. Just use the tool until it begins to slow down and provides reduced function. Batteries are composed of series connected cells. If a battery is run to zero volts (utterly discharged), one or more cells may become reverse polarized, resulting in a permanent loss of capacity.

Recharging the Battery

Many cordless devices come with a charger supplied by the manufacturer. Examples are laptop computers, cell phones, and camcorders. These devices have a microprocessor that determines when the battery is fully charged. They require very little attention from the user and are generally quite effective at determining when the battery is fully charged. Experience has shown that leaving these devices under charge continually (24/7) will reduce battery capacity. In other words, when the device claims that it is fully charged, it probably is. It should be disconnected from the charge source if the device is no longer in use.

In devices that have removable flashlight-sized cells, recharging is more vague. Often the charger supplied by the manufacturer is designed for low cost rather than for maximum battery performance and longevity. A good way to determine if the factory-supplied charger is of high quality is to feel the cells at the end of their charge cycle. Are the cells hot, or even warm? If so, it's time to look for another charger. Modern, microprocessor-based chargers will refill standard-sized cells without overheating them. See the "Things that Work" article about the C. Crane charger in *HP86* as an example of a high quality, standard-sized, cell charger. Cell overheating reduces cell life and is the hallmark of a bad charger.

Some Notes on Specific Cordless Devices

All devices are not created equal. Here are specific tips for some of the more common cordless devices you may own.

Laptop computers. Perhaps the laptop represents the greatest payoff for proper battery treatment. Replacement batteries for laptop computers cost in the hundreds of dollars. Proper treatment can yield long battery life and big savings. The goal here is to see if you can make that original laptop battery last until you are thinking of replacing the computer because the computer itself is obsolete.

First off, if you have a contemporary laptop, you probably have a Li-Ion battery. This means that you have a highly energy dense battery with minimal memory effect. Following three simple rules will make that battery last until you replace the computer.

1. Form the battery with five complete deep cycles when you first take the computer out of the box.
2. Cycle the battery until the computer shuts down, at least once a month.
3. Don't leave the computer plugged into the AC mains 24/7. When you aren't using the computer, switch off the power supply/charger.

Cell phones. About 50 percent of the size and weight of a modern cell phone is the battery. Here is a good place to spend the extra bucks for the best battery you can possibly get. If the cell phone comes with a Li-Ion battery, great; if it doesn't, buy one. The whole reason for a cell phone is the function and convenience of cordlessness. Why place this function at the mercy of a dead battery?

Be sure to give the battery a forming regime when you first get the phone. After that, don't neglect to give it a monthly deep cycle. Don't leave it plugged into its charger all the time. When the recharge cycle is done, disconnect the charger.

Digital cameras. No device seems to suck batteries flat as quickly as a digital camera. Most of these are set up to use standard-sized flashlight cells. The only type of cells to consider using in these devices is NiMH. Most chargers supplied with cameras are designed to be cheap, not smart. Consider buying a smart charger for your camera's cells.

Cordless power tools. NiMH batteries will last longer and deliver better service, so make them your first choice whenever possible. Once again, since you are locked into the factory-sized battery pack, give the battery a forming charge. Cycle it completely every month if it's NiMH and every few cycles if it's NiCd, and don't leave it under charge all the time.

Storing Cordless Devices

If for some reason you are not using your battery powered device routinely, store it properly. Recharge the battery completely and remove it from the device before storage. Recharge the battery before reusing the device. Doing this will ensure long battery life.

Live Long & Prosper…

I hope this article will help you select and use cordless devices better. I welcome feedback from battery powered users. Share the info, and we all benefit.

Access

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"Don's death is a loss to this entire planet... His spirit lives on!"

Don Kulha died on May 6, 2003. He was 52 years old. Don was *Home Power's* CD-ROM dude. If you spin up one of *HP's* CDs on your computer, it's because Don made it happen.

I first met Don when *Home Power* was young, around 1989. He was one of the early computer freaks, and was operating one of the very first computer bulletin board systems anywhere, out of Sonoma County, California. He wanted to put *Home Power* files on-line, and I agreed. Later, totally under his own steam, he produced the very first CD-ROM containing data from *Home Power* magazine. This earned him a permanent position on our crew.

Don was a complex guy, a product of the San Francisco-based consciousness revolution of the mid-1960s. His interests were as wide as the universe and his limitless imagination. He was a believer in us poor humans and in the fragile fate of this planet.

Don wore many hats in his short time here—race car mechanic and motorhead, technoid, NASA space mirror transport coordinator, computer geek, bon vivant, rock star groupie, solar energy user and enthusiast, cranky perfectionist, vidiot, Ham radio operator and emergency communications coordinator, electronics homebrewer, and always, and most important, sterling dad to his beloved son Alex.

Don was my friend. Many times, we sang the fifty-year-old hippie's lament—if I had known I was going to last this long, I'd have taken better care of myself…. I can remember the many mornings we'd solve this small planet's problems over smokes and cups of strong coffee laced with Kahlua. Don had vision and he had hope. Don also had his darker side, succumbing to the hipster's disease of paranoia—his Y2K food stash probably outlives him…

Don held the position of "Captain Trips" during many of *Home Power's* road excursions. Because of his levelheaded and rock-solid road experience, I entrusted him with the lives of our crew. While the crew may have grumbled about his penchant for slow speed and truck stop food, they survived—we had no accidents on the road.

Don's death is a loss to this entire planet—all of us are diminished by his passing. His spirit lives on!

—Richard for the entire
Home Power crew

questions & answers

Time for New Batteries

Dear *Home Power,* Thanks for a great magazine. I have been a subscriber for two years and a reader for much longer than that.

I have a 24 volt, 1,100 amp-hour, deep-cycle, wet cell, lead-acid battery bank (12 Trojan L-16s), used to power my home. These batteries had been very well maintained, until a tenant at the house let the battery cells dry out until roughly half of the battery plates were exposed above the remaining electrolyte. Subsequently, I've seen a significant drop in available battery capacity—I've probably lost about 80 percent.

Can you recommend any products that might be able to restore these batteries? Any chemical additives? How about a desulfator like the Innovative Energy Systems DS-1000 or some similar product? Does exposure to air cause sulfation, or do these batteries have some other cause of failure? Thanks for your help with these questions! Mike Sullivan, Crestone, Colorado • zarmot@yahoo.com

Hi Mike, Once the plates of a lead-acid battery have been exposed to the air for more than a few days, I know of nothing that can restore them to their original condition. The problem is oxidation. Oxygen from the air enters into chemical combination with the lead in the plates. This is not reversible and produces loss of capacity. Sorry, but it's time to buy a new battery bank. Richard Perez • richard.perez@homepower.com

MC Connectors

Hello *HP*, I would like to know exactly what an MC connector is. I hear about them showing up on a lot of the newer PV panels now. What are the advantages and disadvantages of using them compared to a junction box? Thanks, David Bainbridge, Shevlin, Minnesota • dbainbridge@mac.com

Hello David, MC Connector stands for "Multi-Contact Connector," a trade name of Multi-Contact USA in Santa Rosa, California. The MC connection is polarized, "weatherproof," snap together, two-conductor, and housed in plastic. The MC connector is permanently attached to the PV module at the end of factory-installed wire pigtails.

An MC (Multi-Contact) connector.

Most installers like them because they allow for fast, snap together, wiring of PV arrays. Manufacturers like the MC connector because it is cheaper and faster to manufacture than a junction box.

I remain skeptical. I prefer the screwed down (high contact pressure) ring connector inside a waterproof junction box. I worry about the longevity of the MC connector connection—will its resistance increase over the years? Time will tell... Richard Perez • richard.perez@homepower.com

System Metering

Hi *Home Power*, Great magazine. I like the new look. I have a question and need a little help. I have a small (1.2 KW) grid-tied, net-metered PV system installed at my primary residence. It keeps my monthly electric bill at about US$10 month (US$6 of which is a meter reading charge). I participate in the annual solar home tour and would like to add a graphical meter/display to my system.

I have a Trace SW4024 inverter with a dozen L-16s (backup only) and would like to dedicate a laptop PC to display any or all of the normal functions and read-outs that are available. Do you have any recommendations? I would appreciate any help. Thanks, Wilson Reynolds, Colorado Springs, Colorado

Hello Wilson, Nice job with cutting your utility bill with solar electricity! You are probably going to want to check out prepackaged software for your PC that can communicate with the firmware in your inverter. This is done via an SW communications adapter (SWCA) cable that connects your PC to the inverter.

Take a look at the Winverter-Monitor (US$50) at www.righthandengineering or TraceTools v1.0 (US$99) at www.mauisolarsoftware.com. In both cases, you need to purchase the SWCA cable (US$130 from Right Hand Engineering, US$175 from Maui Solar Software). Maui builds a data module that both displays and datalogs a system's operational parameters on a PC. Check out the article on page 22 of HP94 *for more info on this setup. I hope this helps. Please let me know if you purchase one of these programs and SWCA cable. and how the install goes. Good luck! Ciao, A. J. Rossman, Draker Solar Design • draker@adelphia.net • www.drakersolar.com*

Washer/Inverter Trouble

Greetings *HP,* I have a customer with a Frigidaire-built Kenmore front loading washing machine. He is off the grid using a Trace sine wave inverter (don't know which one). The washer has worked fine for more than a year. Now he has problems with the door latch light coming off and on, and an occasional no-spin complaint. I cannot duplicate his problems checking the washing machine in my shop, which is on the grid. I'm wondering if you have had any reports of these computer controlled, front loading washing machines throwing fits when the inverter comes off standby or for any other reason. Thank you for any response. Best regards, Bob Wennerstrom, Blue Streak Appliance, Colorado • bobwenn@frontier.net

Hello Bob, Many off-grid inverters have a "search" function to reduce the inverter's energy draw when no appliances are running. Currently, Trace SW series inverters are very common in off-grid systems, and they include a user programmable search mode. When the inverter is idling, it draws about 16 watts. In search mode it only draws a few watts. Most older U-series Trace inverters (modified square wave) also include a search mode.

In search mode, inverter output is reduced to a pulse. If a load is detected, the inverter output increases to full voltage to power the load. Trace SW series inverters have a user programmable search threshold that operates in 16 watt increments, from 0 to 240 watts. The factory default setting is 48 watts. If the combined load on the inverter is below the programmed search threshold, the load will cycle on and off with the pulse and never bring the inverter out of search mode. The common example is a radio that draws under 16 watts. To pull the inverter out of search mode, a second load like a light is turned on. The combined load is enough to bring the inverter up to full voltage and power the radio—and the light.

We experienced a similar problem to what your customer is reporting up at Home Power Central awhile back. The Staber washing machine was shutting down before the tub drained and the machine went through its spin cycle. The cause was a 48 watt default search setting on a new SW inverter we were testing. The inverter would go to sleep before the spin cycle, and never wake up to finish the job. I reprogrammed the search threshold for 16 watts, and the washing machine has run fine ever since.

Have your customer check the search threshold setting on the inverter. The manual explains how to do this pretty clearly. If the search setting is still at 48 watts, lower it to 32 or 16 watts and see if that eliminates the light and spin cycle problems they're experiencing with their washing machine. If not, the search mode can be set to 0 and the inverter will always be ready to go when any load, regardless of how small, is turned on.

Small off-grid systems are often operated with the inverter's search mode active to conserve energy. Why have the inverter idling and drawing more energy than it needs to if there aren't even any loads to power? In some systems, this makes sense; in others it doesn't. These days, many off-grid homes have 24 hour loads like cordless phone chargers or answering machines, so the use of search mode is a moot point. If the inverter used has a reasonable idle draw, my suggestion is often to run the inverter in idle if search mode is presenting problems with given appliances. The worst stories I've heard along these lines are people coming home from vacation to freezers and refrigerators full of spoiled food due to search mode/appliance compatibility issues. Defeating search mode will mean that the system will draw a little more energy, but the folks living there will have fewer potential headaches, and a cold drink or clean clothes at the end of the day. Joe Schwartz • joe.schwartz@homepower.com

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Long-time Solar Energy International (SEI) instructor Ed Eaton has been a comrade, mentor, and teacher to many of the *HP* staff. His lifelong dedication as a teacher is evident in a recent letter to us, "The youth of today will be tomorrow's consumers and decision makers. Therefore, it is critical for the renewable energy industry to focus on youth education. We must provide the information necessary for young minds to make informed decisions—both as consumers and decision makers."

Ed retired from SEI at the end of May. He taught photovoltaics, solar cooking, and solar water pumping there since 1992. Ed is currently revamping his old company—Our Sun Solar Systems. He will be focusing on solar cooker design and construction, and offering PV consulting, installation, and system design services.

We wish Ed the best in his endeavors, and thank him for the wealth of knowledge and good times that he shared with us.

Ed Eaton has retired from SEI, but will never stop inspiring, and being inspired by, the next generation of renewable energy enthusiasts.

home power

The Hands-On Journal of Home-Made Power

Issue 96

August – September 2003

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- ☐ All electricity
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(continued on reverse)

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❑	❑	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
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