BP Solar–setting the standard for quality and performance.

the natural source for electricity.®

HP102 contents

On the Cover

The Anderson family in front of the PV array and wind generator that sell clean electricity to the grid at their general store on Guemes Island, Washington.

Photo by joshroot.com

Regulars

Education... Flowing with the Sun

One bright and sunny day in May, I spent the morning at a local elementary school's annual Exploration Day. Lots of community organizations were there, showing off music, art, animals—a wide variety of interesting things. Even the local dairy princess was there with a newborn calf.

But one of the most popular exhibits was my solar pump-in-a-bucket demonstration. It's a really simple and wonderful conversation starter for children and adults alike. Kids walk in front of the solar-electric panel and are immediately shown the results of blocking the sun as the water flow slows down or stops.

Other kids walk by and say, "What's that?" It only takes a few key words from me—"solar," "electricity," "pump," "shadow"—to pique their curiosity. I can explain that sunlight hits the PV, makes electricity, and powers the pump. But there's nothing like seeing it firsthand, in action. You can watch the kids "get it" immediately. Line a few kids up in front of the panel to stop the water flow. Then have them back up and watch the water splash out again.

You can do this in your own community. All you need is a PV panel, a DC-powered sump or pond pump, a bucket of water, and a public event. The future of our world went home from school that day, with the understanding that solar energy works.

—Michael Welch, for the *Home Power* crew

Think About It

"The sun, with all those planets revolving around it and dependent on it, can still ripen a bunch of grapes as if it had nothing else in the universe to do."

—Galileo Galilei

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HP access

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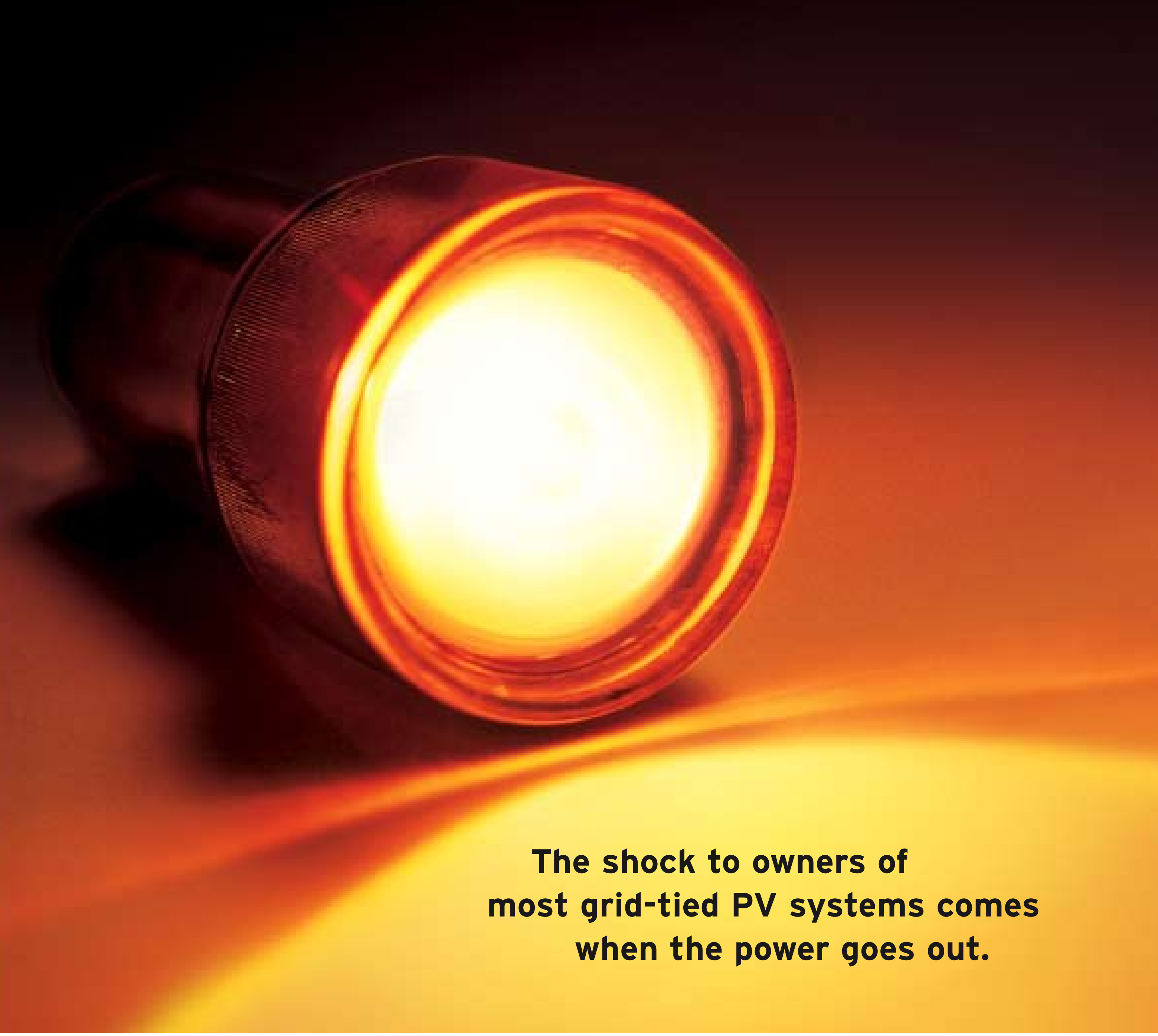


Many homeowners are shocked to discover that when the grid goes down, their grid-tied PV system goes right down with it. We'd like to offer a smarter alternative.

Now there's a grid-tied, battery backup power conversion system that provides instant power the moment an outage occurs ... and keeps it flowing at high efficiency levels day or night.

The Smart Power™ M5 from Beacon Power delivers what you expect from your PV system:

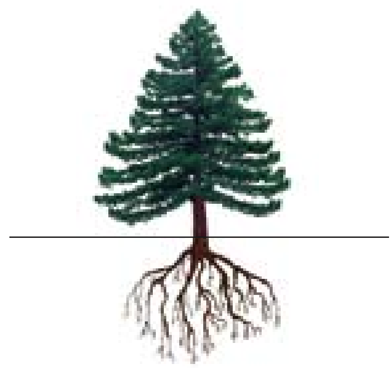
- 5000 watts of clean solar power
- Runs critical loads for hours or more
- Compact, streamlined design
- High efficiency performance
- Energy security and value

Think of the Smart Power M5 as your "silent emergency generator."

*For complete information on the UL-listed, California- and New York-approved Smart Power M5, contact one of the distributors below, or visit our Web site at **www.beaconpower.com.***

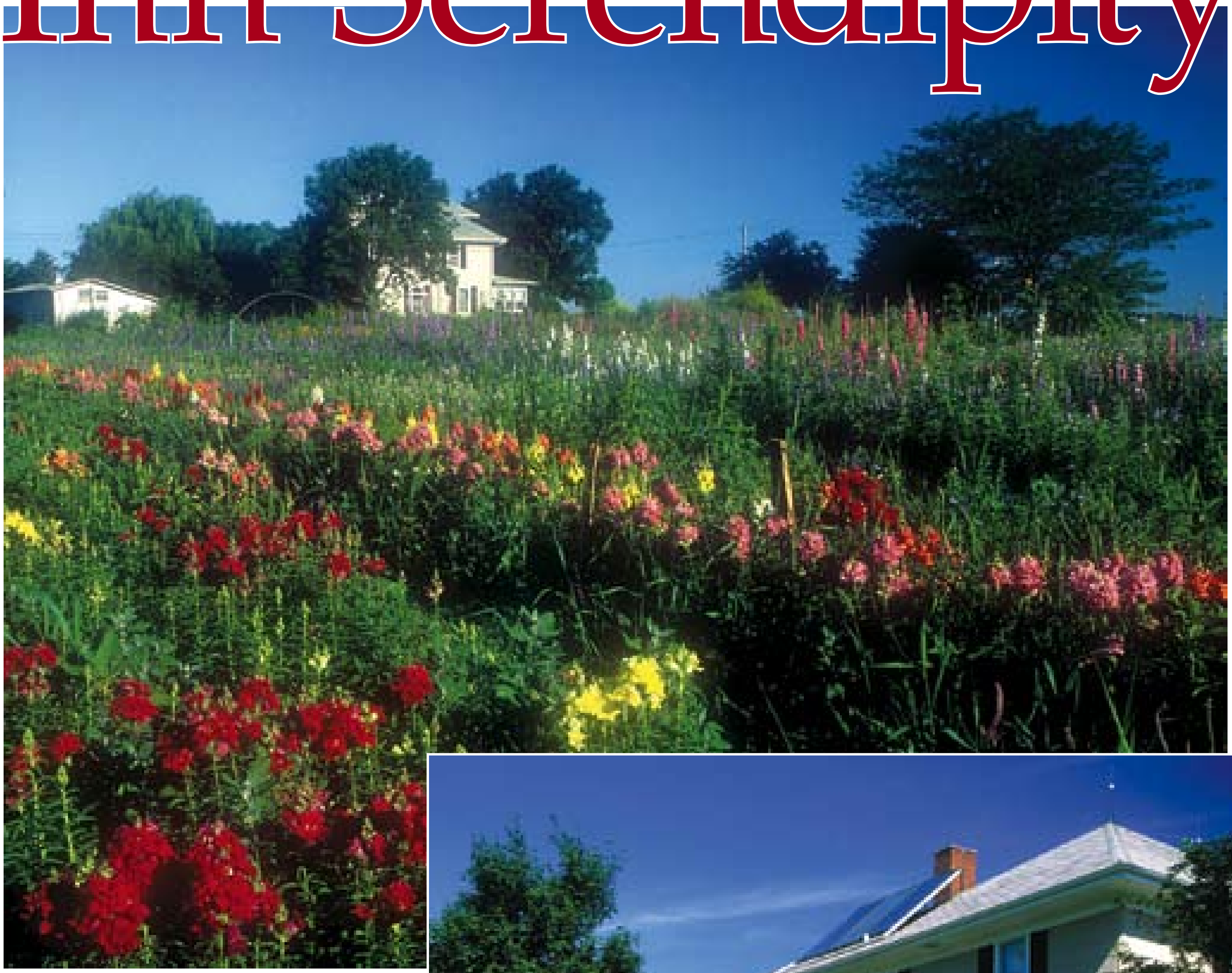
Beacon POWER®

Available from: AEE, Dankoff Solar, Solar Depot, and SunWize Technologies



HP V1.0

Inn Serendipity



Photos © John D. Ivanko

Sustainability as the Bottom Line

John Ivanko and Lisa Kivirist, with Phil and Judy Welty

A business pursuit need not be motivated by "bigger is better," or always selling more products or services. Being successful can be based on generating enough revenue to cover your costs and leave you with enough profit to satisfy your needs, pay the property taxes, and for renewable energy enthusiasts like us, take some time off during the summer and attend an energy fair or two.

We call it equilibrium economics. It's been our ticket to the good life while operating a portfolio of small businesses, including Inn Serendipity Bed and Breakfast and a marketing and creative services consulting company. Both are operated from our five-and-a-half-acre farm located in southwestern Wisconsin.

When it comes to energy, the more we can conserve, use more efficiently, or generate ourselves, the better our bottom line. We strive to avoid waste in our bed and breakfast kitchen and in our home-office, and we explore ways to use readily available renewable energy (RE) resources—sunlight, wind, and locally abundant wood. Our goals are to be fossil-fuel free and produce net zero emissions when combined with other carbon-dioxide sequestering activities, like planting trees.

We're not reading by kerosene lamps or hand-cranking our telephone. Our home office has enough computer power to scan and store John's professional photos, prepare a book manuscript, and complete a marketing plan. The two-room bed and breakfast has most of the amenities you'd expect in an 80-year-old, 1,969 square foot (183 m^2) farmhouse turned hospitality business, like a bedside clock and lamp—and hot showers.

In both our home-based business and lifestyle, energy conservation and the addition of energy-efficient appliances were among the many steps we took before moving into generating our own electricity. We purchased a Sun Frost refrigerator, Maytag Neptune front-loading washer (we line dry laundry), and several other Energy Star appliances. Our KitchenAid convection oven saves electricity by reducing cooking times. Phantom loads are eliminated with switched power strips. An old vertical freezer was replaced by a Frigidaire chest unit and placed in the cool northeast corner of the basement, rather than adjacent to the oven in the kitchen where it had been previously.

Photo © Mick Sagrillo

View of the Inn Serendipity farmstead from atop the 120 foot, guyed, lattice tower for the 10 KW Bergey wind turbine.

Interconnected RE Systems

Nature is our model. It guides us in our organic kitchen gardens, from which we harvest about seventy percent of our food. It illuminates our pathway toward more self-reliant and ecologically mindful living. Our decisions related to employing renewable energy systems were no different. All our RE systems were added incrementally, as budgets permitted. The evolution of the once fossil-fuel-based farm to an organic, sun and wind powered Inn Serendipity homestead is explained in our book, *Rural Renaissance: Renewing the Quest for the Good Life.*

Our first entry into renewable energy systems, paralleling our energy conservation efforts, was to add a solar thermal system for domestic hot water, and two years later, a woodstove for heat in the winter. Next we developed a grid-intertied hybrid renewable energy system using both solar and wind electricity generation, which lets us produce all of our electricity on an annual basis. Excess electricity generated, coming as a credit from our utility, is used to offset summer electricity use and anticipated maintenance costs for the entire hybrid RE system.

To become eco-effective, our frugal lifestyle needs to complement our goals to generate more electricity than we use in our all-electric home and business. Our electricity use was reduced about 40 percent from that of the previous owners, now averaging about 8,500 KWH per year for home, business, and farm. Soon we'll be exploring ways to achieve net zero

The solar thermal system for Inn Serendipity's straw bale greenhouse, with dairy barn in background, now home to two llamas.

Photo © John D. Ivanko

emissions with our car and other transportation. Our ten second walking commute to our office on the second floor was our first step.

Capturing Heat from Sunlight

Recognizing that 10 to 15 percent of an average home's energy use goes toward heating water, we added a domestic solar hot water system. Three, 4 by 8 foot (1.2 x 2.4 m) flat-plate American Solar King collectors were installed on our south-facing roof at about a 45 degree angle, optimized for spring and fall solar gain. Our collectors, like so many of our other systems, are experiencing a second life. They had previously been installed on the Packerland meat processing facility in Green Bay, Wisconsin. We're proponents of the reuse and recondition economy.

Nontoxic propylene glycol is used in our closed-loop active solar thermal system. A Heliotrope DTT-84 differential temperature controller senses when the collector fluid is hotter than the water in the basement storage tank. A super-efficient Grundfos 1/12 hp pump circulates the fluid through a Quad Rod heat exchanger where the heat is transferred to our domestic water.

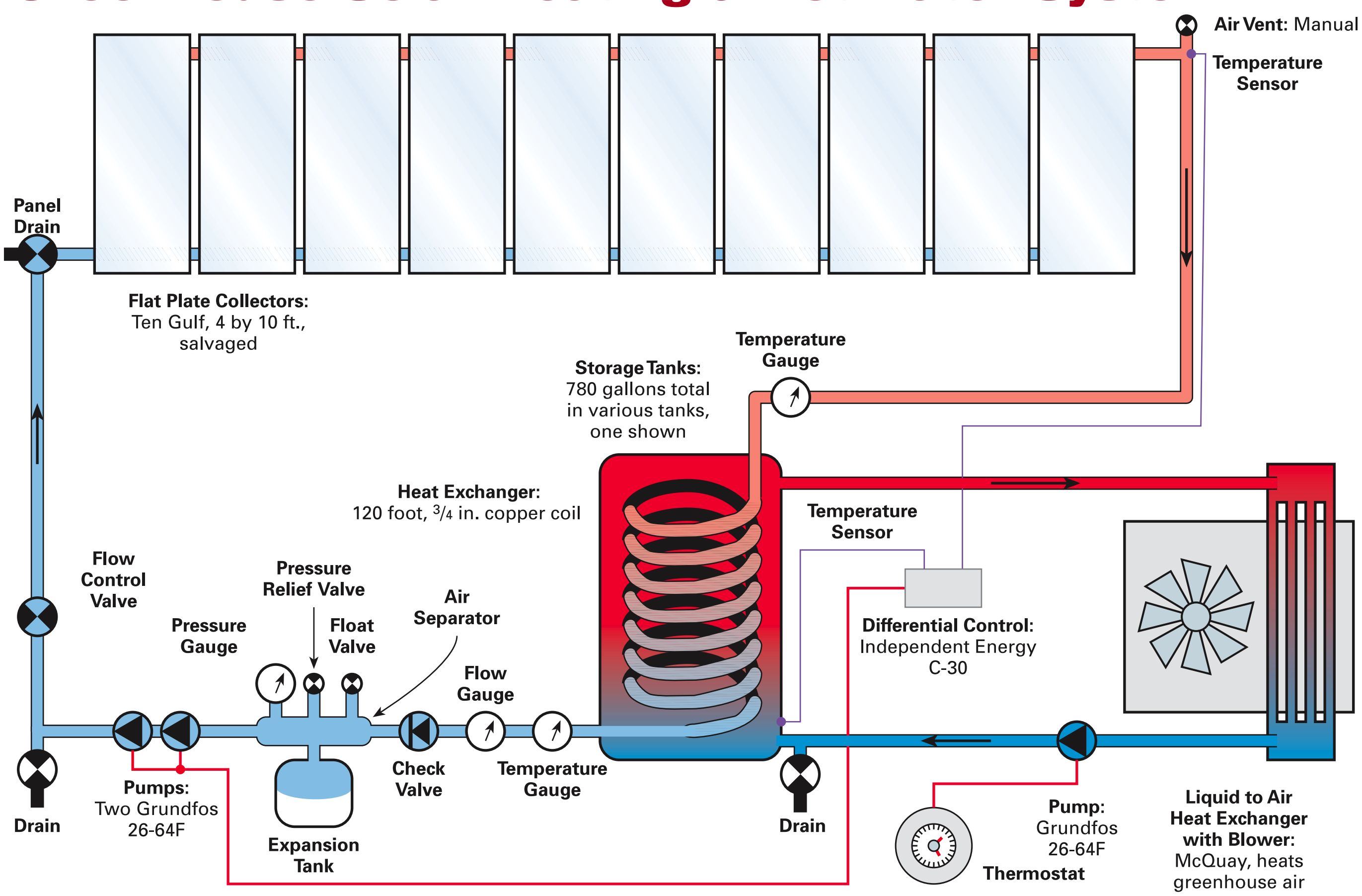
The hot water is stored in a standard 80 gallon (300 l) Rheem water tank that is connected to our existing 65 gallon (250 l) electric water heater tank. Had we to do it over, we would have mounted the collectors on the ground for easier installation and winter access (to brush off snow).

Thermal Systems Costs

SDHW System	Cost (US$)
Hired labor	$928
3 Solar King collectors, 4 x 8 ft. (used)	750
Misc. plumbing	396
Copper pipe, 3/4 in., 100 ft.	360
Quad Rod heat exchanger	287
Mount for collectors	225
Grundfos circulation pump, 1/12 hp	187
Freight	187
Water tank, 80 gal.	128
Heliotrope DTT-84 controller	117
Sales tax	113
Extrol #30 expansion tank	91
Total SDHW System	$3,769

Wood Heating System	
Chimney system	$994
Lopi Endeavor woodstove	900
Terra Green recycled glass tiles	66
Hired labor	1,352
Total Wood Heating System	$3,312

Greenhouse Solar Heating & Hot Water System



Thermal Costs, cont.

Greenhouse Solar Heating System*	Cost (US$)
10 Gulf solar collectors, 4 x 10 ft. (used)	$5,475
Misc. plumbing, insulation, etc.	901
Desert Sun fiberglass tank, 700 gal.	855
10 Gulf mounting frames	650
Heat recovery ventilation system	380
2 Grundfos 26-64F pumps	360
Blower	345
McQuay heat exchanger, 20 x 19 in.	315
10 Posts, 4 x 4 in, 12 feet	180
Glycol antifreeze, 20 gal.	180
Independent Energy C-30 control	143
Heat exchanger (for hot tub)	140
Storage tank, 82 gal.	128
Solar tank, 250 gal. (hot tub)	115
Thermostat (for storage tank)	105
March pump	104
Circulating pump (for hot tub)	100
Controller (for hot tub)	49
Flow indicator	42
Expansion tank	36
Phase change salts storage	33
Total Solar Heating	$10,634
Total Heating Systems Costs	$17,716

Owner/Volunteer Labor Estimates	
Solar heating system	$8,400
SDHW system	495
Wood heating system	150
Total Installation Labor Estimates	$9,045
Total Costs with Labor	$26,761

Rebates & Grants	
Alliant Energy Corp. (utility)	-$3,000
Grand Total	$23,761

* Items mostly from old, reused system; costs estimated & adjusted to present-day amounts.

The solar thermal system for the 1,200 square foot (111 m^2) greenhouse, designed by our neighbors Phil and Judy Welty, collects heat with ten, 4 foot by 10 foot (1.2 x 3 m) Gulf collectors, also reused from previously dismantled systems. The greenhouse itself is a renovated corncrib and granary, with two-thirds of the structure using straw bales as insulation material surrounded by more than 2 inches (5 cm) of stucco.

The heated glycol solution is pumped through underground insulated piping into a heat exchanging coil of 120 feet (37 m) of 3/4 inch copper piping. This allows the heat to be transferred and stored in 780 gallons (2,950 l) of water in several fiberglass tanks inside the greenhouse. The stored heat is then transferred to the air inside the greenhouse through a McQuay liquid-to-air heat exchanger.

In the middle of the winter, with the collectors angled at about 52 degrees for optimal solar gain, about 240,000 BTUs can be collected each sunny day. So when it's a frigid but sunny 10°F (-12°C) outside, the collectors will heat up the water tanks inside to more than 90°F (32°C). The goal and ongoing experiment with the greenhouse is to have a net zero heating cost by using both passive and active solar thermal systems, passive solar design, and the super-insulating qualities of straw bale walls. As much as 45 percent of the annual operation cost in traditional greenhouses is associated with heating. Successfully growing with net zero heating cost means more profit per vegetable or fruit crop sold.

Solar Electricity

Generating electricity using renewable energy for our home and business came in two phases—sun and wind. First, we installed a 480 watt PV system, estimated to generate about 500 KWH per year. Four, 120 watt Kyocera PV panels were mounted on a UniRac fixed rack that we attached to the south-facing wall of an existing equipment shed. The tilt angle of the rack is adjusted four times a year, roughly midway between the equinoxes and solstices.

Installation crew for the 480 watt PV system that was part of the Midwest Renewable Energy Association's educational workshop.

Photo © John D. Ivanko

The PV system was a part of an installation workshop with the Midwest Renewable Energy Association (MREA). Students ran a short DC line through the wall into an Advanced Energy, Inc., 1,000 watt inverter, and tied it into the nearest breaker box in the equipment shed. We sized our inverter to allow us to expand our system to include additional modules.

Wind Electricity

Sitting high on the ridge where we can see for many unobstructed miles in every direction, our farm is well positioned for electricity generation with a wind turbine. A partially state-funded site assessment was completed by Mick Sagrillo of Sagrillo Power and Light. He estimated that a 10 KW Bergey Excel-S system, with our annual wind speed of 13 mph (5.8 m/s) at the tower height of 120 feet (37 m), would generate about 1,130 KWH per month, or 13,560 KWH per year.

Our last, and most significant, investment in renewable energy generation was completed in May 2003 when we added this turbine, also as an MREA educational workshop. Lake Michigan Wind and Sun rebuilt a used Bergey that we had purchased, with any parts most likely to wear out replaced with new ones.

Our public utility, Alliant Energy, required a simple contract, certificate of liability insurance in excess of

PV System Tech Specs

System Overview

System type: Batteryless grid-intertied PV

Location: Browntown, Wisconsin

Solar resource: 4.5 average daily peak sun hours

Production: 44 AC KWH per month average estimated

Utility electricity offset by PV system: 6 percent

Photovoltaics

PV: Four Kyocera KC-120, 120 W STC, 12 VDC

Array: 480 W STC, 48 VDC

Array combiner box: Inverter integrated, 10 A series fuse

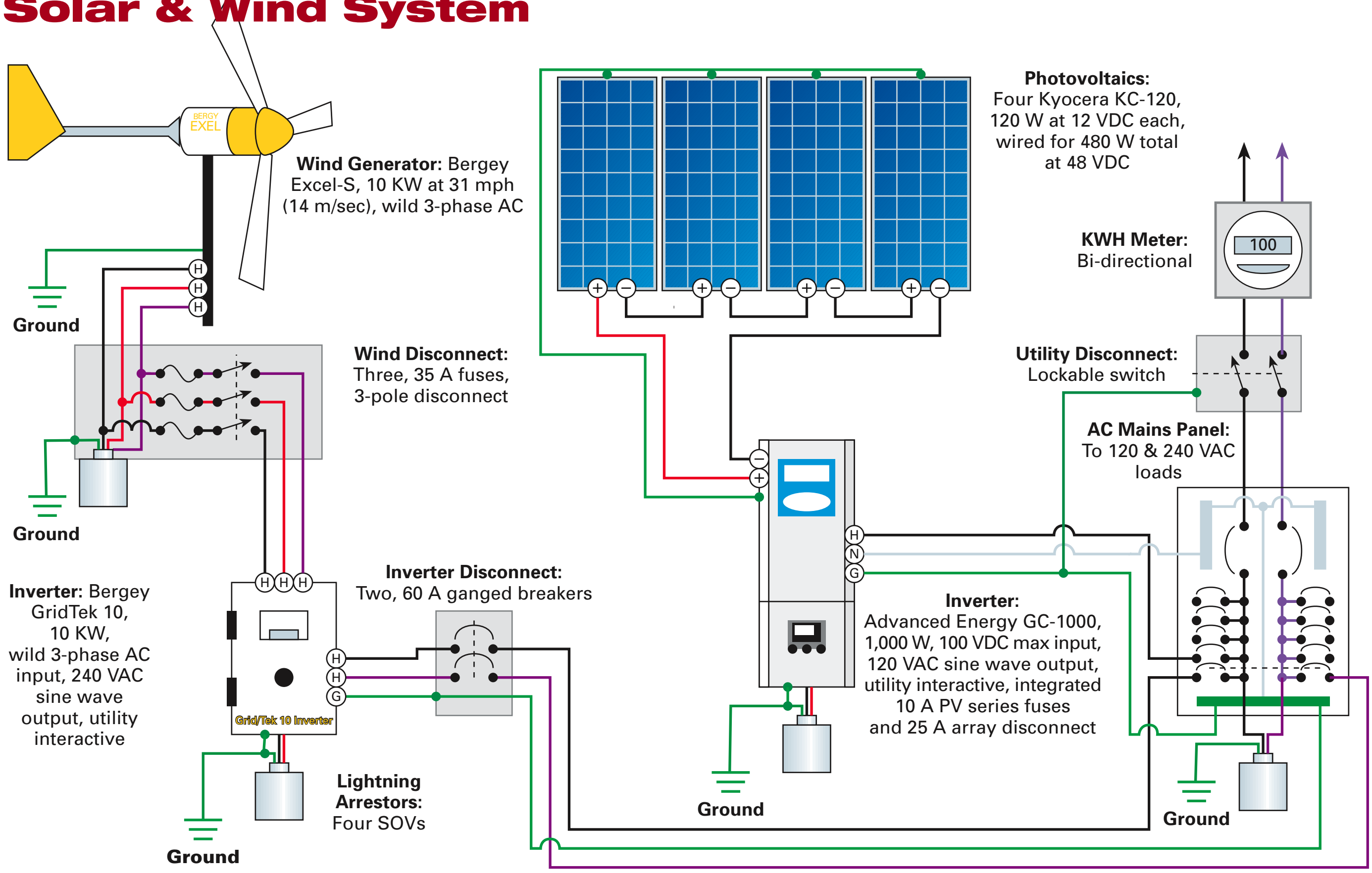
Array disconnect: Inverter integrated, 25 A

Array installation: Wall-mounted UniRac SolarMount, oriented true south; adjustable tilt angle

Balance of System

Inverter: Advanced Energy, Inc. GC-1000, 100 VDC maximum input, 120 VAC output, 52–92 VDC MPPT window

Solar & Wind System



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

Wind System Tech Specs

System Overview

System type: Grid-tied, batteryless wind

Wind resource: 13 mph (5.8 m/s) annual average

Production: 7,049 KWH for first year

Utility electricity offset: Projected in excess of 100 percent

Wind turbine: Bergey (BWC) Excel-S

Rotor diameter: 23 feet (7 meters)

Energy output: 900 AC KWH at 12 mph (5.4 m/s) average per month (grid-tied)

Power output: 10 KW @ 31 mph (14 m/s) peak

Tower: 120 foot (37 m) Rohn, guyed, lattice

Balance of System

Inverter: Excel-S GridTek 10 Power Processor, wild 3-phase AC input, 240 VAC output

System performance metering: AC KWH meter and integrated inverter LCD display

US$300,000, equipment specification sheets, and a lockable external AC disconnect for the project. The only unanticipated aspect of the system came with the computations contained in our first "credit" electric bill in December 2003. While we have a bi-directional meter, we are only able to "bank" (and get a credit for) our excess generation at Alliant Energy's retail rate, not the "green energy" rate, due to the way green energy is purchased by our utility.

Photo © John D. Ivanko

Inn Serendipity's grid-intertied, hybrid electric system features a 10 KW Bergey wind turbine on a guyed, lattice tower.

The MREA installation class in front of the 10 KW Bergey turbine and tower prior to being raised.

Photo © John D. Ivanko

Heating with a Woodstove

We don't mind getting snowed in with our Lopi Endeavor woodstove ablaze, using dry, seasoned, hardwoods that are readily available locally. We can snuggle self-sufficiently around the stove, strategically placed between our kitchen and front room. By using this efficient, high-tech, noncatalytic woodstove, our winter heating bill plummeted, conversations around the hearth mushroomed, reliance on fuel oil largely disappeared, and environmental impacts lessened.

According to the Midwest Renewable Energy Association, the cycle of burning wood and regrowth of trees produces no net increase in carbon dioxide to the atmosphere. We make sure our tree planting efforts more than replace the trees that we end up burning.

The Lopi stove is among the cleanest burning large stoves ever tested, in part because of the use of fire brick and baffles, which ensure that the gases are burned in the

Electrical System Costs

Wind Turbine System & Workshop	Cost (US$)
Bergey Excel-S 10 KW wind genny, lattice tower, & GridTek 10 inverter (used or rebuilt)	$23,000
Excavation	1,668
Sales tax	1,348
Utility service upgrades	1,324
Tower wiring kit	950
MREA workshop costs	716
Shipping	566
Wire run to tower	485
Permits	438
Crane rental	422
Misc. hardware	158
Total Wind System Costs	$31,075

PV System	
4 Kyocera PV modules, 120 W	$2,680
AE, Inc. GC-1000 Inverter	1,785
Misc. electrical (wire, etc.)	326
UniRac U-LP/106 PV rack	250
Sales tax	244
Freight	142
Misc. hardware	55
PV wiring	45
Total PV System Costs	$5,527
Total Electrical System Costs	$36,602

Owner/Volunteer Labor Estimates	
Wind system	$8,390
PV system	2,825
Total Installation Labor Estimates	$11,215
Total Costs with Labor	$47,817

Rebates & Grants	
WI Focus on Energy (wind system)	-$15,595
WisconSUN (PV system)	-3,000
WI Focus on Energy (PV system)	-536
Total Rebates & Grants	-$19,131
Grand Total	$28,686

combustion chamber. The combustion air is preheated along the sides of the firebox, and the five-sided convection chamber surrounding the firebox draws in cool room air, circulates it around the outside of the firebox, and returns heated air to the room.

The new woodstove models have up to 75 percent fewer emissions according to the EPA, which implemented woodstove standards in 1990. In contrast, an open fireplace sends up to 80 percent of a fire's heat up the chimney and significantly contributes to air pollution because of incomplete combustion of gases. The key to burning wood cleanly is burning all the gases that the wood releases. These are not only dangerous if left unburned, but contain more than 50 percent of the available energy. The gases burn only at temperatures in excess of 1,100°F (593°C), which can rarely be achieved other than through modern, airtight woodstoves.

Passive Solar Redesign & Daylighting

Passive solar features capture the heat of the sun entering our house. Daylighting allows sunlight to naturally light a space or room, and reduces the need for electric lighting. We employed daylighting when remodeling our attic, and used passive solar design as much as possible in the greenhouse. Our attic remodel involved the addition of a south-facing dormer with low-emissivity (low-E), gas-filled, double-pane Andersen windows. Overhangs above the attic windows help shade them from the hot summer sun.

In the greenhouse, extra thermal mass in the concrete slab floors, a 250 gallon (950 l) water tank, a phase-change salt tube, and water-filled Sun-Lite thermal storage tubes,

Energy Independence & Community Interdependence

We're not tinkerers. Nor are we financially independent. Our systems were selected based upon their reliability, affordability, and the recommendations from the "hired hands" who made our renewable energy journey possible. We chose some of the seasoned and experienced designers, consultants, and dealers that served our state.

Our success in employing the RE systems would not have been possible without these experienced guides, plus numerous neighbors pitching in with a tractor or construction expertise, and MREA's installation workshops. Various statewide funding programs helped us to the tune of US$19,131. In our quest for energy independence, we rediscovered social and community interdependence.

each in their own way, absorb and store extra heat, which slowly radiates at night.

Sun-Lite thermal storage tubes, made from fiberglass-reinforced polyester, resemble cylindrical fish tanks. They, like the phase-change salts, passively collect and store heat, which is then slowly released at night. The 250 gallon (950 l) open water tank takes advantage of the same passive heat-capturing opportunity, doubling as our hot tub. The water for the hot tub is made safe by an ultraviolet light placed next to the transparent filter canister.

Being Part of the Solution

Adding renewable energy systems goes beyond saving energy and reducing our ecological footprint. These are some of the many advantages.

Direct energy savings. Our hybrid wind and solar-electric system should offset about US$1,000 in electricity bills paid each year.

Tax credits and accelerated depreciation (for businesses only). Cash in on the federal renewable energy tax credit of US$0.018 per KWH generated for wind, or 10 percent tax credit for solar energy equipment. You can also accelerate the amortization for the system with the federal modified accelerated cost recovery system (MACRS; Section 169 of the Internal Revenue Code). Consult your tax advisor for the latest information.

Magnet for visitors and a competitive advantage. We are one of the few bed and breakfasts in the world powered by renewable energy—guests choose us over other lodging options because of our concern for the environment.

Free advertising. In nearly every significant renewable energy system addition (wind turbine, PV system, straw bale greenhouse, and solar thermal systems), we found an interested and engaged media, eager to report on our sustainable living methods.

Operating cleaner and greener. Our decision to use renewables was more than about the economics of energy, since reducing carbon dioxide, nitrous oxide, and mercury emissions and achieving greater energy self-reliance were just as important. It's a matter of operating our business as responsibly as possible, given financial limitations.

Economics and the environment do go hand-in-hand. It comes down to our understanding that the health of our community and success of our business is connected in much the same way as our physical health is based on what we eat and drink. In striving for a more ecologically responsible model of conducting our business that sustains

An old granary and corncrib was reconstructed as a straw-bale-insulated greenhouse with the help of neighbors, friends, and installation workshops by the Midwest Renewable Energy Association.

Photos © John D. Ivanko

Photo © Jason Perry

Wind and sun farmers Lisa Kivirist and John Ivanko with their son, Liam, next to the perennial flower bed at Inn Serendipity Bed and Breakfast.

us and provides our livelihood, we discovered how to harness renewable energy and greater profits for our business.

Access

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Rural Renaissance: Renewing the Quest for the Good Life, John Ivanko and Lisa Kivirist, 2004, ISBN 0-86571-504-1, 304 pages, US$22.95 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

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Database of State Incentives for Renewable Energy (DSIRE) • www.dsireusa.org

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Grid-tie with Back-up Made Easy

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Side-by side, real world testing completed by OutBack in Grass Valley, CA has shown that the KWH performance of our grid-tie inverter system with battery back-up is within 5% of the KWH performance achieved by a SMA Sunny Boy 2500. The tests were conducted with near identical PV arrays. The OutBack battery back-up inverter performs better than some batteryless inverters!

Simple Installation
Our new PS1 makes grid-tie with battery back-up quick and easy to install - even outdoors with limited wall space. The PS1 system is available factory wired with a complete ETL listing. We've taken all the guesswork and complexity of the assembly process out of the picture!

Maintenance Free
Designed to work with four Group 27 or 31 sealed AGM type batteries (such as those offered by Concorde, MK, Deka etc.) eliminates the need for periodic watering. Our advanced charge control algorithm and smart battery management techniques should allow for battery life to exceed 10 years in typical grid-tie back-up applications.

MATE2 system controller comes with a 50' cable

Micki Delaney
Micki is our Production Manager.
She has been involved with inverter manufacturing for more than 12 years.

Don't let your lights go out just because your neighbors do.
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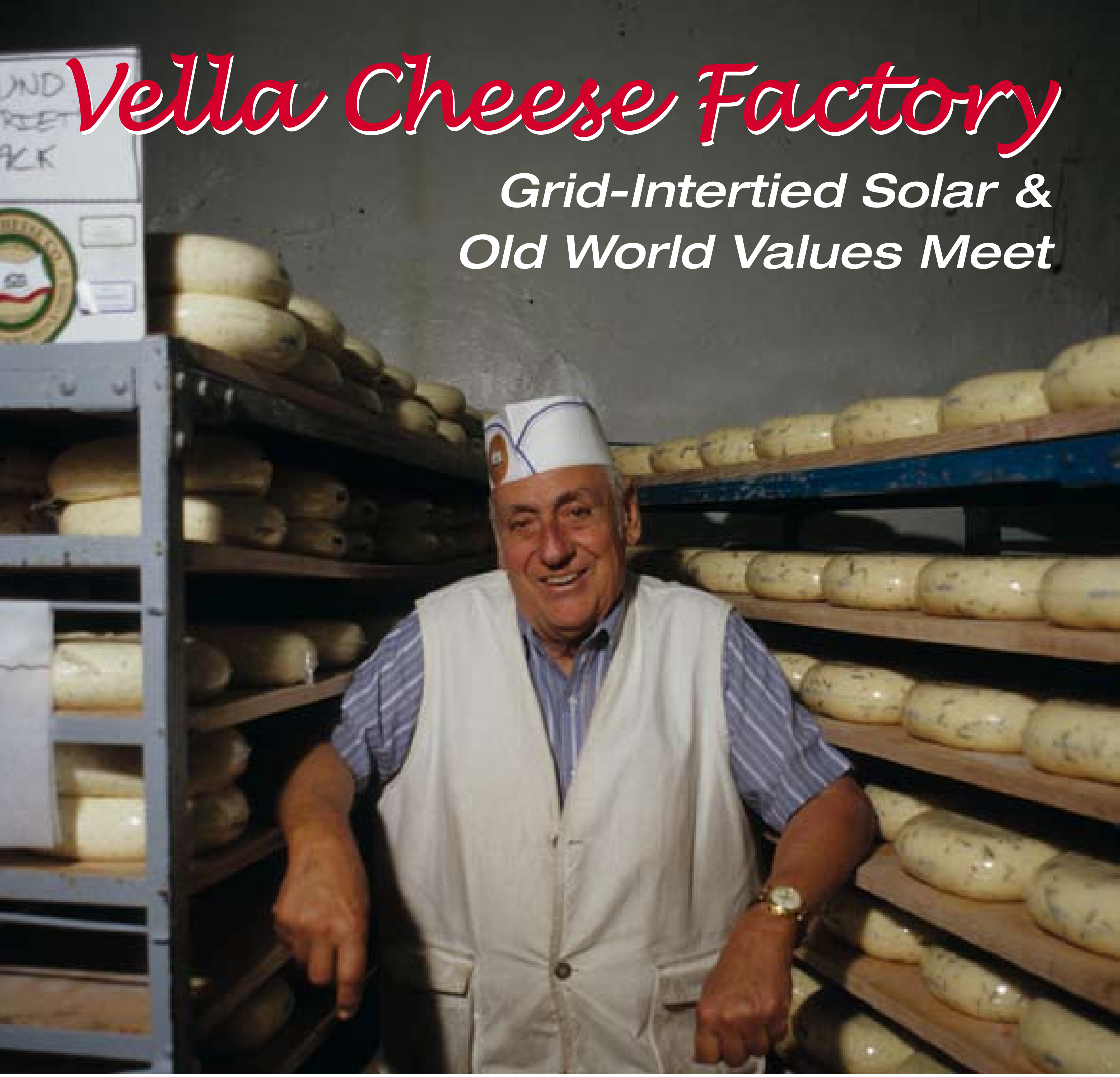

Ignazio Vella shows off some of Vella Cheese Factory's solar-produced artisan cheeses.

Brad Albert

Photos by Alberto Bresson
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The Vella Cheese factory has been soaking up the abundant California sun—and solar energy rebates and tax credits. This family-owned and operated small business saves money on its monthly electricity bills with a 30 KW grid-intertied, solar-electric system. The factory combines Old World values and modern technology to produce its fine cheeses at one of Sonoma, California's, oldest and most historic businesses.

Ignazio Vella understands that his success in making award-winning cheese lies in his attention to each day's production and the quality of his raw materials. Milk for Vella cheese comes from Sonoma cows that are grass fed and hormone free. With the milk coming from only four miles away, deliveries are scheduled to meet Vella's production, ensuring that the milk is fresh as the cheese making process begins. In short, high quality inputs create great cheese.

A portion of the 234 BP photovoltaic modules that make up the 30 KW system.

Solar Just Made Sense

With Vella's holistic approach to manufacturing, it makes sense that they decided to put clean and locally produced energy into their manufacturing process. However, it is uncanny how traditional European values led a 70-year-old, family-owned, cheese manufacturing business to become an early adopter of grid-tied solar electricity and set an example for both their industry and the city of Sonoma.

Ignazio Vella's generation doesn't take modern conveniences for granted. And like any successful business, they can't ignore the bottom line. Ig is outspoken about things just not making sense these days. For example, he winces and rolls his eyes as he says, "People object to hanging their laundry out to dry because it doesn't look good, and certain neighborhoods don't even allow it." Ig has 75 years' perspective to see the value of investing in a technology that will help offset his energy costs for 25-plus years.

Keith Burkland, head electrician at Sun First!, after finishing up installation on the system's 13 Sunny Boy inverters.

Ig has been running the creamery since 1971. He has seen his energy costs increase year after year. He explains, "Cheese ages before it can be sold. We use a lot of energy for refrigeration, and while we have done everything from fluorescent lighting to new, energy-saving, cold storage motors, our rates continued to creep up."

From November to May, Vella Cheese is saddled with a US$4,000 electricity bill each month. In the summer (May–October), the cost can spike to US$6,600. In harmony with the seasons, the solar-electric system will have greater output in the summer when rates are higher and more energy is used for refrigeration.

For Ig, the choice was simple. When asked why he decided to install a solar-electric system, he said, "I looked at my electricity bills and decided that they weren't going to go down. I went to my board of directors, who are my three sisters, my wife, and me, and they said, "Fine Ig, see what you can do."

Ig contacted the wholesale distributor Solar Depot, who in turn called Sun First!, an established solar installer in the San Francisco Bay Area. I was working for the company at the time, and took on the management of the project. We explained the financial incentives available, and Ig didn't need much encouragement to sign on to the project.

California companies can purchase a solar-electric system for less than a quarter of the gross price. There are many ways to account for these

System Cost & Financial Incentives

The table below shows that Vella Cheese only paid approximately 19 percent of the actual system cost after their Pacific Gas & Electric (PG&E) Self-Generation Incentive Program rebate, tax credits, and depreciation were taken into account. Here are some details about how these credits and incentives reduced the system's cost.

PG&E rebate. The PG&E Self-Generation Program rebate pays the lesser of US$4.50 per watt or 50 percent of the installed system cost. Vella's rebate of US$140,652 is based on one-half of the contract amount of US$287,285. To qualify, the system must be a minimum of 30 kilowatts and less than 1 megawatt. A licensed California contractor must install the system, and it must be approved by the appropriate building inspector and PG&E. Systems under 30 KW qualified for a US$3.20 (now US$3) per watt subsidy under the California Emerging Renewables Program.

Tax credits. The company received state and federal tax credits worth approximately US$34,000. As part of the Federal Energy Policy Act of 1992, there is a 10 percent renewable energy investment tax credit. A 15 percent state solar tax credit (under SB1849) was also available. This tax credit has been reduced to 7.5 percent for systems installed after 2004.

Depreciation. The cash value of the system's depreciation (after accounting for combined state and federal tax rates) will be approximately US$58,000. The federal government offers a six-year accelerated depreciation schedule for all solar energy equipment. The accelerated depreciation schedule is 95 percent of system cost over five years. Without this legal provision, such equipment would be depreciated over a twenty-year period. The schedule allows depreciation of 20 percent the first year, 32 percent the second year, 19.2 percent the third year, 11.52 percent for the fourth and fifth years, and 5.76 percent in the sixth year.

The system is estimated to reduce Vella's energy costs by US$6,908 in the first year, which would mean a simple eight-year payback if Vella paid cash for the system.

Cash Positive for the Life of the System!

While an eight-year payback is a very good return, further financial analysis shows that the system would be cash positive from the very first year with long-term financing. If Vella Cheese financed the remaining portion of costs of the system (after rebate, tax credits, and depreciation) by taking out a 30-year secured loan, the payments on the loan would be approximately US$300 per month, while the reduction in their average monthly electricity bill would be approximately US$500 per month.

The graph below shows the amortized cost of solar electricity per KWH at Vella Cheese over 30 years versus the expected cost of utility electricity per KWH. All numbers are after taxes. The graph shows what happens if utility costs rise by 3 percent or 6 percent over the next 30 years. Over the last 30 years, prices per KWH for California utility customers like Vella Cheese have actually risen by an average of 7 percent per year. An interest rate of 5 percent was used for the amortization. The economic model assumed the PV array production would drop 1 percent each year.

Another way to achieve a cash-positive system is to borrow the entire amount of the system cost, and then put the rebate money in a special account that pays the monthly loan payments. This fund, coupled with tax credits and energy savings, will also produce a positive cash flow for the life of the system.

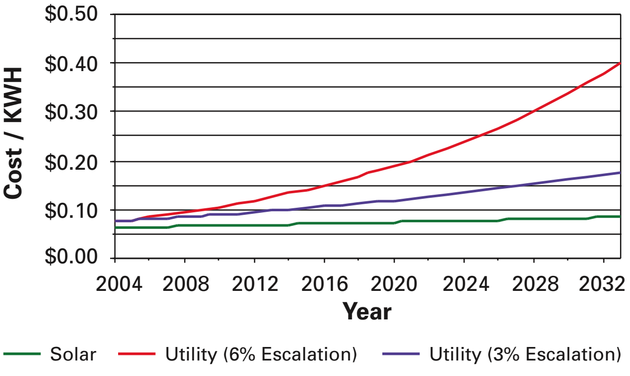
—Financial analysis prepared by Solar Depot

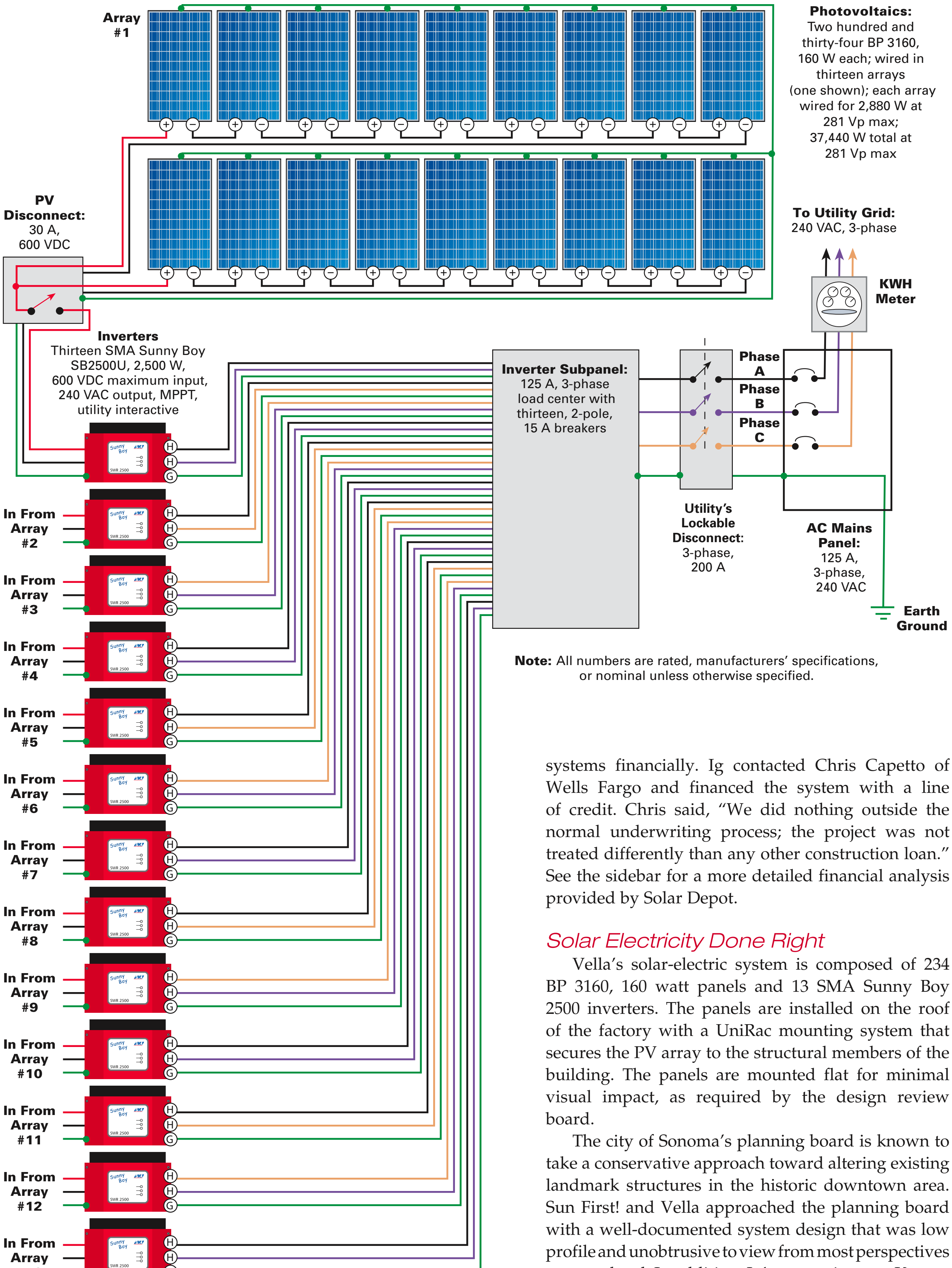
System Cost Analysis

Item	Amount (US$)	Cost (%)
System cost	$287,285	100.0%
Rebate ($4.50 / watt)	-140,652	49.0%
Federal tax credit (10%)	-14,633	5.1%
State tax credit (15%)	-19,800	6.9%
Accelerated depreciation*	-58,520	20.4%
Net Cost	$53,680	18.7%

*Assumes 35% federal tax bracket and 8.8% state tax rate. Federal depreciation schedule is 95% of system cost over 5 years.

Projected Electricity Cost Comparison





systems financially. Ig contacted Chris Capetto of Wells Fargo and financed the system with a line of credit. Chris said, "We did nothing outside the normal underwriting process; the project was not treated differently than any other construction loan." See the sidebar for a more detailed financial analysis provided by Solar Depot.

Solar Electricity Done Right

Vella's solar-electric system is composed of 234 BP 3160, 160 watt panels and 13 SMA Sunny Boy 2500 inverters. The panels are installed on the roof of the factory with a UniRac mounting system that secures the PV array to the structural members of the building. The panels are mounted flat for minimal visual impact, as required by the design review board.

The city of Sonoma's planning board is known to take a conservative approach toward altering existing landmark structures in the historic downtown area. Sun First! and Vella approached the planning board with a well-documented system design that was low profile and unobtrusive to view from most perspectives at street level. In addition, Ig's reputation as a Korean

Ignazio Vella in front of Vella Cheese factory.

He hopes that other businesses step up and become solar leaders.

Paperwork & Politics

Sun First! has done more than two hundred systems for homes, businesses, and institutions through the CEC Emerging Renewable Program. But this was their first system over 30 KW that qualified though Pacific Gas & Electric's (PG&E) Self-Generation Incentive Program. Understanding the process was not difficult, but executing the paperwork was not streamlined.

The grant program and the interconnection agreement require a lot of redundant forms to be filled out with multiple copies and original signatures. Sara Birmingham from PG&E's grant department and David Orr from their interconnection department were both very helpful and assisted Sun First! with wading through the required documentation.

Ig is also quick to point out that while Sun First! has been a buffer in the whole application process, he feels that PG&E and the other utilities are talking out of both sides of their mouth. "It ain't no piece of cake. Bottom line is that the utility companies don't want it, so they don't make it easy."

Sun First! takes a more middle-of-the-road view. Aran Collier acknowledges that there are great incentives and opportunities available for solar electricity that have created a market, that didn't exist five years ago. However, as Ig said, within the utilities there are lobbies that are trying to find loopholes to block the grid connect revolution, including exit fees and other limitations that effectively make installing a solar-electric system less attractive.

War vet and a former city planning commissioner pulled weight and helped the architectural review commission not only approve, but also commend the idea.

The planning board made it clear that a few residential systems with less integrated mounting and aesthetics had soured them about solar-electric installations. Ig addressed the committee and pointed out, "The other systems were not done by professional solar installers. When solar-electric systems are done right, you benefit on two accounts; one, you typically get more efficient systems, and two, you make sure that they are not visually offensive."

Ultimately, Ig hopes that his system will be the cornerstone for more systems in his community. Vella's is the first commercial grid-tie system in the city of Sonoma.

California—Leading the Industry

These politics aside, California with all its energy ironies and scandals is leading the nation and creating the American market for grid-tied solar electricity. Today, 85 percent of all solar electricity generated in the United States is produced in California, according to Platts Research and Consulting. Platts predicts that photovoltaic generation in California will increase nearly six-fold in the next twelve years, from an estimated 40 megawatts to 224 megawatts. Even though other states are beginning to provide subsidies for solar-electric systems, California will still produce about 60 percent of all U.S.-based solar electricity in 2015, Platts forecasts.

Although the growth of solar energy is heavily weighted toward California, businesses in every state benefit from the same 10 percent federal investment tax credit and five-year accelerated depreciation schedule, as Vella did. More states are following California's lead, and great rebates and incentives are available in New Jersey, New York, Oregon, Massachusetts, Hawaii, Florida, Arizona, and Nevada.

Besides financial incentives, businesses can benefit from applying solar energy toward their ISO manufacturing statements, as well as in their public relations and marketing. While solar electricity makes sense for the home, it's a slam dunk for businesses.

Access

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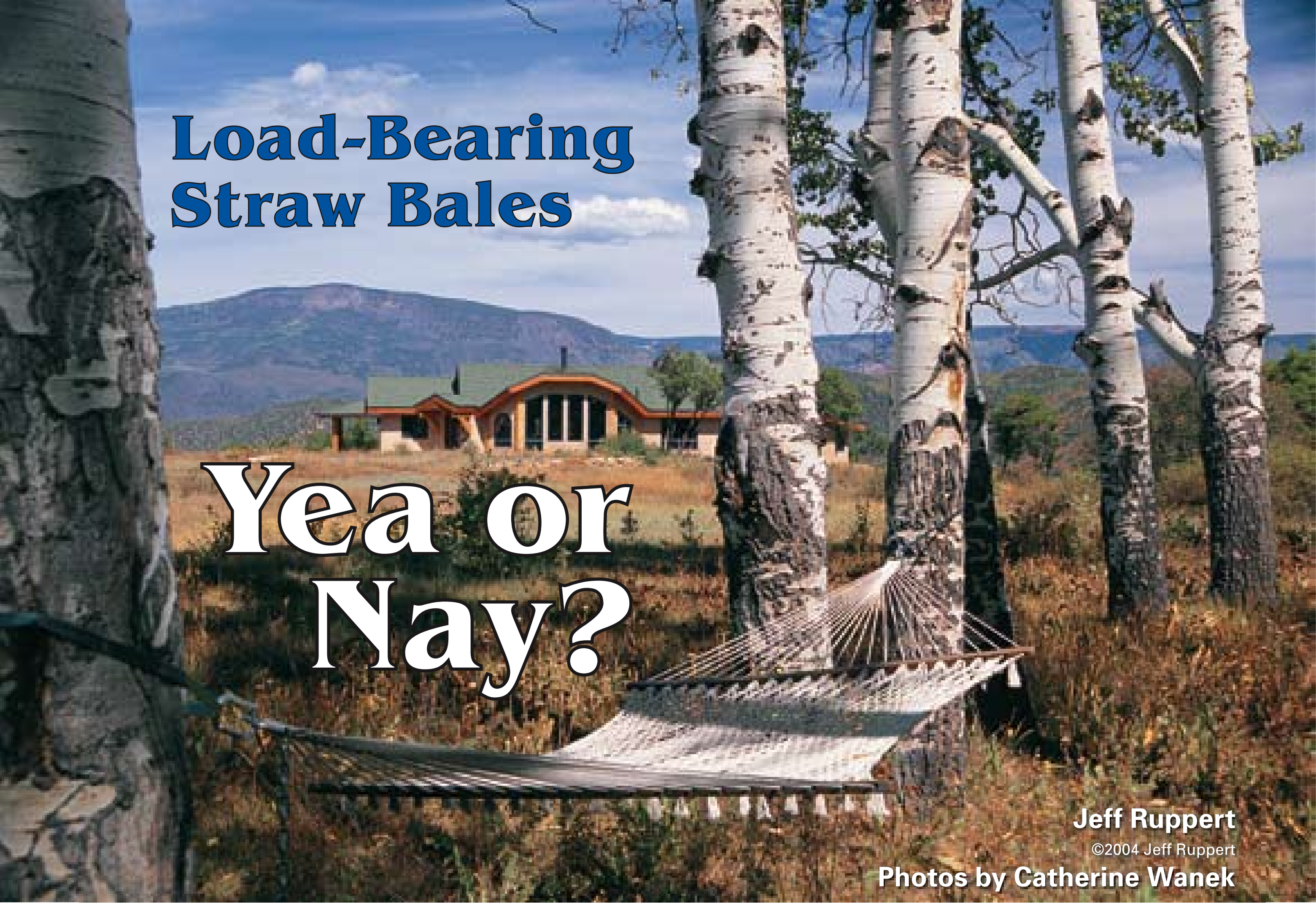
Load-Bearing Straw Bales

Yea or Nay?

Jeff Ruppert

Photos by Catherine Wanek



This PV powered straw bale home in the Colorado Rockies keeps the owner warm during the long, cold winters.

For more than a hundred years, people in the U.S. have been using bales of grass and straw to build their homes and accessory structures. The early pioneers of this building technology did not use frames within their walls, but relied on the strength of the bales and plaster to hold up the roof.

In modern times, straw bale builders often use a frame with the bale and plaster walls. We have found that evaluating each project based on a number of factors helps to determine which system should be used.

Load-Bearing Construction

In load-bearing construction, the straw walls and their plaster skins are both the structural wall element and the insulation. Many believe that load-bearing construction is the purest form of bale construction. Following in the footsteps of our forebears, why complicate matters with a wood framework? Simplicity used to be forced by necessity, but sometimes the results are surprisingly desirable.

Constructability. Stacking a bale wall without having to work around a structural framework takes less time. Without posts in the walls, there are fewer joints between different materials that need to be reinforced with some type of mesh. Both of these characteristics save time and materials.

However, load-bearing construction requires some unusual steps, including the use of something to level the roof-bearing assembly that sits on top of the bale walls. If you are a builder who insists on everything being perfect, you may become very frustrated by this process. Remember that the tolerances of bales are in full inches, whereas the tolerances in frame construction are within a fraction of an inch.

Cost factors. Some people believe that it is not any cheaper to build a load-bearing wall than a post-and-beam wall. The truth of the matter is, it depends on who is building the structure. In the case of an owner-builder, the goal is to locate materials cheaply, while supplying as much labor as possible. This reduces total out-of-pocket expenses.

If you hire a builder to do most or all of the work, a load-bearing structure might end up costing more due to higher labor costs. Load-bearing construction can take a level of care and understanding that many builders don't

This load-bearing straw bale home in Nebraska, built in 1905, is one of the oldest surviving straw bale homes.

In load-bearing walls, the window "rough buck" is inserted into the bale wall as it goes up.

want to mess with. All of these issues affect costs, and you need to determine beforehand what type of system will fit your plan best.

A post-and-beam wall can use as much or more lumber than a typical 2 by 6 framed wall—approximately 13 to 15 board feet of lumber per lineal foot of wall. A typical load-bearing bale wall uses about 6 board feet of lumber per lineal foot of wall. Lumber can be a substantial cost in construction, so using load-bearing walls may reduce the cost of materials.

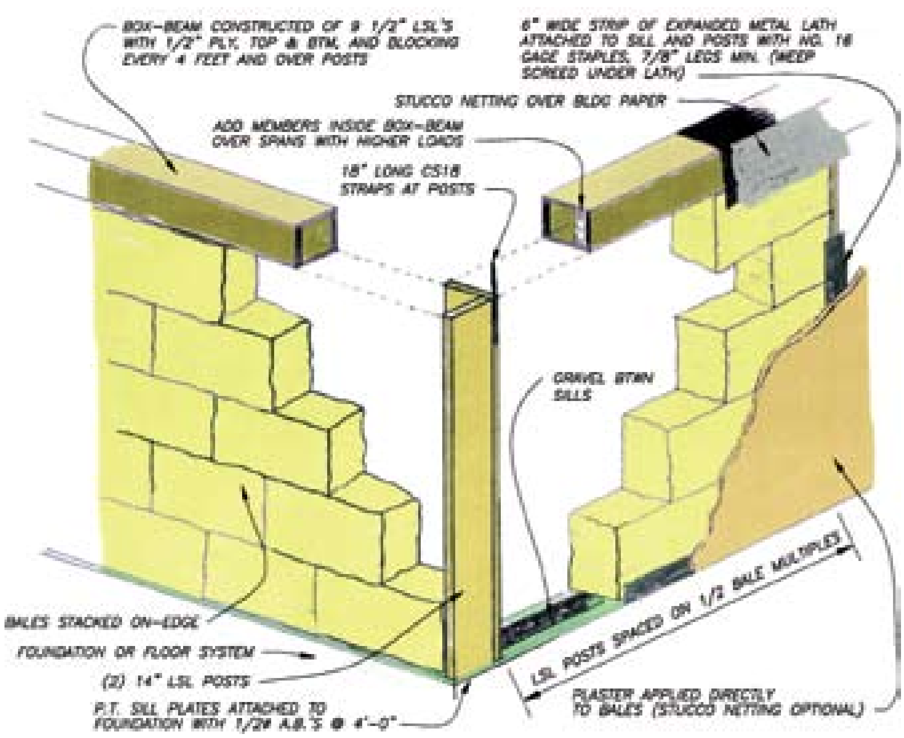
Timing. Deciding when to place bales in the walls can make it easy to decide whether to go load-bearing or not. When building a load-bearing structure, you will not have the luxury of a roof overhead to protect the bales. You will need to stack the walls, place the roof bearing assembly, strap the walls, and then build the roof. The walls will be more exposed to the elements. If you live in a climate that receives rainfall throughout the year in unexpected quantities and without much warning, load-bearing construction will be difficult. In drier climates, it can make more sense.

Stacking. Until recently it was thought that the strongest, most stable straw bale construction method is using three-string bales, laid flat, with cement plaster on both faces. However, recent testing at the University of Colorado has shown that two-string bale walls may in fact be close to twice as strong as three-string walls. These results also show conclusively that it is the rigid plaster skins that provide the bulk of the strength.

Two-string bale walls with the bales laid on edge are stronger probably because the plaster skins are closer together, with less straw between them than their three-string counterparts laid flat. When placed under the same compressive loading regime, three-string bales deform sooner than two-string bales, causing local buckling, which leads to global instability of the plaster.

Other advantages to stacking bales on edge make this configuration worth considering in every situation. For example, the same building will use fewer bales when stacked on edge. Also the walls will be narrower, using up fewer of those valuable square feet of floor space. And finally, they do not compress when stacked on edge (or

Post-&-Beam Detail



Bales can be notched around posts, or the posts can be left exposed on the interior or exterior.

compress very minimally). Of course, the R-value of the wall will be somewhat less with bales stacked on edge.

Post-&-Beam Construction

Using a support structure within or next to bale walls instead of using bales for support adds to the predictability of the situation. This can ease the permitting process, and helps ensure that the bales will stay dry during construction.

Straw bales can be used as an insulative infill in conjunction with many kinds of structural frameworks, including timber frames, stud walls, post and beam, concrete, and steel frames. Each of these framing styles has its own advantages and disadvantages, and must be researched fully for its own merits and its ability to blend with straw bale walls.

Constructability. The first advantage that comes to people's minds when using a post-and-beam system is the ability to get the roof up as soon as possible. This provides a dry working space to both store and work on bales.

Another advantage is the predictability of the structure both from a design and construction standpoint. Many engineers are not at all familiar with bale construction. They prefer to use a structural system that they can easily define, leaving the bales to act as insulation and as a backing for the plaster. While this may make your process of approvals and design easier, the costs of materials may offset these advantages.

Cost factors. Many framing options are available, and they can vary widely in price and ease of construction. Finding builders familiar with the chosen system will have a significant impact on the cost. The frame design must also take into account its interaction with the bale walls. Frames can exist outside the walls, within the bales, or inside the walls, and each interface must be well thought out.

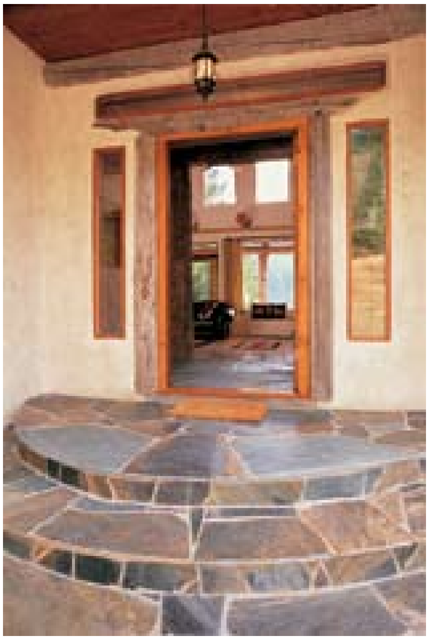
If there are many joints between different materials, such as window bucks and posts with bales, the labor to fit custom bales and cover the joints and partial bales with some type of mesh will make the process slower and more expensive. The biggest cost savings with post-and-beam options comes from being able to raise the bales and plaster them at a comfortable pace under the protection of the roof.

Timing. Bales can be inserted as soon as the roof bearing assembly is placed on the posts. The timing of bale placement within the walls is very flexible. This issue alone can make the decision very easy.

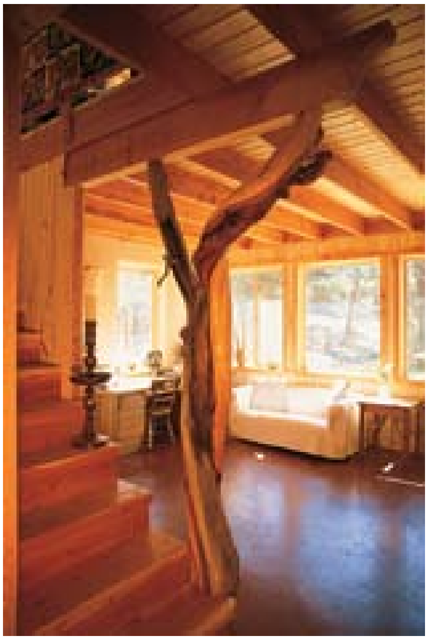
Load-bearing vs. Post & Beam

At this point, you may still be asking yourself, "What system will work best for me?" The answers are not easy, but here are some guidelines we like to use.

The round timber frame creates a dramatic front entry in this British Columbia home.



The load-bearing, juniper tree post harvested from the site adds an artistic touch to this room.



Natural plasters and cement stucco help give load-bearing walls their structural strength. Many co-housing communities are using straw as a building material, such as in this home on Whidbey Island, Washington.

Who will be building the structure? As engineers, we actually discourage load-bearing construction for those unfamiliar with straw bale structures, unless it is a very simple structure. The potential for frustration and a lack of understanding can create a situation no one wants to be involved in.

Load-bearing construction is almost more of an art than a skill. You need to be able to account for the variability and embrace the unknown when something unexpected happens. However, it does save wood, and if labor costs can be kept in check, it can be the right choice for many people.

If the structure has two stories, we almost always opt for post and beam. Another possibility is to construct the first-story walls with a frame and do the second story load-bearing. If you decide to go for a two-story load-bearing structure, some important engineering issues need to be addressed. How complicated is the structure? If it is very complicated with many point loads and few walls to resist wind loads, we will opt for a post-and-beam design due to its predictability.

Who are the owners? Some people may insist on post and beam because they are not comfortable with the idea of "straw holding up the roof." Even though this is not the way it really works (it is primarily the plaster that bears the load, and it is more than strong enough), it may be too difficult to change someone's mind once it is made up.

Wood Content for Straw Bale Wall*

	18 In. Wide Post-&-Beam Wall		18 In. Wide Load-Bearing Wall	
Item	**Materials**	**B. F. / L. F.****	**Materials**	**B. F. / L. F.****
Sill plate	Two, 2 x 4s continuous	1.33	Two, 2 x 4s continuous	1.33
Post, every 9 ft.	Three, 2 x 4s; 8 ft. x 18 in. of 1/2 in. plywood	2.52	None	0.00
Top plate	Two, 2 x 10s; two, 18 in. wide strips plywood cont.; 2 x 10 blocking every 4 ft.	5.46	Same	5.46
	Totals	9.31		6.79

* For 8 ft. tall wall without door, window, or other penetrations
** Board feet of lumber per lineal foot of wall

This two-story, post-and-beam straw bale home is in an urban environment in the heart of Montreal.

In a post-and-beam house, beams can be exposed on the interior, as shown in this Charlemont, Massachusetts, home.

No Black & White Answers

As with many issues related to the construction of a building, the answers are rarely black and white. You need to apply both common sense and the experience of those who have done these things before.

To choose a bale wall system that will fit your project, decide who will be doing the work, look at the complexity of the structure, and consider who owns and will occupy it. Also, how comfortable are you working with a system with lower tolerances than is typically acceptable on a construction project? Good luck in your straw bale building, whatever wall system you choose.

Access

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The New Strawbale Home, Catherine Wanek, 2003, Hardback, 188 pages, ISBN: 1-58685-203-5, Gibbs Smith, Publisher, US$39.95 from Black Range Films & Natural Building Resources, 119 Main St., Kingston, NM 88042 • 505-895-3389 • Fax: 505-895-3326 • blackrange@zianet.com • www.strawbalecentral.com • Books & videos about natural building

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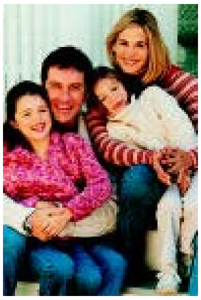

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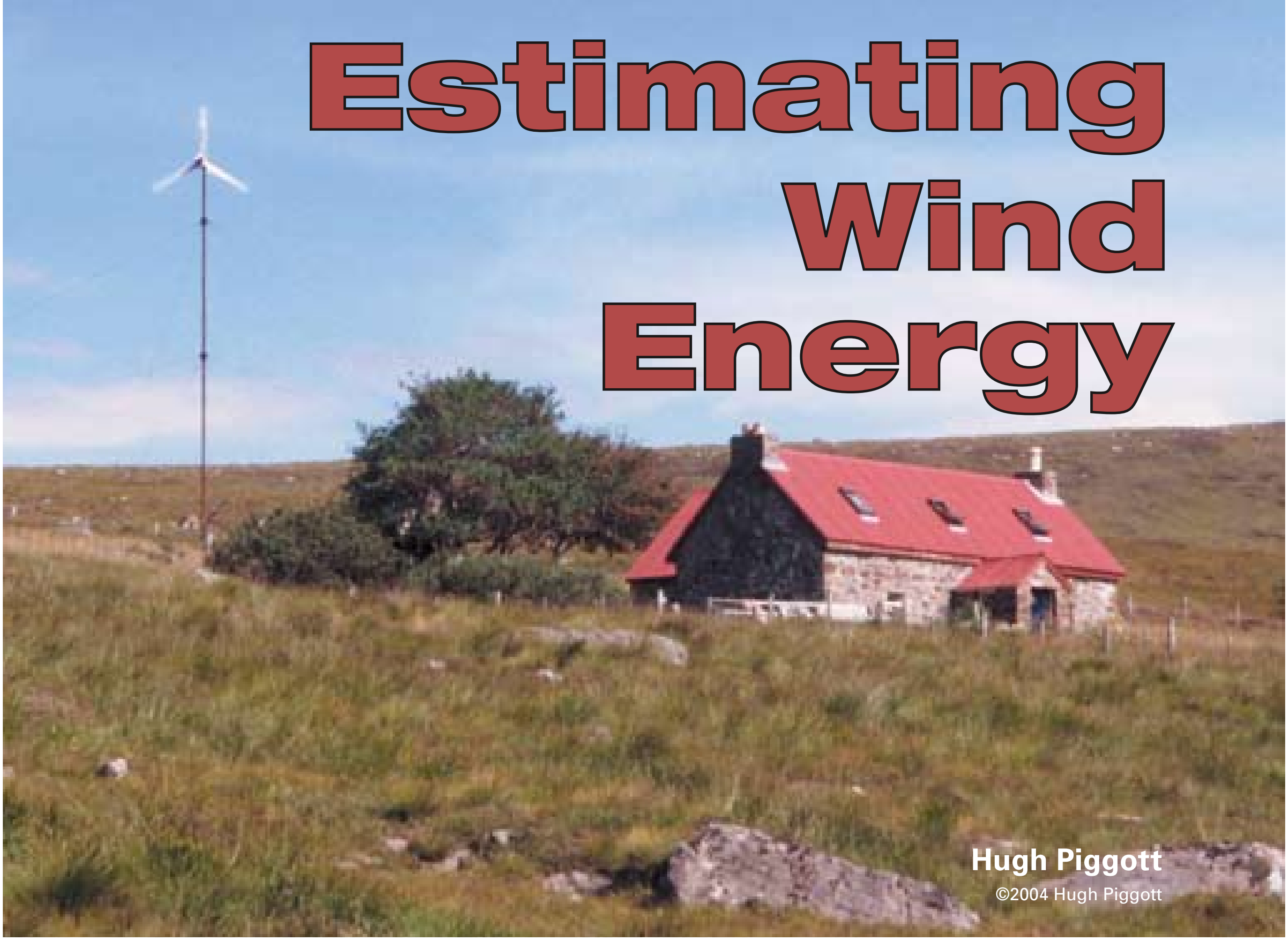


This AWP 3.6 turbine has a comparatively large, 3.6 meter rotor diameter, and produces well in low winds as a result.

What can you run from a wind turbine? How much does it produce? What size turbine do you need to power your home? This article will begin to help you answer these questions.

Wind generators are sold with power ratings. For example, a particular model might be advertised as "1 kilowatt" (1,000 watts). But you cannot conclude that it will produce energy at the rate of 1 kilowatt all the time. In fact, it will only produce its rated output a very small percentage of the time.

Few energy sources are as variable as the wind. A wind turbine is designed to deal with a whole range of wind speeds, often from 3 meters per second (7 mph; 11 kph) to 12 m/s (25 mph; 40 kph). You will only see the advertised output in strong winds. The average output is going to be a fraction of the advertised output because the wind is rarely high enough to enable rated output.

The Power & Probability of Wind Speed chart illustrates what happens at different wind speeds on a typical site, where the average (mean) wind speed is 5 meters per second (11 mph). One curve shows the power available at each wind speed. The second curve shows "probability" of the wind speed—in other words, the percentage of the time for which the wind will blow at that speed. The wind turbine might produce 1,000 watts at the highest wind speed shown, but it only occurs for 3 percent of the time.

You will typically need a battery to store the energy produced by your wind turbine, and to make the energy available when you need to use it. The peak power output of the wind generator in windy weather is therefore not very important. What matters is how the actual power output averages out into energy production (kilowatt-hours) over a period of time, and whether that energy total meets your needs for that same period.

Average Energy Use

You can convert between the average power and the kilowatt-hours of energy per day, month, or year by knowing the number of hours involved. For example on a daily basis, 100 watts average output translates into the following amount of electrical energy per day:

100 watts x 24 hours =
2,400 watt-hours ÷ 1,000 = 2.4 KWH

On a monthly basis, that means:

100 watts x 720 hours ÷ 1,000 = 72 KWH.

Here in the UK, the average person's domestic electricity needs average out at 210 watts, or:

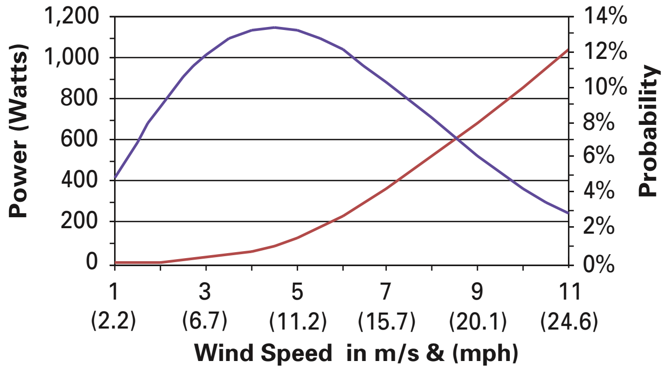
210 x 24 ÷ 1,000 = 5 KWH

With energy efficiency measures, this demand can easily be reduced by half. See Scott Russell's load analysis article in this issue for help with predicting your energy needs.

Wind Speed & Swept Area

Energy production from wind turbines depends on two main variables—wind speed and blade rotor diameter. The fuel is the wind. The wind speed and the amount of that wind you can catch with the blades are the best indicators of the useful output.

Power & Probability of Wind Speed



The author with a Windseeker turbine. Rated power is 500 watts, but the diameter is only 1.5 meters. This machine is rated at a high wind speed. It will not capture much energy in low winds.

If you have a rotor that sweeps a large area, exposed to a good wind, you can get plenty of energy. Finding out the average wind speed for your site and tower height is no simple task, but there are good books to help you. Paul Gipe's *Wind Power for Home and Business* is one (see Access).

This assumes that the machine does a good job of converting the wind's energy into electricity. Conversion efficiency varies somewhat, but there is an upper limit that no manufacturer can break through without breaking the laws of physics. Manufacturers will publish figures for energy production, but it is a good idea to check these and see how realistic they are. Maybe their product is super-efficient, or maybe they are hyping it up a little.

A Rough Guide

As a rough guide, the average power output equals the cube of the wind speed, times the square of the diameter, divided by "X." The constant X depends on the efficiency and the units used. The ultimate theoretical best value of X is just under 1.25 for metric units (meters and meters per second) or 150 for "English" units (feet and mph).

But this theoretical case is like a car without friction—a nice idea, but it's not going to happen. In manufacturers' data, X often comes out close to 3.5 (420 for English units), and this is around the limit of credibility. In the real world, it is maybe safer to assume that X equals 5 for metric units, and X equals 600 for feet and mph.

There is no point in trying to be precise with this calculation. There are too many uncertainties. It is unlikely that you will have a very accurate idea of the average wind speed on your site, and the energy produced is very sensitive to wind speed. So I do not recommend trying to predict energy figures to several decimal places.

Example

Average output from a wind generator equals:

(wind speed in mph)^3 x (rotor diameter in feet)^2 ÷ 600

Estimated Average Power

Average Wind Speed		Avg. Power (W) for Rotor Diameters			
m/s	mph	1.0 m 3.3 ft.	2.0 m 6.6 ft.	3.0 m 9.8 ft.	4.0 m 13.1 ft.
3.0	6.7	5	20	50	90
5.0	11.2	25	100	225	400
7.0	15.7	70	270	600	1,100

Site with average wind speed of 5 m/s (11 mph). Data generated by WindCad from Bergey Wind Power Co.

For example, take an average wind speed of 4.5 m/s or 10 mph (16 kph), and a rotor diameter of 3 meters or 10 feet. The cube of 10 is 1,000, and the square of 10 is 100. Multiply them together and divide by 600 to get 167 watts average power output. Energy per day would be:

24 hours x 167 watts ÷ 1,000 = 4 KWH

You can be reasonably confident that you will get about 4 KWH on an average day. If there is no wind on one day, you will get nothing. Another day you might get much more.

Losses

Do not forget that you will lose energy in the process of storing it in the batteries and taking it back out. Twenty percent or more of the energy can be lost in this way. Another loss in a stand-alone system is the dump load that regulates your battery charge rate. If the battery reaches full charge, surplus energy will be dumped into heat. This is inevitable unless you have such a huge battery that it never reaches full charge, which would be both expensive and foolish. The battery needs to be fully charged regularly or it will deteriorate.

Batteryless grid-intertie systems do not suffer these issues with battery storage, but you still have to take account of the efficiency of the inverter that converts your wind-generated electricity into utility-grade AC electricity.

This LMW has a diameter of 5 meters. With its large rotor and tall tower, it is ready to catch the slightest wind.

Use the Wind

Wind energy is free, so let's use it. If we are careful, it can meet our needs and free us from the unwelcome side effects of other energy sources. I hope this short article has helped you understand what you can realistically do with the wind blowing past your door.

Access

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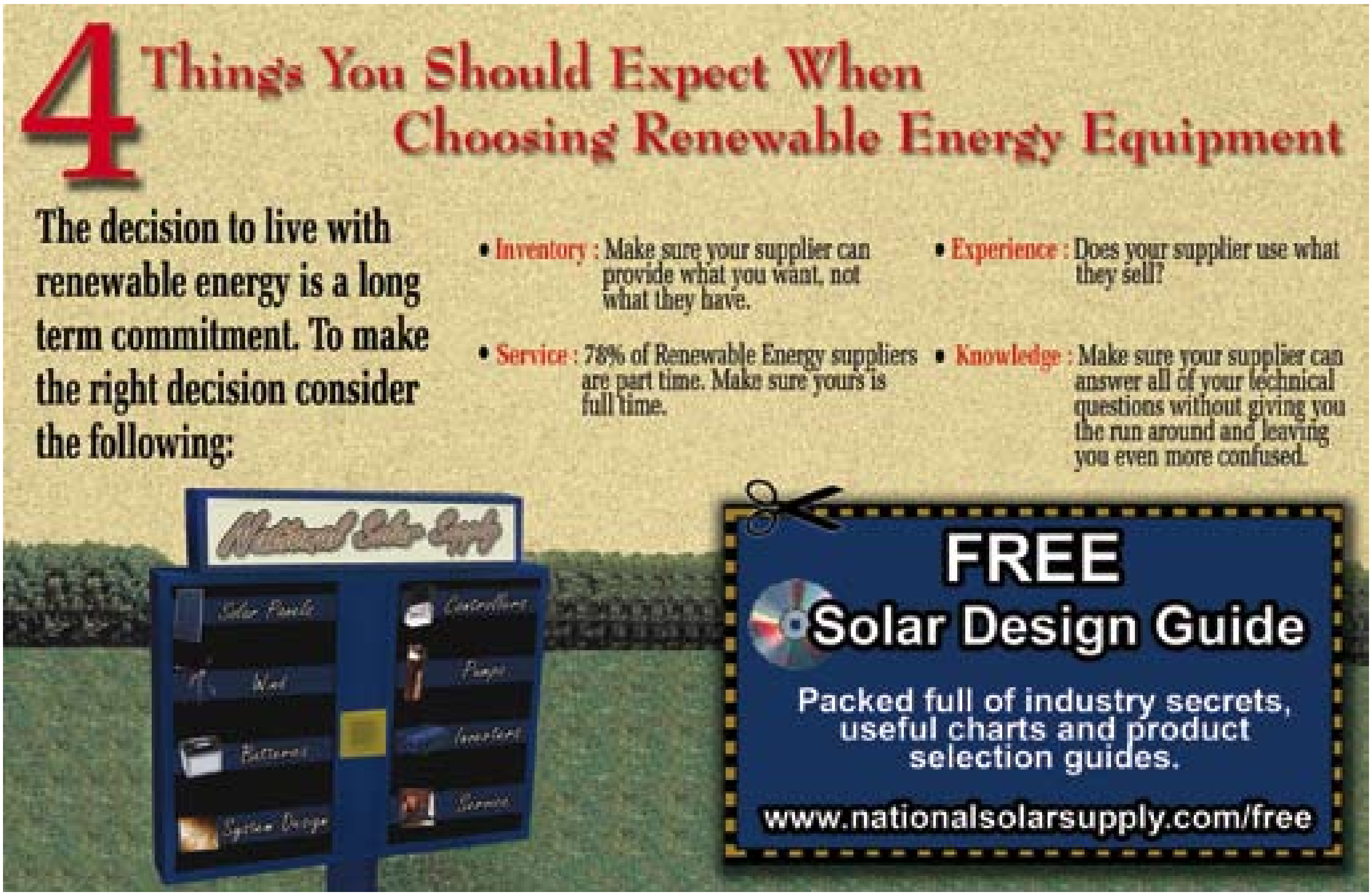
Bergey Wind Power Co., 2001 Priestley Ave., Norman, OK 73069 • 405-364-4212 • Fax: 405-364-2078 • sales@bergey.com • www.bergey.com • WindCad Turbine Performance Model spreadsheet

"Apples & Oranges 2002: Choosing a Home-Sized Wind Generator," Mick Sagrillo • *HP90* and available on the *HP* Web site.

Wind Power: Renewable Energy for Home, Farm, and Business, Paul Gipe, 2004, Paperback, 498 pages, ISBN 1-931498-14-8, US$50 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


4 Things You Should Expect When Choosing Renewable Energy Equipment
The decision to live with renewable energy is a long term commitment. To make the right decision consider the following:
• Inventory : Make sure your supplier can provide what you want, not what they have.
• Experience : Does your supplier use what they sell?
• Service : 78% of Renewable Energy suppliers are part time. Make sure yours is full time.
• Knowledge : Make sure your supplier can answer all of your technical questions without giving you the run around and leaving you even more confused.
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Renewable Energy Education in the Northwest

Paolo Savelli

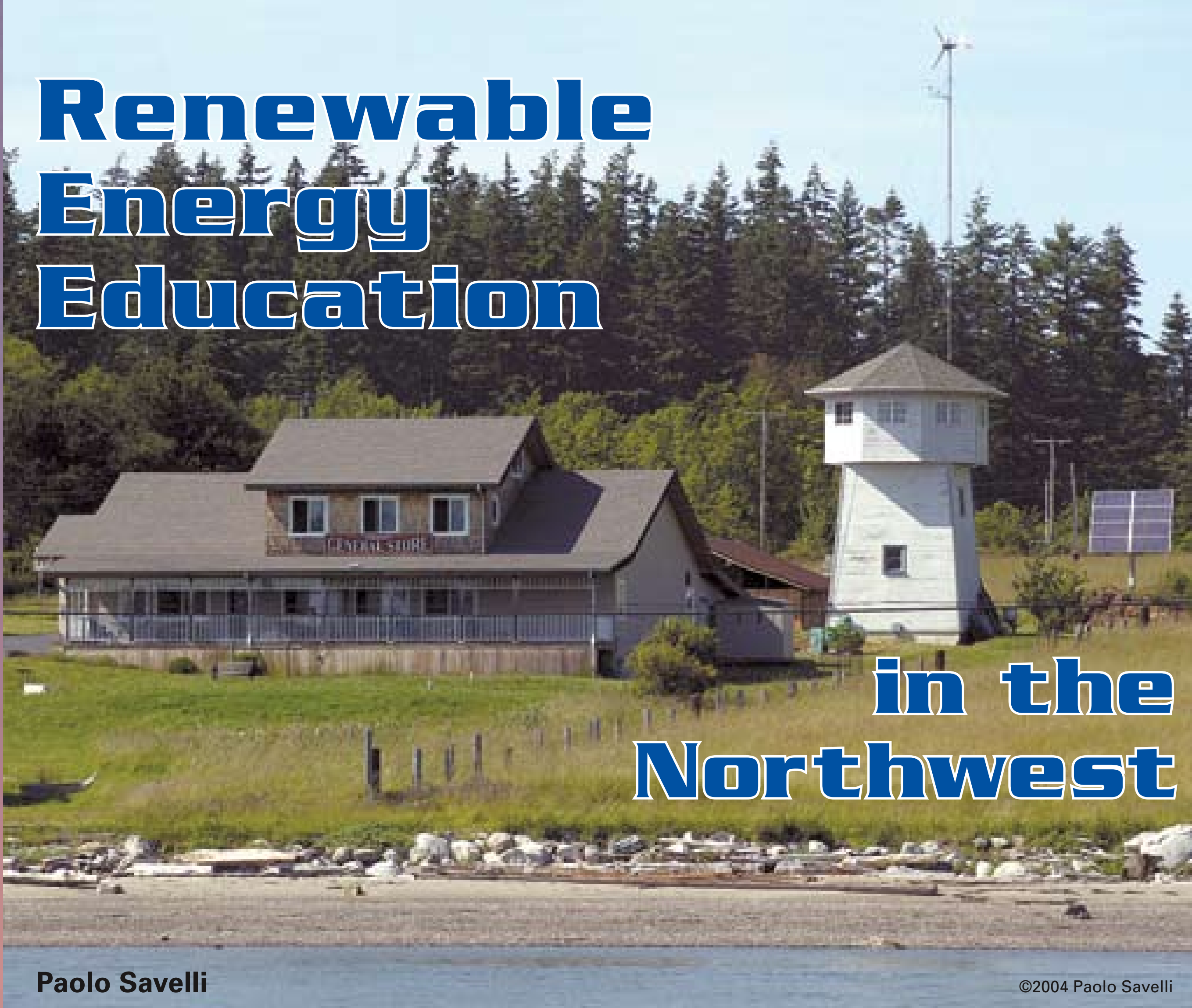


Photo by www.joshroot.com

Anderson's General Store with its wind generator and PV array—as seen from the Guemes Island ferry.

It was a long two weeks, and I learned more than I ever thought possible about wind and solar-electric systems, and renewable energy in general. Solar Energy International (SEI) put together two workshops back to back in the middle of October on Guemes Island, home of Ian Woofenden, senior editor of *Home Power* and our host for the two weeks. The first workshop was "Solar-Electric Design and Installation" and the second was "Wind Power." Since I had a strong interest in wind energy and knew next to nothing about photovoltaics (PV), I went to Washington State to learn about these two exciting technologies.

I grew up mostly in Europe, where I was exposed to frequent shortages of electricity and subsequent shortages of water (no electricity means no electric pumps). Some of my memories of growing up were of our family maintaining our bathtubs and assorted containers full of water (whenever the water pressure was up) so that we would have drinking, cooking, and cleaning water available whenever there was no running water.

Because I frequently travel back to Europe, I am regularly exposed to their more energy aware and energy efficient culture. I bring this back to my home in Rochester, New York, and try to live as energy cheap a life as I can. But I felt that I could do more, so one of my goals in attending these workshops was to see if I could step it up, and both increase my energy conservation and find ways to actually generate some of my own energy.

Photo by www.joshroot.com

Charlotte Anderson Clifton proudly shows off their store's magazine rack, while her husband Dave minds the till.

Instruction

Both weeks were chock full of instruction. The workshops were really made up of four distinct parts:

Classroom sessions. In the classroom we learned theory, were introduced to concepts and technologies, and looked at slides of existing PV and wind systems.

Field trips. There were two flavors of field trips. The first involved visiting on and off-grid renewable energy homes. The second involved visiting manufacturers of renewable energy components.

Informal evening sessions. Guest speakers were invited to the Guemes Island Resort every evening, and after brief presentations, would engage in question and answer sessions with the students. For those staying in Guemes House, the main "lodge" at the resort, these discussions would usually start up again around coffee in the morning and usually around the dinner table as well.

Hands-on. The heart of the training was installation of solar-electric and wind-electric systems (complete with tower) for a grid-tied RE system. This made up the bulk of the hands-on training, but there was also quite a bit of exposure to various tools and components used in setting up renewable energy systems.

First Week—Solar-Electric Workshop

The Solar-Electric Design and Installation workshop took place during the first week. Our main instructor was E. H. Roy of Stewartstown, New Hampshire, who was a wealth of knowledge, both on the technology of solar electricity, and on the business end.

The general goal for the workshop was to be able to evaluate a potential site and decide how to add PV to it. To do this, we learned many things:

- How to determine the site's electrical loads and how those could (and should) be reduced
- How to match the PV array to those loads
- Where to locate the PV array based on shading and what season the energy from the PV array was most likely to be used
- How to wire systems, taking into account voltage drop based on wiring resistance
- How to compensate for basic inefficiencies in the various components

To make sense of all this, we also learned some basic electricity theory, and the immutable relationship between volts, amps, and ohms. We learned about maintenance and care of a PV system (especially batteries), and we learned about safety. Finally, as a way to stress what we had learned, we designed a PV system and installed and wired all the component parts of that system on a real site.

To point out design constraints and technologies, we visited a number of homes on the island that use PVs as a source (sometimes the only source) of electricity. One home, the Buchmans', built entirely with renewable energy and conservation in mind, was particularly inspiring. It was fueled by an array of twelve Shell SP150s, wired in parallel and series to generate 1,800 W at 48 V. The energy

Background: Sunrise over Mt. Baker as seen from the Guemes Island Resort.

Anderson's General Store System Tech Specs

System Overview

System type: Battery-based, grid-intertied, PV and wind hybrid
Location: Guemes Island, Washington
Solar resource: 4 average daily peak sun hours
Solar production: 90 DC KWH per month average
Wind resource: 7 mph (3 m/s) per month average
Wind production: 59 DC KWH per month average

Wind Turbine

Wind turbine: Homebuilt by SEI students, Hugh Piggott axial design
Rotor diameter: 8 feet (2.4 m)
Energy output: 75 DC KWH at 12 mph (5.35 m/s)
Power output: 500 W at 22 mph (10 m/s) peak
Wind turbine controller: Xantrex C40
Tower: 80 foot Southwest Windpower tilt-up kit (2.5 inch, schedule 40, galvanized steel pipe)

Photovoltaics

Modules: 8 Shell SP140s, 140 W STC, 24 VDC nominal
Array: 1,120 W STC, 48 VDC
Array disconnect: 60 A
Array combiner box: OutBack PSPV combiner with 15 A breakers
Array installation: UniRac U-PT/128L mounted on 20 feet (6 m) of galvanized 6 inch schedule 40 pipe, south facing, 45 degree tilt angle

Balance of System

Inverter: Xantrex SW5548, 48 VDC input, 120 VAC sine wave output
PV charge controller: Blue Sky Solar Boost 3048DL, MPPT, PWM
Wind charge controller for diversion load regulation: Xantrex C40, PWM
System performance metering: RightHand Engineering Winverter software; two Xantrex Link 10 AH meters; NRG Windwatcher and Clean Energy Products recording anemometers

Energy Storage

Batteries: 4 Interstate VRLA AGM, 12 VDC, 100 AH at the 20-hour rate
Battery pack: 48 VDC, 100 AH total
Battery/inverter disconnect: 250 A

is inverted using an AEI Multi-Mode grid-tie inverter that provides electricity to the house and feeds any excess to the grid. With Washington's net metering law, the Buchmans can bank surplus energy credit in the summer, and generate almost all of their energy with their solar-electric array. Their total electricity bill for the last year was US$60.

In addition, the inverter keeps a bank of batteries charged for limited backup in the event of a utility outage. This home was inspiring not only because of its source of energy (PV), but because of its very efficient use of energy. All of the appliances were chosen for their limited energy requirements, and all appliances that are phantom loads are on switches, so they can be totally disconnected when not in use, and thus reduce the load.

We also visited the Xantrex and OutBack Power manufacturing facilities. Inverters are the bread and butter products of both of these companies, although they also make other components for RE systems. Visiting these facilities exposed us to some of the engineering, marketing, and regulation constraints that these outfits have to deal with when building new products. Indeed, at both locations, we learned of upcoming new grid-tie inverters that we were told should be market-ready shortly.

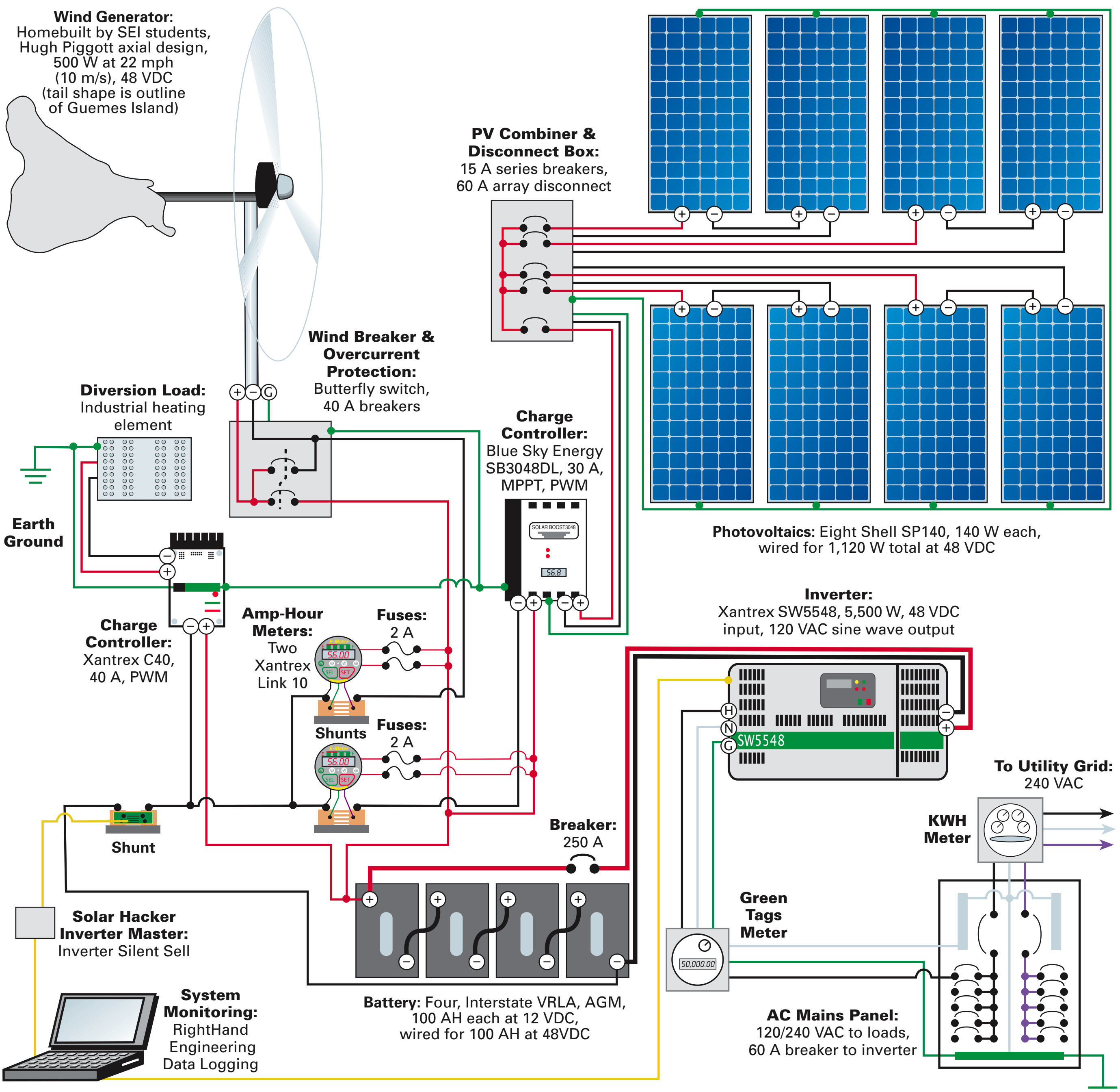
Photo by www.joshroot.com

The store's power room.

Second Week—Wind Power Workshop

My second week in Washington was a very intense workshop on wind turbines and wind turbine installation. Mick Sagrillo of Sagrillo Power and Light, with more than 700 installations behind him, was our instructor for the week. The purpose of this workshop was to learn about wind turbines—wind turbine design, siting, maintenance, and installation.

Relying heavily on past experience and lessons learned, Mick spent a good amount of time discussing the economics of wind siting based on wind speeds at various tower heights, and how to determine wind speed at those tower heights. A large component part of wind-electric systems is the tower, so we learned about different tower types, how to install them, how to maintain them, and what their pros and cons are.



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

We visited a grid-tied home that is powered by wind and PV. An African Wind Power 3.6 provides the wind power. This is a three-bladed, 3.6 meter (12 ft.) diameter wind turbine that is rated at 1,000 W at 48 V. Due to its large swept area, this machine generates even in moderate winds. Indeed, on at least two occasions, we noticed that it was generating electricity (albeit not very much) in as little as 8 mph (3.6 m/s).

The tower was a guyed lattice tower, with three guys every 35 feet (11 m). Part of our training was doing maintenance on this tower and turbine. The tower maintenance consisted of checking for any loose bolts or guy cables, and checking for rust both at the ground anchors and at the tower anchors. The turbine maintenance involved inspecting the turbine for wear, cleaning the blades (to maintain efficiency), and greasing all pivot points.

All these things seem easy enough, but they are quite daunting and challenging when you are hanging from a harness 140 plus feet (43 m+) in the air. Besides the obvious tip of not looking down, another good tip is to not look up, since the moving clouds lend the impression that the tower is falling.

Hands-On PV & Wind Installations

Both weeks were set up around the installation of a grid-tied, battery-backup wind and PV system. The project was at Anderson's General Store at the ferry dock

SEI students Larry Owens (left) and Tom Brenton fastening PV modules to the top-of-pole rack.

on Guemes Island. The site is a south-facing slope with great solar and wind exposure. In addition to generating electricity, the site was chosen as a demonstration site. The store is right at the island's ferry terminal, and the project will attract curious passersby and introduce them to renewable energy.

The generating sources consist of an array of eight Shell Solar SP140 PVs, and a homebuilt, 8 foot (2.4 m) diameter wind turbine perched on an 80 foot (24 m) Southwest Windpower tilt-up tower. The PV panels are wired in series and parallel to generate 1,120 W at 48 VDC. The wind turbine, built in the April 2003 SEI Homebuilt Wind Generators workshop, generates about 500 watts in a 22 mph (10 m/s) wind.

Since about 25 students were in each workshop, we broke up into teams to install all the components. In the PV workshop, one team wired the PV modules, another mounted them, and a third team ran the conduit to the building. There was also a team that first laid out and then installed the inverter, controllers, and batteries.

Everyone was urged to rotate among teams to get exposure to the various parts, and although the instructors were always present, their main goal was to advise, steer, and mostly get out of the way. It was a good learning experience, and it became obvious that although the wiring diagram may have appeared straightforward on the white board, the actual wiring was no easy task. We ended up working late most nights getting the system up, and were rewarded by AC output late on the last day of the workshop.

A handful of us from the first week stayed on for the wind workshop. Joined by new students, our job was to install and wire the wind turbine into the same system. Given the forces that are levied against a tower-mounted generator, it is important to ensure a very strong tower installation. Much of our hands-on experience revolved around that.

Fully installed turbine. The two anemometers supply wind data, which is accessible at the tower base and inside the power room.

After a first half-day of introduction and basic theory, the group marched outdoors in the Washington wind and rain. We spent the rest of the daylight hours and the first twilight hours measuring out and locating tower anchor points and mixing and pouring concrete to set the anchors. It was necessary to do this early in the week to ensure that the concrete would be cured by the end of the week, when the tower would be erected.

As with the solar crew, we broke up into teams focusing on specific tasks. Although the tower erection was daunting and quite intimidating, it proved to be less of a bottleneck than the wiring of all the components in the control room. No doubt the wiring should become easier with experience, but it is a testament to how hands-on these workshops were that as students we wired, and then rewired, and rewired away our mistakes instead of just having an instructor do it right the first time.

For this installation, Kelly Keilwitz of Whidbey Sun & Wind was the site supervisor. Kelly was always present to steer us in the right direction. In addition, he put countless miles on his biodiesel Ford to pick up whatever connector, wire, or conduit was missing for the task at hand.

Proud PV installation workshop group after connecting the Anderson's Store PV array to the power system and the grid.

certainly so much of what we covered about system components in the PV workshop made the wind workshop more understandable and enjoyable to me. If I had any complaints, I suspect this would be it—the wind workshop contained an enormous amount of advanced information, and I believe I would have been overwhelmed without the preceding PV workshop.

I came to these workshops with three very specific goals: to learn more about the technologies of renewables; to learn more about the economics of renewables; and to meet other members of the renewable community. I can honestly say that those goals were met and I am seriously considering returning to Guemes Island for the wind turbine building workshop.

Access

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Place & People

Guemes Island is a truly beautiful place, and I would recommend visiting it just for the bald eagles, sea otters, and herons. It is a bit remote—only accessible by ferry—but that just adds to its charm. Be forewarned, if you come out to one of these sessions, read the information packet and arrive prepared. The island is not the big city with all the conveniences you might have at home. You'll certainly want to pack enough clothes for the week, and definitely bring your rain gear.

The students and guest speakers stayed at the Guemes Island Resort, an older, low-key facility that sits right on the edge of the beach. You couldn't have asked for a more picturesque place, with views of Mount Baker and access to boats, kayaks, and crab pots.

The students were as big a part of the education process as the instructors and guest speakers. The slice of cultures that made up the student base was amazing—from a Pennsylvania-based river guide, to a retired airline pilot living on a 2,500 acre ranch in Utah, to an off-grid fishing guide living with his wife and two children on a remote island in Alaska. Everyone was eager to learn and eager to help, and it seemed that someone always had a legitimate and useful contribution right when you needed it.

More to Learn

It was a great two weeks. I would recommend it to anyone who is interested in learning more about these two renewable technologies in specific, and renewable energy in general. I was glad that I took the two workshops instead of just the wind workshop. I don't know that the PV workshop should be a prerequisite for the wind workshop, but

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

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Mick Sagrillo, Sagrillo Power & Light, E3971 Bluebird Rd., Forestville, WI 54213 • 920-837-7523 • msagrillo@itol.com • Wind instructor

Kelly Keilwitz, Whidbey Sun & Wind, 986 Wanamaker Rd., Coupeville, WA 98239 • Phone/Fax: 360-678-7131 • sunwind@whidbeysunwind.com • www.whidbeysunwind.com • Installation coordination

Project Sponsors

Anderson's General Store, 7885 Guemes Island Rd., Anacortes, WA 98221 • 360-293-4548 • Fax: 360-299-9798 • www.guemesislandstore.com

Abundant Renewable Energy, Newberg, Oregon • www.abundantre.com • Dump load

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All Creatures Under the Sun

My Solar Powered Barn

Penny Loeb

Angel the donkey enjoys her solar powered barn.

In the winter of 2002, I decided to build a small horse barn on the two acres I own behind my house in Great Falls, Virginia, a semi-rural area near the Potomac River. One day, as I was making one of numerous daily walks between my house and the construction site, it dawned on me—why not use photovoltaics to power my little barn?

I have been committed to renewable energy since 1977 when the fuel oil bill hit US$1,500 a season at my mother's 200-year-old colonial in Dutchess County, New York. I took a course on energy sources at the state university at New Paltz (where the state's first Green Party mayor recently took office). Eight years later, just before the federal renewable energy tax credits expired, I built a passive solar house, with a roof full of solar hot water panels for space heat and domestic hot water. I also installed a wind generator on a very windy hillside. It all worked quite well, but I had to sell the house when my career took me to northern Virginia in 1993.

When we were searching for a new home, the one we liked best already had solar hot water panels. I would come to discover that this northwest corner of Fairfax County has dozens, maybe hundreds, of homes with solar hot water, courtesy of those tax credits. In fact, when the panels had to be moved this year for a new roof, the very same contractor who did the original installation showed up to move and then reinstall the panels. The system, which hadn't been checked in 10 years, still works perfectly.

I didn't do a lot of research on the photovoltaics for my barn. I just searched the Web for companies in the Washington metro area. At first, I thought it would be too expensive. The first company I called quoted approximately US$10,000 for an AC system. That was too much for a 24 by 36 foot (7.3 x 11 m) structure with two horse stalls, a tack room, and feed area.

DC System

But a few days later, I realized that maybe I could do with just a DC battery setup. This time, I tried Atlantic Solar Products in Baltimore, Maryland. In about a week, Mike Howell came to look at the barn, and within days I had a price. Most important, Atlantic would be able to install the system.

Tut, a retired racehorse and great grandson of Secretariat, stands under a solar powered fluorescent light and ceiling fan.

Tech Specs

System Overview

System type: Off-grid PV
Location: Great Falls, Virginia
Solar resource: 4.5 average daily peak sun hours
Production: 12 DC KWH per month average

Photovoltaics

Modules: 2 Solarex SX-60U, 60 W STC, 12 VDC
Array: 120 W STC, 12 VDC
Array disconnect/overcurrent protection: terminal block with 15 A fuses
Array installation: Zomeworks GMSOL2 ground mount, south-facing, 60 degree tilt

Balance of System

Charge controller: SunSaver, SS10L, 10 A controller with LVD
Battery: Concorde PVX-12105, 12 VDC, 105 AH at the 24-hour rate
System performance metering: Bogart Engineering TriMetric 2020

The proposal included two, 60 watt BP Solarex panels. I would have an 18 watt fluorescent light in each of the two stalls, the tack room, the feed room, and the aisle. There would be an 18 watt light outside on one side and a 36 watt light on the other. The lights would be on four circuits, each with a one hour timer switch. The sealed, maintenance-free battery would be installed in a metal box above the door in the feed area. The battery would support the lights for ten days without sun. Components cost US$1,910, and installation was US$880.

Mike and his associate, George Stulock, came early on a morning in the middle of May. Installation took about six hours. Since the barn has no ceiling, they put 2 by 4s across the rafters as bases for the lights. Heavy-duty wire was run from the panels to the battery and from there to the lights. They were finished by 3 PM, so they could get on the Beltway around Washington and back to Baltimore ahead of the god-awful, rush-hour traffic.

Adding Fans

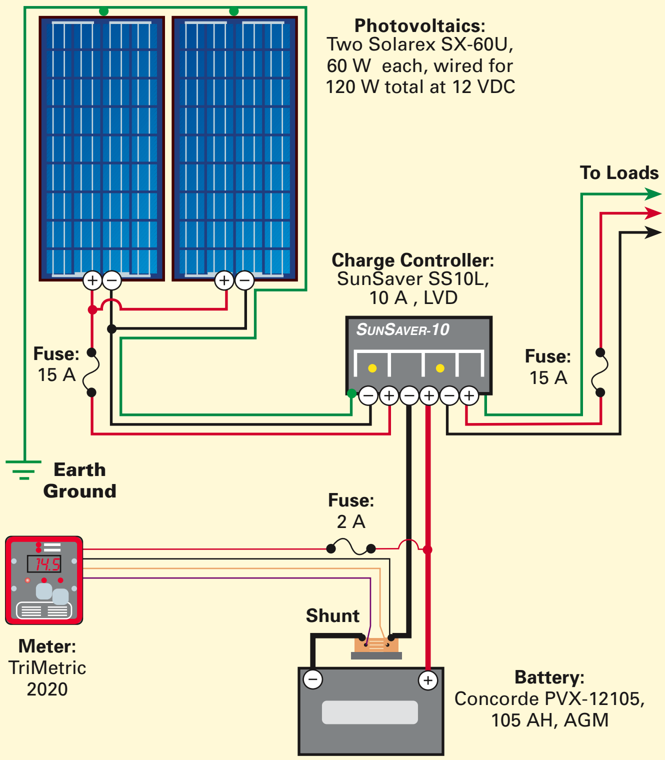
I was very content until July approached. Then came the second hottest summer in the last century. I e-mailed Mike: Could we install DC-powered fans? He and I both found the same vendor on the Web—fanworks.com. RCH Fanworks builds the most commonly used DC-powered ceiling fans. Three fans cost US$462 (one in each stall and one in the aisle), and installation by Atlantic Solar would be US$65 an hour.

This time, George came by himself on July 3, just as the ghastly heat and humidity rolled in. In three hours, he was finished. Luckily, he went off to buy me a new fluorescent light, and I tested the fans. Oh lord, they didn't seem to send out any cool breezes. I looked at the ceiling fans in the house and determined that the ones in the barn were spinning backwards. George agreed—something was amiss. Must need to reverse the polarity, he thought. But we wanted to be sure. I tried calling the company. The owner's son answered and said that his dad was at the laundromat. Fortunately, Foster Hankins called back just as George was leaving. Yes, it was the polarity. The change took about a minute.

The fans work great, and I even left them on 24 hours many days last summer. Only once or twice did the load of the fans and lights drain the battery low on a string of cloudy days. The battery level indicator light warned me to shut something off.

The solar-electric system has been running for a year. I have only one small complaint. I found that the fluorescent lights dimmed somewhat on really cold days. Switching from GE to Phillips brand solved that problem. The blacksmith, who shoes my horse, would like AC power for his equipment, but he is grumblingly making do.

Loeb PV System



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

System Costs

Item	Cost (US$)
Installation	$880.00
2 Solarex SX-60U, 60 W modules	620.00
Outdoor floodlight, 36 W	201.00
Battery enclosure	167.00
Outdoor floodlight, 18 W	162.00
TriMetric AH meter with shunt	160.00
5 Indoor lights, 18 W	158.25
Concorde PVX-12105, 105 AH battery	150.00
Zomeworks GMSOL-2 mount	108.00
4 Twist timers	100.00
SunSaver SS10L, 10 A controller w/ LVD	56.92
Output wiring kit	20.91
Module wiring kit	5.45
Total	$2,789.53

Solar Option

Running electricity from the house would have cost at least as much as installing the solar-electric system. A second breaker panel would have been needed for the barn.

The barn uses approximately 59 KWH a year for lights and about 14 KWH for the fans. This adds up to a tiny savings of about US$7 on my utility bill. The real savings came in avoided installation costs of conventional electricity. The rewards come in burning a little less fossil fuel—electricity in Northern Virginia comes mainly from coal.

I would highly recommend this system to anyone building a small barn or shed for animals, especially if it is a distance from any house or utility source. Conestoga Buildings, the company that built my barn, constructs about 700 barns and sheds a year in the mid-Atlantic region. I am hoping it, and other barn companies, will inform their customers about the solar option.

Access

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RCH Fan Works, 2173 Rocky Creek Rd., Colville, WA 99114 • 800-529-6306 or 509-685-0535 • Fax: 509-684-5199 • info@fanworks.com • www.fanworks.com

Conestoga Buildings, 202 Orlan Rd., New Holland, PA 17557 • 800-544-9464 or 717-355-9170 • www.conestogabuildings.com

Good cost comparison of DC solar-electric systems to the costs of extending utility lines • www.mme.state.va.us/de/chap7c.html

Good basic primer on solar energy • www.randtel.com/general/basic-solar-help.html

Community TV with PV

Laurie Stone

Neighbors line up to see the shows at the TV *sala* in Los Tumbos, Pinar del Rio, Cuba.

Throughout the developing world, people in rural areas want electricity. After water pumping and lighting, the next priority for most people is television.

I grew up as a TV junkie, and for years could have aced any *Brady Bunch* trivia game. However, once I hit my early twenties, I gave it up for good. I threw out my TV and decided to immerse myself in books and saving the world. While I haven't quite reached my second goal yet, I thoroughly enjoy not owning a TV. Ironically, now that I work in the rural electrification field, I find myself once again wrapped up in the television culture.

Revolutionary Television

Cuba's revolutionary *Programa de Salas de Televisión*, or TV Room Program, has brought solar powered television to half a million people living in rural areas without grid electrification. Before you start thinking *Who Wants to Be a Millionaire?* and *The Osbornes*, be aware that the Cuban program is using television to educate rural people in many important cultural and social matters.

The program began in May 2001. Cuba had already been electrifying rural communities with photovoltaic modules (PV) for more than a decade. After the revolution of 1959, Cuba was trading oil for sugar with the Soviet Union at very profitable rates. With the collapse of the U.S.S.R., Cuba had to buy oil on the world market at prices they couldn't afford. Thus began a big push for renewable energy. In 1989, the nongovernmental organization Cubasolar electrified the first rural health clinic in the country with PV. Since then, Cubasolar, along with the renewable energy company Ecosol, has electrified all of the rural health clinics in the country (see *HP66*).

Each health clinic (called a family doctor clinic since the doctor lives above the clinic) was equipped with a TV and a VCR to show educational health videos. Unfortunately, since it was the only television in town, the doctor did not

Some of the standard TV *sala* equipment—TV, inverter, controller, batteries, and VCR.

Video *Sala* Costs

Item	Load (W)	Cost (US$)
2 PV modules, 165 W ea.		$1,470
Television	120	324
4 Batteries, 6 V, 220 AH		320
VCR	22	95
Prowatt inverter, 300 W		80
Isoler controller, 20 A		55
2 Lights	30	30
TV antenna		7
	Total	$2,381

get any rest because of people coming by to watch the tube. So the Cuban government decided to put a TV/video center for the general public in each community. Thus began the Programa de Salas de Televisión.

Solar Electrification

After studying each of the rural communities not hooked up to the grid, and evaluating the best way to build the *salas* (TV rooms), construction began. In the first stage, 790 salas were built in off-grid communities having the largest populations. In the second stage, communities having microhydro plants that don't run throughout the dry season and communities with poor electrical service from the grid were included. Cuban-manufactured photovoltaic panels power all of these video rooms.

The electrification process was similar to that which Cuba used to electrify all 1,997 rural schools with PV (see *HP86*). The same brigades of workers who installed the systems at the schools installed the systems at the salas. The employees of the salas were trained in the maintenance of the systems. Every three months, a technician from Ecosol visits each community to check on the systems at the health clinic, school, and video room.

Now, all 1,885 video salas in the rural communities are powered with photovoltaics. Of those, 1,157 have a 30-person capacity, and 728 have a 50-person capacity. Each sala employs four people selected by the community members. In this way, the program has created 7,540 new state jobs, mostly among women and youth.

The system is sized to operate without the VCR for ten hours per day, with the VCR for eight hours per day, and for three days of autonomy. The salas operate throughout the day and night according to the interests of the community.

Community Content

People watch recreational, cultural, informational, political, and children's programs. The salas also receive educational materials that go to the doctors, teachers, and educators in the community. Every sala has received eight blocks of educational materials, each one with six hours of video. Altogether, each sala has 165 educational programs. The themes covered include:

- Health and social impacts of tobacco and alcohol addiction
- Sexually transmitted diseases
- Consequences of domestic violence
- The necessity of mammograms
- AIDS
- Risks of adolescent pregnancy
- Promotion of a healthy lifestyle
- Benefits of breast feeding
- Benefits of eating vegetables
- Cuban *campesino* identity & traditions
- Cuban history

Some of the communities are also starting libraries in their salas, with the help of the Cuban government. So far, three of the salas have libraries with 25 books each. And they are beginning to equip the salas with chess games. Their goal is to have four chess boards in each sala as "another form of bringing in new knowledge and a healthy distraction to these remote places," according to one of the directors of the program, Amado Calzadilla, of Cubasolar Granma.

Tool for Change

Besides being sources of employment, the salas have become central meeting places, which also helps to raise the knowledge of the population. According to Calzadilla, the family doctor, teachers, and members of the organizations that work with women, children, youth, and campesinos all use the instructional and educational videos "to increase the population's knowledge in the important issues of health, culture, the creation of healthy living habits, etc...."

Having lived without a TV for over a decade, and watching my son grow up not only unacquainted with Bugs Bunny, but also loving books with a passion, it's hard to work in rural electrification and see people hooking up to the TV the first chance they get. However, I realize that television, like any tool, has impacts, depending on how it's used. Cuba has shown that powering TVs in rural areas with photovoltaics can make a huge difference in people's lives for the better.

Access

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Lessons:

From Solar-Electric Systems in Belize

Elliot Burch, Jeff Burch, Jim Moore, & David W. Winkler

On a recent trip to Belize to examine PV facilities at remote biological research stations, our team documented a range of issues plaguing their systems. In this article, we will examine these issues and focus on electric load patterns and how inadequate attention to batteries and loads can undermine the success of a solar-electric system.

Programme for Belize's (PFB) Hill Bank field station consists of three separate solar-electric systems. The larger systems are configured with 24 volt battery banks. The largest system, which is rated at 3,880 watts, supplies electricity to the dormitory, followed in size by a 2,756 watt system that provides electricity to the kitchen, main office, and staff housing, and the smallest system, at 500 watts, which powers the manager's house. PFB also operates another field station, the La Milpa site, which is a two-hour drive west, and is powered by a 3,296 watt PV array. The East Gate entry point to the reserve is also powered by a small system that is rated at 900 watts. Battery bank capacities for the 24 volt systems ranged from 2,400 to 1,000 amp-hours (AH) at a C/10 discharge rate.

L to R: The local electrical contractor Orlando Quan and the Hill Bank site manager Victor Alegra with Jim Moore and Jeff Burch in the kitchen battery room.

Signs of Trouble

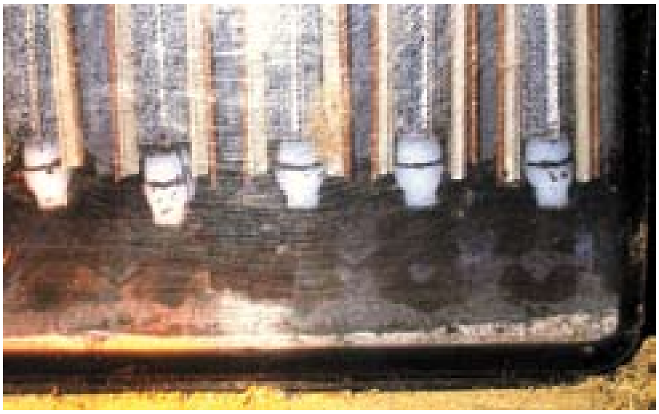
Battery mortality at PFB's biological field stations approached 20 percent (17 out of 84 batteries) after six years of service. Warning signs of system failure were only too obvious (see sidebar).

But why were batteries failing? A typical battery, such as the Trojan T-105, is expected by its manufacturers to undergo about 3,000 shallow cycles to about 80 percent (down 20 percent) capacity if properly charged and equalized. The industrial batteries used in PFB's four solar-electric systems (120 to 200 AH) should have had an even longer life, yet many had begun to fail after only 2,800 significant charge/discharge cycles.

At first we wondered whether the tall, thin shape of the batteries could have caused excessive electrolytic stratification, which diminishes battery function. Varta, however, claims to the contrary that the tall design requires a minimum of gassing (bubbling) during charging phases to ensure a good mixing of the electrolyte. Our data likewise suggests that battery design was not to blame. What did go wrong is the subject of this article.

Symptoms of Battery Failure

- Heavy sulfate deposits in bottom of case (Varta batteries have clear cases)
- Low cell voltage as compared to others; < 1.9 V when bank is charged
- Higher cell voltage, well above nominal; excess of 5.0 V per cell
- Minimal cell gassing during equalize mode
- Excessive temperature gain during equalize mode; very warm to the touch
- Specific gravity is low; difference > 0.08 kg/l difference from other cells
- Specific gravity unreadable even after charge; < 1.100 kg/l
- Very quick charge and discharge cycles



Close-up of sulfated battery showing accumulated sulfate in the bottom of the case.

Proper charging, discharging, and maintenance kept these six-year-old batteries in like-new condition.

Deterioration of batteries can be attributed to "hard" sulfation and structural decay. It has been reported that without proper charging of the battery bank (at least once every three days), lead sulfate deposits build up on the plates. If left for more than 72 hours, lead sulfate converts into a "hard crystalline" form that is very difficult to reverse during charging.

Sulfation promotes electrical shorting due to sulfate bridging between the plates, and causes high electrical impedance due to the active plate area being masked by deposits that create barriers to current. Gas bubble entrapment and electrolyte stratification during discharge cycles cause degradation of the plates.

Making the Best Investment

The dormitory system at the Hill Bank Research Station provides a good forum to examine the total price of energy once the batteries have been installed in a functioning PV system. We measured a load of between 6 and 15 KWH per day and a 2,400 AH bank capacity. Costs in Scenario 1 in the table below are based on our measurements at Hill Bank. Although the batteries are at the end of their useful life, the other components, including panels, charge controllers, inverters, etc., will probably last another eighteen years. Over the assumed life span of the system (24 years), the electrical energy exported to run appliances will lie between 132,000 and 508,000 KWH (5.8 to 15.1 KWH per day x 365 days x 24 years). The cost comparison in the table shows the frighteningly high cost of energy in this system lying somewhere between US$0.99 and US$2.59 per KWH.

Scenario 2 is hypothetical. It examines the same PV system at the dormitory with one notable change: the batteries are better managed and last twice as long (12 years). As expected, these tough, industrial batteries should be able to undergo up to 4,500 shallow discharge cycles if well maintained. Note that in the more optimistic cost range, batteries that last twice as long lower the cost of electricity by US$0.27 per KWH.

As a model of good battery performance, we can refer to a system at the East gate, a remote outpost on the Programme's property line. This system had a small load of less than 470 WH per day with 840 AH of battery storage capacity. The solar-electric array generated 900 watts peak. Because loads were so low, this system was rarely discharged to any significant degree. Although the batteries were not regularly equalized, they were in excellent health. The rangers had so much extra energy that they intentionally left lights on during the day for fear that the batteries would overcharge! These batteries looked virtually brand new through the clear cases, with little or no sign of sulfation after more than six years of service.

In hypothetical Scenario 3, the Varta batteries have been replaced with Trojans, which are less expensive and can be purchased locally in Belize. Many installers feel that in smaller systems, the Trojan T-105 is the best battery in terms of cost per stored watt-hour, and if properly managed will provide six to eight years of reliable service. The manufacturer states that the Trojans will undergo 750 deep

Three Battery Scenarios in Belize

Scenario	Individual Battery Cost (US$)	# of Batteries	Life (Yrs.)	Battery Cost (24 Yrs.)	Other PV Costs	Total System Cost	$ Per KWH @ 5.8 KWH / Day	$ Per KWH @ 15.1 KWH / Day
1	$765	24	6	$73,440	$58,000	$131,440	$2.59	$0.99
2	765	24	12	36,720	58,000	94,720	1.86	0.72
3	80	42	6	13,440	58,000	71,440	1.41	0.54

Battery Maintenance Strategies

- During the week, keep most daily discharges within shallow designation—20 percent.
- Discharge to deep level (max 50 percent DOD) not more than once a week.
- Every day, bring the bank back up to nearly full charge (90–95 percent).
- Float charge the bank to 100 percent full charge once a week.
- Equalize the battery bank once a month.

discharge cycles or 3,000 shallow discharge cycles. The table shows that using the T-105s for six years might prove to be the most economical strategy. Even if the Trojan batteries lasted for only three years, the cost for generating electricity would still be cheaper than in scenarios 1 and 2.

The costs for the three battery scenarios in Belize are higher than reported costs for solar-generated electricity from elsewhere (US$0.30 to US$0.40 per KWH). Factors that could account for this discrepancy include cloudy weather and increased shipping costs to Central America for batteries and PV components.

PVs Worked Flawlessly

On the bright side, all of PFB's solar-electric arrays were functioning as planned. At solar noon, the biggest array delivered more than 3,880 watts. Despite the tropical heat and rain, the Kyocera panels (51 watt) showed little signs of deterioration after seven years in the tropical sun.

The Ananda Power PV charge controllers also functioned well, but didn't have a float mode. The array at the dorm system was divided into three groups, each equipped with its own controller capable of regulating up to 48 A at 28 V peak. The three different controllers had slightly different cutoff settings (27.9, 28.0, and 28.1 V respectively), which enabled them to work together, but also allowed the controller with the higher cutoff setting to act as an intermittent float charger. True float charging was available only when the generator was on and electricity was fed back through the inverter on equalize mode.

At the La Milpa field station, a generator was often used to float charge the battery bank. As a result, the batteries at this facility fared pretty well. Unfortunately, at the Hill Bank field station, there were three separate PV systems, but only one of them was conveniently hooked to the generator. The chore of loading the generator into the back of a pickup truck and driving it to the other two systems was only occasionally carried out, even though this step could have postponed system failure and saved many expensive batteries. Maintaining management standards was not easy, since it involved educating a diverse staff whose obligations ranged from being naturalist guides, maintenance workers, gate keepers, and back country rangers.

Problems with Inverters & Chargers

The Xantrex inverters (model SW4024) also performed as designed. However, the design of this inverter promoted excessive bank discharge. The Xantrex inverter disconnects the AC loads when battery voltage drops below a "low battery cutout" threshold for more than a specified time. The default values of 22 volts and 15 minutes were being used at Hill Bank.

Lead-acid batteries can be destroyed if they are excessively discharged. They should never be discharged below 60 to 80 percent of full capacity, and should always be recharged promptly after deep discharges. Unfortunately, the control strategy of all inverters is based only on the voltage level of the entire bank, not on that of individual cells.

Under light discharge rates over long time periods, the bank voltage decreases more slowly than expected and the inverter is able to severely deplete the battery bank. With moderate to high discharge rates, the voltage of the bank is artificially depressed relative to full capacity and the inverter shuts off before depleting the battery bank. The lesson learned was that an inverter's low voltage disconnect

Elliot and Jeff Burch (bottom) check the specific gravity of each cell.

feature should not be seen by the user as a method of normal system regulation, but rather as a last resort method of battery protection.

Loads

Electrical load issues must be understood to prevent system failure. Loads exceeding a system's capacity are not initially planned, but seem to creep in over the years as a facility's program grows. A good example was the 700 watt insect sampler recently installed by Cornell University. The staff assured researchers that there was sufficient capacity in the system to run this sampler under bright skies.

It is now clear that the PV system was already overloaded, and that adding this load further stressed a system already struggling to keep up. Additional PV panels are needed. Our calculations indicate that the electricity for the insect sampler could cost up to US$1.54 per KWH (average rate for scenarios 1 and 2). If the researchers were charged for this, the field station could use this revenue to upgrade and maintain their solar-electric system.

An additional research device, which had been installed a few years earlier by another institution, uses 75 watt incandescent lightbulbs to dry plants. Although this dryer was used only a few months each year and it is unknown how many of its fourteen lights were used at a time, its peak energy consumption was excessive for this PV system. This dryer could easily use all of the energy from the array, leaving none for charging the batteries! A meter could be installed so that the institution using this piece of equipment could be billed for each kilowatt-hour consumed.

Energy Efficiency

Appliance inefficiencies can make or destroy a solar-electric system. Although the kitchen PV systems at Hill Bank and La Milpa both used energy efficient Sun Frost refrigerator/freezers, several old chest freezers consumed energy at unsustainable rates. One outdated freezer's automatic defrost began working overtime, heating up the outside of the cabinet until it was nearly too hot to touch.

Typically, state-of-the-art, energy efficient freezers save more than 50 percent when compared with older models. Replacing this single appliance would save at least 10 percent of the total system load! This appliance was found to be an energy hog after we had tested all loads at the entire field station, a daunting exercise. Without proper surveillance of all the electrical appliances in a system, changes in appliance performance would be easy to miss.

Technological Advances

Balancing equipment upgrades with capital budgets can be a challenge. Almost all fluorescent lighting at Hill Bank used inefficient magnetic ballasts. Because lighting represents from 45 to 68 percent of the AC loads, upgrading to efficient electronic ballasts is justified. The existing lights are probably only 60 to 65 percent efficient (watts per lumen) and new electronic fluorescents are around 90 percent. Such an upgrade would decrease lighting loads by around 30 percent. This equates to a decreased system load of 14 to 20 percent!

Jeff Burch, Lori Prichard, and Jim Moore gather data from the Xantrex inverter.

Because there are conversion losses along the electron chain from PV panels to AC output of at least 30 to 40 percent, load savings dramatically diminish the energy needed from the panels. Decreasing the loads by 25 percent (lighting plus freezer upgrades) is equivalent to increasing the solar-electric array output by 36 to 42 percent! The bottom line—spend your money first on decreasing loads. Every dollar spent on efficient appliances will save between three and five dollars of PV generating equipment.

Decreasing the workload of the batteries is equally important to minimize total costs. The AC water pumping stations at PFB illustrate this point. Pumping up to 1,600 liters per day required considerable electricity. Although the pumping system performed its function, upgrading to a more efficient, low-volume DC pump would save a significant amount of energy.

A 78 watt DC pump could deliver 6.9 liters per minute and accomplish the job at a cost of 0.19 WH per liter. The current AC pump delivers more than twice the amount of water in one-fifth the time, but requires 0.25 WH per liter to do it, which works out to be 30 percent more costly in terms of energy. However, using a DC pump has an additional advantage in that it can use electricity directly from the solar-electric panels while the sun is shining, thereby bypassing the inverter and batteries entirely, saving wear and tear on them, and increasing overall system efficiency.

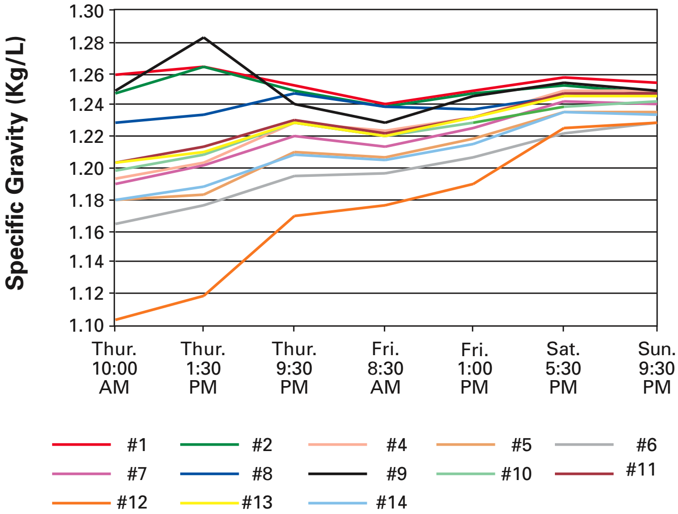
Typically, about 10 to 20 percent of the DC energy from the panels is lost through chemical inefficiencies when charging batteries. This percentage varies widely depending on the age and temperature of the battery bank. An additional 15 percent is lost on average when the inverter converts the DC energy stored in the batteries to AC. So, very roughly speaking, for every 100 watts of energy coming out of the panels, only about 65 watts are actually converted into useable AC electricity.

Staff and team gather in front of one of the solar arrays.

There are also ways to minimize battery wear and tear in cloudy weather. Rather than using the batteries to store energy to pump water during cloudy periods, the water system could be redesigned to store more water in larger tanks. Doubling or even tripling the storage could almost eliminate the need for using the batteries for pumping water. By pumping water with a DC pump only when the sun is shining, significant energy savings can be redirected to other tasks such as float charging and equalizing the battery bank. Remember, however, that line losses are higher for low voltage. This means that to reap the full savings of using low voltage DC appliances, the appliance must be located near the battery bank or PV array.

Replacing the AC pump with a DC pump makes energy sense, but requires capital outlay that appears expensive. Doing nothing, however, is not cheap either. Energy efficient system design and conservation are the most effective ways to save money.

Specific Gravities of Kitchen Bank Batteries



Lessons Learned

Our study of the four systems in Belize left us with these guidelines for successful stand-alone PV systems:

- Examine the individual components and how they work together.
- Size loads on array output, not on battery bank capacity.
- Always follow proper weekly charging protocols and perform monthly equalization.
- When upgrading capacity, always add to array output first, battery capacity second, and extra load third.
- Maintain appliances to reduce electrical losses.
- Purchase more efficient appliances; it is the cheapest way to increase system capacity and save money.
- Do everything possible to use electricity straight from the PVs rather than via the batteries. This strategy increases effective array size more than anything else.
- Dedicate enough human resources to manage the system.

In summary, the most important lesson is that the load on a system has to be balanced with solar-electric array output. You can add batteries to a system and get an inflated sense of capacity, but this does not change how much energy is available. Equalization is critical to the long life and daily usability of a battery bank. We used a three-day equalization protocol on the heavily sulfated kitchen bank of batteries. The graph shows that the disparate specific gravities of the batteries converged with treatment.

Every watt saved on the appliance end (by using energy efficient appliances and using electricity only when needed), saves about 1.5 watts at the PV panel. It is far cheaper to save electricity than to generate it. Amory Lovins of the Rocky Mountain Institute said it so well when he coined the term "negawatt" (saved watts), which ultimately convinced major energy companies such as Pacific Gas and Electric to give energy-efficient water heaters to their customers instead of building new power plants. Our experience with renewable energy systems in remote Belize confirms this. Energy efficiency and awareness makes these systems successful.

Access

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www.sandia.gov/pv/docs/BattIntro.htm • Detailed technical studies of real-world battery failures

www.homesteadtechnology.com/power/power_battery.html • Tutorial on battery cost

www.homepower.com/files/battvoltandsoc.pdf • Tutorial on state-of-charge vs. voltage

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Starting Smart

Calculating Your Energy Appetite

Scott Russell

From solar to microhydro, in Barbados or Barrow, for a hen house or a townhouse, every renewable energy system should begin with a load analysis. This analysis is an assessment of your site's electrical use—your electrical "load profile." You'll need to ponder and juggle a lot of numbers in the process of selecting, sizing, and installing a solar-electric system. A reliable load analysis is essential to get your calculations off on the right foot.

While a load analysis is a necessity for an off-grid system, it's also an excellent idea for a grid-intertied system. For most grid-tied systems, your old electricity bills are an excellent record of how much energy your new RE system will need to produce. But only a thorough load analysis can enable you to target efficiency opportunities and ultimately minimize your system costs. Even if you plan to have a professional installer handle the entire project, your help with this critical task will ensure the highest possible value for your money.

As any RE veteran will tell you, for every dollar you spend on efficiency measures, such as replacing old, energy-hogging appliances or lighting, you'll save US$3 to $5 on the final cost of your system. Note that we're talking about increased efficiency, not necessarily conservation. While conservation is a wonderful thing, you don't need to be a puritan to use less electricity and "buy down" the cost of your system. Most important—you don't need to sacrifice the conveniences that you enjoy to afford an RE-based electrical system!

Where Does My Electricity Go?

The load analysis process can take a little time, but it's easy. A form like the sample featured in this article is available in the Promised Files section on our Web site (see Access) in Microsoft Excel format. This spreadsheet can make the necessary calculations for you. Or you can just grab a calculator and a blank sheet of paper.

The idea is to itemize everything in your house that uses electricity, and then estimate how much each item uses in "watt-hours per day." All the information you need is already either in your house or in your head. Just write it down. Many system articles in *Home Power* include an abbreviated load table, so good examples are readily available.

A complete load analysis collects and calculates several bits of data. What follows is a column-by-column breakdown of the form, describing what each piece of information means and how to get it.

Load

The term "load" refers to an electricity-consuming item—a toaster, DVD player, water pump, alarm clock, lightbulb, or power drill. List everything in your house that uses electricity, no matter how insignificant you think it is. The more complete this list, the more accurate your load profile will be. For multiple, identical loads that are on for the same length of time—for example, ten, 60 watt lightbulbs—list the item once and indicate the quantity in the next column. Multiplication will take it from there.

Load Voltage & Run Watts

Time for a little legwork. For each item, you'll need to specify both its voltage and wattage ratings. No cause for panic—every electrical load is required to have this information printed directly on it. All you need to do is march around with your clipboard and jot down the numbers.

Voltage, amperage, and run wattage data is usually located on a sticker or plate found on the bottom or back of the appliance. There is no universal standard for how the information appears. Voltage can be listed in a number of forms: 120 volts, 120 V, 120 volts AC, or 120 VAC. Sometimes an appliance nameplate will just list voltage and current, and leave off the watts (W). Current is expressed as amperage, and appears in a number of forms: 0.5 amps, 0.5 A, or 500 mA. To figure out the run wattage, just multiply the volts and amps (V x A = W).

Nearly all of the standard electrical loads found in North America run at 120 volts AC (alternating current). Larger appliances, such as electric stoves, clothes dryers, and electric water heaters usually run at 240 volts AC.

Although increasingly rare, if you happen to have any DC (direct current) loads in your off-grid home, they'll probably operate at 12, 24 or 48 volts DC. Battery operated appliances, such as cordless drills, cordless phones, or (unplugged) laptop computers, operate on DC. But for your load analysis, use the information on their battery recharging units, rather than on the appliances themselves, unless you're running them directly off of DC.

For each load, indicate whether its voltage is AC or DC in the next column of the spreadsheet. Although voltage type isn't terribly important to your load analysis, it's critical for off-grid system design purposes. As long as you're collecting data, better to do it now.

Helpful Tools & Aids

- Load profile chart
- List of approximate wattage for common loads
- Clipboard and pencil
- Watt-hour meter
- Calculator
- Willing assistant (must have opposable thumbs)
- Flashlight
- Stepladder

Run wattage is usually the *maximum* an appliance will draw during operation. The watt rating on the appliance typically represents a "worst case" estimate, but since you rarely watch your television at full volume or use your jigsaw to cut granite, feel free to reduce this number by about 25 percent for "variable wattage" items such as these. For the most accurate readings on these and all of your loads, consider getting a handy watt-hour meter to breeze through the task with digital precision.

Hours & Days

Now comes the sitting-and-thinking part of the exercise. It may involve some collaboration with others in your household to get the most accurate estimates possible. The task simply requires that you approximate how many hours

Two typical name plates are shown here.

The sticker on the left lists the running watts as 18 W.

The sticker on the right reports the voltage as 120 V and current draw as 9 A. From this information, we can estimate that this vacuum draws about 1,080 watts.

What's a Watt-Hour Meter?

Watt-hour meters are great tools for anyone interested in collecting and analyzing electrical energy consumption data. Although effective on any 120 VAC electrical load, they're particularly useful for variably cycling appliances, such as washing machines, that are difficult to measure based solely on their run time. Most watt-hour meters can tell you the instantaneous power (watts) and the total energy used (watt-hours or kilowatt-hours) by an appliance. They take the guesswork out of your load analysis by providing actual numbers instead of estimates.

Common models include the Kill A Watt by P3 International, several models by Brand Electronics, and the Watt's Up? meters by Electronic Educational Devices. Meters from all three of these companies have been reviewed in past issues of *Home Power* (see Access). All of these meters are easy-to-use, plug-and-play models. Retail prices range from US$40 to $350, and features vary accordingly.

Three common watt-hour meters (from left to right): the Kill A Watt, Brand Electronics, and Watt's Up?

(or fractions of hours) per day and days per week each of the items you've listed is used or may be used down the road.

In most cases, this is perfectly straightforward, but a couple of notable exceptions will apply. Appliances that turn themselves on and off automatically based on need have what are called "duty cycles." Refrigerators, water pumps, and any thermostatically controlled electrical devices fit this description. You can try estimating the percentage of time that they run by observing how often they turn on and for how long they stay on. But a watt-hour meter is the only way to obtain accurate consumption information for such loads (see sidebar).

The second exception is with "phantom loads" and always-on loads. Phantom loads are electrical loads that use energy even when turned "off." Instant-on TVs, microwave ovens, computer printers and modems, and many other devices consume electricity 24 hours a day unless unplugged or "interrupted" using a plug strip. Always-on loads include answering machines, fax machines, VCRs that you don't want to reprogram, smoke detectors, and others. Some of these loads can be eliminated, for example by using a voicemail service instead of an answering machine.

Unless you plan to get rid of your phantom and always-on loads, they should all be listed in your load profile as 24 hour, 7 day loads. Most phantom loads draw less than 15 watts, but that adds up to a whole lot of energy over a span of weeks or months. Use a watt-hour meter for a precise measurement of phantom loads. Sometimes you will need to list a load twice—once for its phantom load and once for its full, "on" load. The two together should add up to 24 hours.

Before you accept your hours-per-day and days-per-week numbers as final, it might be a good idea to compare them to a few weeks of real life. Pay attention to your electricity habits for two or three weeks and then revise your estimates as needed. You can also check your estimate against your monthly utility bill. It's also important to consider seasonal variations in your electricity use. For instance, you may use your lights much more in winter and fans more in summer. Ultimately, for most grid-connected installations, you want a load profile that represents a year-round daily average.

Average Watt-hours per Day

Light math, anyone? With the essential data now in hand, use the formula below to calculate "Average watt-hours per day" for each item. This is the average amount of electrical energy that each load consumes in a day.

Quantity x run watts x hours per day x days per week ÷ 7 days = average watt-hours per day

Once completed, the sum of this column in your load profile will represent an estimate of the total amount of electricity you use on an average day. This is the consumption rate that your renewable energy system must support if you plan to produce 100 percent of your energy. When you get around to system sizing and component selection, you'll adjust this number to account for a number of seasonal and technological variables.

Lightening Your Load

At this point, it's helpful to add a column for calculating the percentage of your total load that each individually itemized load represents.

Individual load average watt-hours per day ÷ the sum of all items' average watt-hours per day = percentage of average daily load

This information will help you target specific, high consumption loads when taking efficiency measures—your next step following a load analysis. One of the best examples of the potential impact of such measures is described in John Robbins' article, "Recipe for a Solar Office: 1 Part Solar, 5 Parts Load Reduction" (see *HP97*). John reduced his home-office loads by more than 85 percent at a cost of US$1,500, saving him US$5,000 on the cost of his solar-electric system. That's real money.

Home Load Profile

Loads (Before Efficiency Measures)	Qty.	Volts	AC / DC	Run Watts	Hours / Day	Days / Week	Avg. WH / Day	% of Total WH / Day
Refrigerator, 18 ft.^{3} (old)	1	120	AC	400	7.00	7	2,800.0	35.20%
Well pump 1/3 hp	1	120	AC	850	1.25	7	1,062.5	13.36%
Television, 24 in. color	1	120	AC	170	5.00	6	728.6	9.16%
Incandescent bulbs	12	120	AC	60	1.00	7	720.0	9.05%
Computer monitor	1	120	AC	90	8.00	5	514.3	6.47%
Combined phantom loads	1	120	AC	21	24.00	7	504.0	6.34%
Light fixture (4 incandecent bulbs)	1	120	AC	240	2.00	7	480.0	6.03%
Washing machine (old)	1	120	AC	500	0.75	7	375.0	4.71%
Mac G3 computer	1	120	AC	60	8.00	5	342.9	4.31%
Microwave	1	120	AC	800	0.16	7	128.0	1.61%
Vacuum cleaner	1	120	AC	840	0.50	2	120.0	1.51%
Alarm clock	1	120	AC	3	24.00	7	72.0	0.91%
Toaster	1	120	AC	1,050	0.06	5	45.0	0.57%
VCR	1	120	AC	40	3.00	2	34.3	0.43%
Food processor	1	120	AC	600	0.05	3	12.9	0.16%
Coffee grinder	1	120	AC	150	0.05	7	7.5	0.09%
Power drill, 1/2 inch	1	120	AC	600	0.05	1	4.3	0.05%
Printer	1	120	AC	15	0.30	5	3.2	0.04%
Totals Before Efficiency Measures				6,489			7,954.4	

Loads (After Efficiency Measures)	Qty.	Volts	AC / DC	Run Watts	Hours / Day	Days / Week	Avg. WH / Day	% of Total WH / Day
Refrigerator, 20 ft.^{3} (Energy Star)	1	120	AC	175	7.00	7	1,225.0	29.62%
Well pump 1/3 hp	1	120	AC	850	1.25	7	1,062.5	25.69%
Television, 24 in. color	1	120	AC	170	5.00	6	728.6	17.61%
iMac G4 computer w/ LCD display	1	120	AC	45	8.00	5	257.1	6.22%
Light fixture (4 fluorescent bulbs)	1	120	AC	80	2.00	7	160.0	3.87%
Compact fluorescent lights	12	120	AC	13	1.00	7	156.0	3.77%
Microwave	1	120	AC	800	0.16	7	128.0	3.09%
Vacuum cleaner	1	120	AC	840	0.50	2	120.0	2.90%
Washing machine (Energy Star)	1	120	AC	120	1.00	7	120.0	2.90%
Alarm clock	1	120	AC	3	24.00	7	72.0	1.74%
Toaster	1	120	AC	1,050	0.06	5	45.0	1.09%
VCR	1	120	AC	40	3.00	2	34.3	0.83%
Food processor	1	120	AC	600	0.05	3	12.9	0.31%
Coffee grinder	1	120	AC	150	0.05	7	7.5	0.18%
Power drill, 1/2 inch	1	120	AC	600	0.05	1	4.3	0.10%
Printer	1	120	AC	15	0.30	5	3.2	0.08%
Totals After Efficiency Measures				5,551			4,136.4	

If John could save that much money on RE equipment by making his office efficient, think of the potential for a whole house. Compare the tables above for the electrical loads of a modest home before and after efficiency measures. By replacing incandescent bulbs with compact fluorescents, replacing the old refrigerator and washing machine with modern Energy Star appliances, replacing the desktop computer and separate CRT monitor with a model that has an LCD screen, and switching off phantom loads, the home's energy use was reduced by nearly 50 percent.

A few of the ideas in Zeke Yewdall's article in *HP101* focus on home electricity efficiency, and many more solutions can be found. The U.S. government's Energy Star and energy efficiency and renewable energy Web sites are great places to start (see Access).

An Essential Cornerstone

Without a load analysis, designing a renewable energy system is a shot in the dark. It's like trying to plan your weekly food shopping trip without knowing how many

This plug strip is used to control multiple phantom loads with the flip of one switch.

guests you'll have and how much they'll eat. It's also where you'll save the most energy and money. Many people get excited about making their own electricity, and lose sight of the fact that analyzing energy usage and increasing efficiency is where you get the most bang for your buck. Don't skip this step!

It's easy to make the case for a comprehensive load analysis. So take the time to do a good job and then reap the rewards. Not only will it tune you in to how and where you use the electricity you pay for, but it enables you to construct a lean, green foundation on which to build your renewable energy system.

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Brand Electronics, 421 Hilton Rd., Whitefield, ME 04353 • 888-433-6600 or 207-549-3401 • Fax: 207-549-4568 • info@brandelectronics.com • www.brandelectronics.com • Brand watt-hour meters

Electronic Educational Devices, 2345 South Lincoln St., Denver, CO 80210 • 877-928-8701 or 303-282-6410 • Fax: 303-282-6411 • info@doubleed.com • www.doubleed.com • Watts Up? meters

P3 International Corp., 132 Nassau St., New York, NY 10038 • 888-895-6282 or 212-741-7289 • Fax: 212-741-2288 • sales@p3international.com • www.p3international.com • Kill A Watt meter

U.S. DOE energy efficiency and renewable energy info • www.eere.energy.gov/consumerinfo

Energy Star • www.energystar.gov • Info on energy efficient products & tips for home energy efficiency

Load Calculation Excel spreadsheet • www.homepower.com/magazine/downloads.cfm

"Watts Up? Pro KWH Meter" by AJ Rossman & Joe Schwartz, *HP95*

"Things that Work: P3 International's Kill A Watt Watt-Hour Meter" by Joe Schwartz, *HP90*

"Things that Work: Brand Electronics' Digital Power Meter," by Richard Perez, *HP67*

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Measuring Absurdity

Tony Pereira

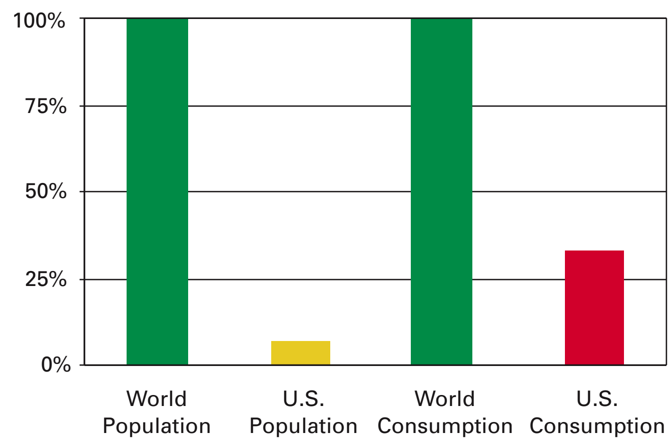
Many of us reading these pages are quite apt at measuring volts, amps, watts, wind speeds, or dollars. A few others may know how to calculate more sophisticated physical properties from the world around us like entropy or enthalpy. But can absurdity also be measured? The answer is a resounding yes. Being able to measure absurdity is at least as important as being able to measure volts, amps, and all the other things.

The first law of thermodynamics states that energy cannot be created nor destroyed, only converted from one form to another. The second law of thermodynamics can be stated in many ways. For our purposes, we will state that to convert energy into work, heat must be dumped. There are no processes known anywhere that disobey these two laws.

Apply the closed system model used in thermodynamics to our beloved planet. In this model, mass cannot cross the boundaries of the system being analyzed—only energy can. All the energy this system gets, it gets it from the sun. We lose some energy, but again those losses are negligible. We can calculate all of these quantities, so grab a calculator and let's start analyzing.

With a population of just under 300 million, the U.S. has less than 5 percent of the world's population—now more than 6.4 billion and growing. The U.S. consumes roughly a third of all the world's resources—air, water, soil, rubber, aluminum, electricity, steel, coal, gas, oil, fish, beef, timber, anything. If you don't believe it, please check the references at the end of this article.

Population vs. Consumption



That means that just two more countries consuming and wasting at the same rate as we do would consume all of the Earth's resources. That also means that, if all the Earth's population consumed at the same level as we do here at home, we would need not one, two, three, or four planets, but about seven planets. We do not have seven planets. We have one. This is my first measurement of absurdity.

Consumption

The first measurement has at least one significant flaw though. It does not take into account other properties of the system we are analyzing, namely the ability of the system to regenerate itself. In our case, the Earth's resources are regenerated by using the energy it gets directly from the sun. A recent report by the National Academy of Sciences, later also published by the United Nations, gives credit to an earlier way of looking at it called the human footprint, developed at the University of British Columbia.

First, the world's productive and accessible acreage was assessed. It was then divided by the present world population. That gives the amount of productive land available to each human being on average—approximately 4.6 acres. Next, the total acreage needed to support human activity, country by country at their current levels of consumption, was also calculated. The number for the U.S. rate of consumption is around 25 acres per person. Divide that number by the available 4.6 acres, and we would need roughly five planets to sustain the whole of humanity in the grand American way of life. That's my second measurement of absurdity.

The problem with this calculation is that the 4.6 acres average productive and available land for human use (amazing!) does not include other species. So much for that then. An article was published in *BioScience* in 1986, based on a study by Stanford University. In it, the question was asked: from the energy that we receive from the sun (remember, in either our closed or actual system, that is all the energy we get) that is transformed by photosynthesis, how much do human beings appropriate for their own use?

In other words, the sun shines, plants and animals thrive on the energy from the sun, humans make T-shirts from cotton, wool sweaters from sheep, and eat burgers, all using the first and second laws of thermodynamics. How much do we humans appropriate? In 1986 numbers and with a global population of 5 billion then, humans were appropriating around 40 percent of the total photosynthesis of the planet. Double the size of the world's population (which will happen) without changing the consumption and waste patterns (which won't—they will certainly increase), and the number goes up to 80 percent, which leaves 20 percent for the rest of creation. That's my third measure of absurdity.

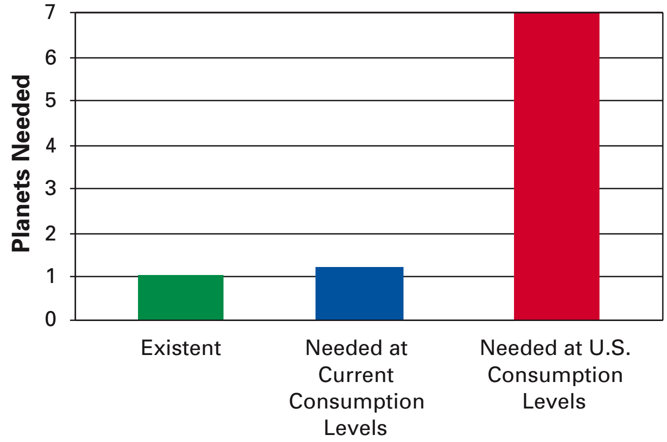
...if all the Earth's population consumed at the same level as we do here at home, we would need not one, two, three, or four planets, but about seven planets.

Wasting Breath

Do we really use any air at all? It's nothing, really, most people think. Well, let our cars do it for us then! On average, a U.S. car uses as much oxygen in one year as a human being consumes in a lifetime, never mind the carcinogens. If you start driving at age 16 and quit at age 76 (the average U.S. life span), it results in a factor of 60. Multiply this factor by the population of the earth and assume everyone has a car (which we will—we are presently at about one car per three inhabitants, or well over two billion cars). That's equivalent to 372 billion human beings breathing. Hey, but wait a minute—that's only cars! That's my fourth and final measurement of absurdity. Rest assured, there are quite a few other ways to measure it.

Many may ask at this point how we can use above 100 percent, say, 120 percent of what we do not have? Well, imagine going to the bank and withdrawing 20 percent more than what you've deposited. Bankruptcy is the inevitable result, except that the Earth does not keep a Chapter 11 office open at any time.

Planet Supply & Demand



It's the Law

Humans neither create nor produce. We can only convert one form of energy into another. Anything else would violate the first law of thermodynamics. It has never been done.

Human beings, like all other things around us, can manipulate, alter, and transform one form of energy into another with various levels of entropy in the process. In the very short run, we need to reduce our global bank account spending by 20 percent everywhere. In the not too long run, we need to reduce spending even further to allow the natural biological systems of the Earth to catch up and regenerate themselves—and halt the present biggest extinction of species in the known fossil record.

One thing is true and tried—there are and always will be problems. The trick is to solve the ones that are solvable. That implies being able to calculate the answers, but also being able to imagine the questions that are useful in the first place.

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Thermodynamics: An Engineering Approach, Yunus A. Cengel and Michael Boles, 2002, Hardcover with CD-ROM, ISBN 0072549041 • US$120.93 from McGraw Hill, 860 Taylor Station Rd., Blacklick, OH 43004 • 800-262-4729 or 609-426-5793 • Fax: 614-759-3641 • customer.service@mcgraw-hill.com • www.books.mcgraw-hill.com

Our Ecological Footprint, William Rees and Mathis Wackernagel, 1995, paperback, ISBN 0-86571-312-X • US$14.95 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

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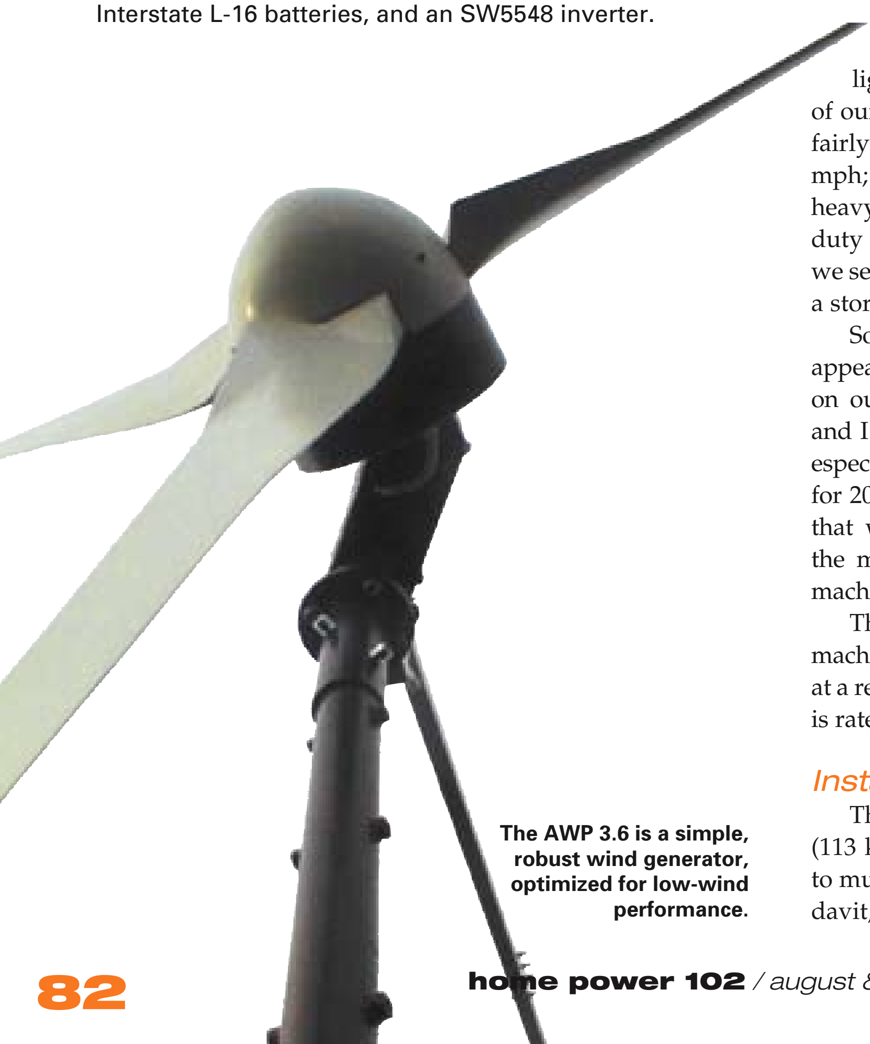
Calculate your ecological footprint • www.earthday.net/footprint/index.asp

African Windpower 3.6
Wind Generator

Ian Woofenden

Application: I installed the first African Windpower (AWP) 3.6 wind turbine in the U.S., and ran it for two years. I coordinated a Solar Energy International (SEI) workshop that installed another AWP 3.6, which has now been running for 18 months in my neighborhood.

System: My AWP was connected to my home system, which consists of two PV arrays totaling 1,220 watts, an older Whisper 1000 wind generator, eight Dyno L-16 batteries, and an SW4024 inverter. The SEI workshop's AWP is connected to a system with 960 watts of PV, eight Interstate L-16 batteries, and an SW5548 inverter.



The AWP 3.6 is a simple, robust wind generator, optimized for low-wind performance.

Heavy Metal

When it comes to wind generators, I have been under the influence of the persistent preaching of Mick Sagrillo's gospel of heavy metal. Mick and many other old-timers in the wind industry favor sturdy machines designed to last a long time. So when I caught wind of the African Windpower machine, designed by my friend and colleague Hugh Piggott, I jumped at the opportunity to try one at our home.

I've been using wind electricity for more than 20 years, starting with a 450 watt Windcharger, and most recently running a Bornay Inclin. Until the installation of the AWP generator, all of my machines were high speed, lightweight machines. They have been an essential part of our off-grid electricity system, and they have functioned fairly well over the years in our moderate wind site (about 7 mph; 3 m/s average). We may not be prime candidates for a heavy duty machine, since we don't have consistently heavy duty winds. On the other hand, though our average is low, we see peaks of 60 to 70 mph (26–31 m/s) many winters, and a storm ten years ago hit over 100 mph (45 m/s) near us.

So the idea of a low speed, heavy wind generator appealed to me. I took the plunge and installed an AWP on our 125 foot (38 m) tower. Wow! My RE-installer son and I were both flabbergasted at the smooth operation, and especially at the low wind speed performance. We'd lived for 20 years with high rpm machines, and we were amazed that we could still see the individual blades move when the machine was kicking out several hundred watts. The machine was virtually silent, and a beautiful thing to watch.

The AWP 3.6 is a three-bladed, permanent magnet machine with a rotor diameter of 3.6 meters (11.8 feet). It runs at a relatively slow 350 rpm peak, and the 24 V model I tested is rated to produce 900 watts at about 23 mph (10 m/s).

Installation

The AWP is a heavy machine. Weighing in at 250 pounds (113 kg) tower-top weight, it's not something you're going to muscle up the tower by yourself. We used a gin pole and davit, pulleys at the top and bottom of the tower, and a truck to install our machine. Slinging the machine with rope was tricky, and we didn't get it to hang exactly level for the lift. I have since added an eyebolt to the machine for easy lifting, which makes a world of difference.

I prefer to hoist machines that are completely assembled, taking great care not to damage the blades while lifting. But this machine has a large tail boom and vane, and our tower is in close quarters, so we opted to hoist it in pieces. Next time, I'll do it all in one lift. We found that adding the tail at the tower top was a tough job, though AWP has now added a lifting eye to the tail boom to make it easier.

Many AWP machines are installed on tilt-up towers, so there is much less of a problem with mounting and hoisting. In either application, the machine's main mounting flange bolts onto a flange on the tower, so attachment is straightforward. Blade attachment is simple, and a large junction box built into the main housing makes wiring very easy.

This machine does not have slip rings, the assembly that allows the energy from the yawing (pivoting) wind turbine to be transmitted to the wires on the stationary tower. So the transmission wires hang freely from the tower top, and twist and untwist with the yaw of the machine. The tower-top attachment and strain relief seemed inadequate to me, so I added a Kellums grip (like a finger trap toy) to support the wires.

North Americans have become used to having yaw slip rings in their wind generators, so there has been some resistance to machines without them. The AWP designer maintains that on most sites, a machine will yaw about the same one way as the other, and that untwisting the wires is not a problem anyway. On my site, which is somewhat turbulent, I found that the wires twisted about 45 turns per year. On the SEI installation site, it's been a more modest 10 or 15 turns per year. To me, untwisting the wires every few years is a small price to pay for the added simplicity and reliability of no slip rings. But customer demand has led AWP to add slip rings to their new units, due later this year.

Tale of Two Wind Generators

It's a common mistake to compare wind generators by their peak output. Most machines are rated at their peak, which tends to be in the 28 to 32 mph (12.5–14 m/s) range. But we should really be looking more at low wind speed performance, since our turbines spend most of their generating lives in the 10 to 18 mph (4.5–8 m/s) range. The peak output really tells you very little about how much energy a turbine will put into your battery bank.

The AWP has a relatively low peak output compared to its energy potential. It is optimized for low wind speeds, and the designer recognizes that this is much, much more important than bragging rights for the highest peak output.

For the two years that I ran the AWP, I also ran an older Whisper 1000 at our place. The Whisper peaked at 1,000 watts, true to its name. The AWP peaked at 900 watts. So you might think that the Whisper generated more energy, since it peaks higher. But the AWP, at about 110 square feet (10 m^2) of swept area (the circular area swept by the blades) generated more than twice the energy of the Whisper, which sweeps about 65 square feet (6 m^2). Swept area tells you more about the production capability of a wind generator than anything else.

Comparison parameters: The Whisper was 13 feet (4 m) lower than the AWP, and is of the old tail-tilt design that loses the wind when it governs. But the AWP was screened a bit more from our second most prevalent wind, by trees to the SW. Energy outputs were measured on two channels of a single Omnimeter AH meter.

Features

High Points:

- Simple, rugged design
- Large swept area
- Low speed
- Quiet
- Passive governing
- High output while governing
- Aesthetically pleasing

Low Points:

- Construction and finish a bit rough
- Transmission cable suspension undersized
- Requires heavy duty tower and lifting rig

SEI students Nicole Lavick and Eric Youngren finishing the installation of an AWP 3.6 wind generator during a workshop.

Electronics

AWP manufactures a rectifier box and controller for their turbine. This has gone through several upgrades. Our original AWP has a very large rectifier box with a volt/amp meter in the face. We opted not to use the AWP controller, since our system already had a diversion charge controller in operation. The SEI installation uses a newer version of the AWP controller, with rectifier and controller built into a compact box with an ammeter and brake switch.

The AWP 3.6 is available in 24 and 48 VDC models, and a high voltage grid-tie model. Abundant Renewable Energy (ARE), the U.S. importer of the AWP, has recently developed a new controller for direct grid-tie of the AWP with an SMA Windy Boy inverter. This is a huge step forward for the small wind industry, allowing very efficient, small, wind-electric, grid-tie systems. The controller/inverter combo tracks the maximum power point of the wind turbine's output, boosting output over battery charging systems by 50 to 75 percent. See Bernd Geisler's article in *HP100* for more information on this system.

My system now has wind speed monitoring via an NRG Wind Explorer, but unfortunately, this was not installed when we were running the AWP. The SEI installation uses a Clean Energy Products anemometer, which has a bike computer coupled to a high-quality anemometer head. Energy data is taken monthly with a TriMetric AH meter and a clipboard.

For this review, I've also drawn on data from Mike Klemen in North Dakota, who has been running an AWP 3.6 for the last two years. Mike's data and data acquisition methods are detailed on his Web site at www.ndsu.nodak.edu/ndsu/klemen. He has tested a number of small turbines, and his site has data on them as well.

Energy Production

There's a reason why I am not including a power curve with this review. A power curve shows the average instantaneous output of a turbine over a range of wind speeds. Unfortunately, most people see a power curve and immediately look at the top end. But wind generators don't spend much time at the top end, so this is not a good point to fixate on. Instead, ask the manufacturer how many kilowatt-hours the machine will generate in your average wind speed. Then you'll have something to go on.

Data from the two test sites tells us that the AWP will generate about 2.5 KWH per day in an 8 mph (3.6 m/s) average wind speed, roughly 4.5 KWH per day in a 10 mph (4.5 m/s) average wind speed, and roughly 6 KWH per day in a 12 mph (5 m/s) average wind speed. See the graph for details. Note that some manufacturers can get "enthusiastic" with their energy predictions. I've found AWP and ARE to be refreshingly conservative with their claims.

Of course, wind is complex. To get an exact prediction of the energy you might get on your particular site, you'll need not only your average wind speed, but the wind speed distribution. Every wind site is different in terms of how often it sees each wind speed. These variations can make a significant difference in turbine output, and therefore in energy prediction. In real life, most people get a rough idea and go for it. Then they find out what they actually get once the system is up and running.

Tech Specs

Turbine Configuration: 3-bladed upwind, side furling

Average Output: 189 KWH per month at 12 mph (5.4 m/s) average wind speed

Rated Power: 900 W

Rotor Diameter: 11.8 ft. (3.6 m)

Cut-In Wind Speed: 6 mph (2.5 m/s)

Rated Wind Speed: 25 mph (12 m/s)

Blade Construction: Fiberglass

Alternator: PM, 3-phase, 0–70 Hz

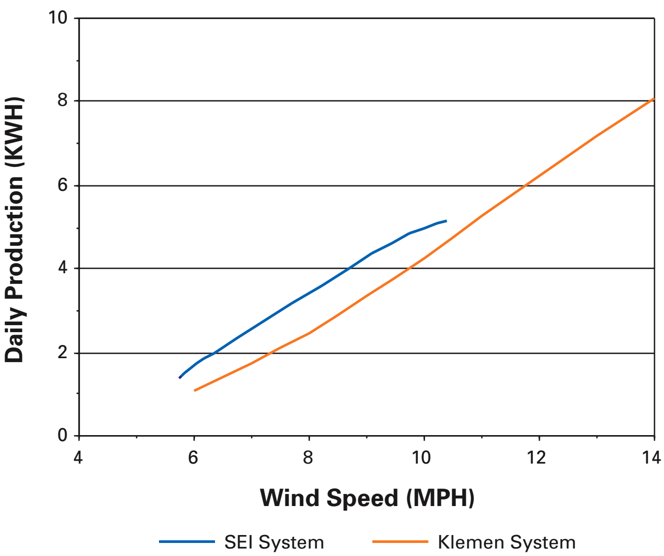
Voltages: 24, 48, 110 VDC

Tower-Top Weight: 250 pounds (113 kg)

List Price: **Wind Turbine:** US$2,250
Controller: US$195–210
Diversion Load: US$95–105

Warranty: 2 years

Average Production Per Day



Caveats

As I mentioned above, the AWP 3.6 is a heavy turbine. It needs a sturdy tower. The manufacturer recommended a 3 inch schedule 40 pipe, which is what I ran it on. My next tower for the AWP will use 4 inch schedule 40 pipe, since my gut feeling was that 3 inch was a bit on the light side for this heavy turbine.

This machine has been manufactured in Zimbabwe, a developing nation that is having serious political and social problems. The manufacturer has recently transferred operations to South Africa, which should make the business more stable. Supply of the turbines is not always timely. Abundant Renewable Energy is stocking turbines and parts in their Portland, Oregon, location, which eases this concern somewhat.

Designing reliable wind generators is a tough job. The AWP is not perfect. There have been blade failures due to manufacturing glitches. The alternator has been criticized as not being super-efficient. And as with any product, early models have bugs, and the manufacturer and importer have made changes in the design. But overall, this simple design has been very effective and reliable. It proves that wind power can be the strong silent type. Or as the U.S. importer says, "as strong as an elephant, but not quite as heavy."

Smooth Turbine

I found the AWP to be a very smooth running and quiet turbine. I was particularly pleased with its output while governing. All of the other turbines I've lived with have seen huge output drops when governing, and tend to thrash around and make me nervous in high winds. The AWP is very steady on the top end of its power curve. I routinely saw it putting out a steady 30 A at 29 V in storm winds. It's important to be able to smoothly spill high winds, and making some energy at the same time is a good thing.

I'm testing another turbine on my tall tower (now 150 feet; 46 m), but I'm starting to build another tall tower, and I'm looking forward to getting my AWP back into action. Its quiet, powerful operation is a welcome addition to our off-grid system, and its simple, durable design is satisfying to live with.

Access

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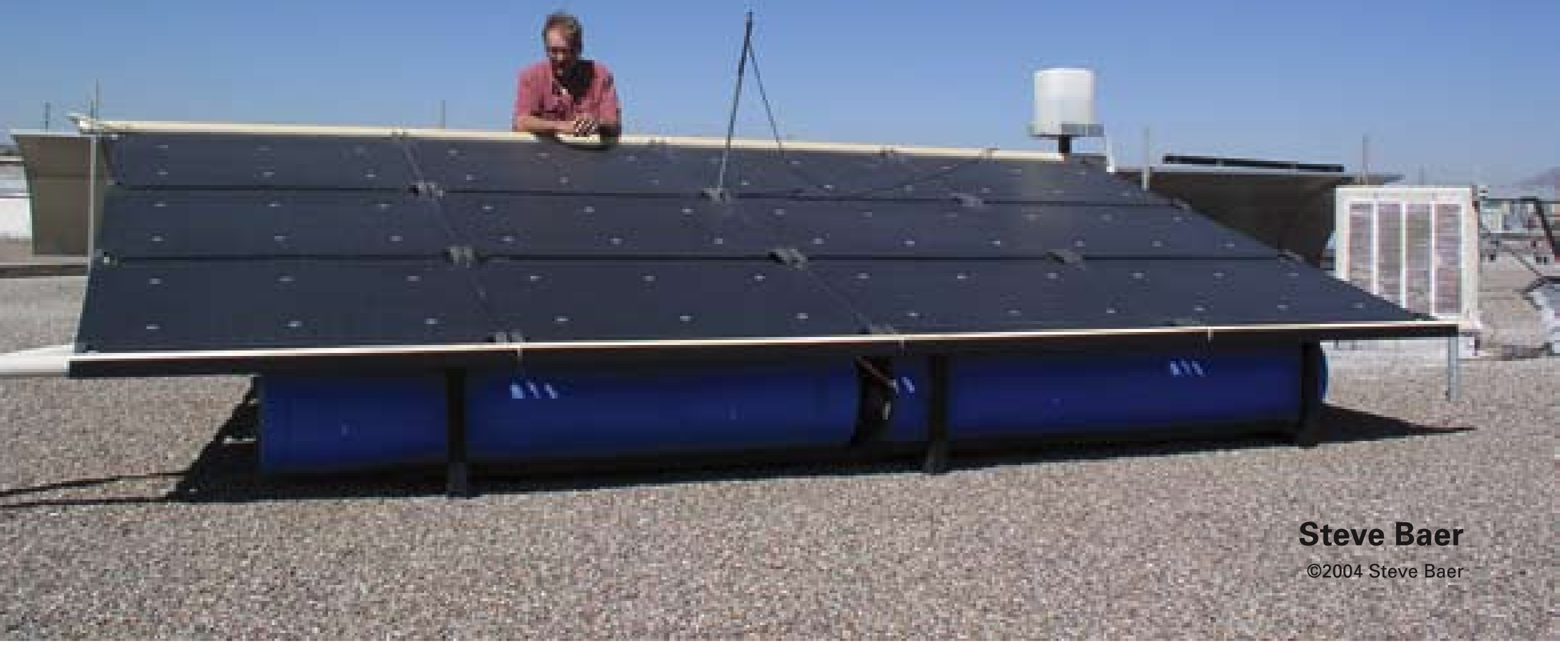
U.S. Importer: Abundant Renewable Energy, 22700 NE Mountain Top Rd., Newberg, OR 97132 • 503-538-8298 • Fax: 503-538-8782 • info@abundantre.com • www.abundantre.com

Double Play

An Experimental Solar Heating & Cooling System



Steve Baer

Steve on the roof of the Zomeworks offices, standing behind the array of polypropylene collectors that heat and cool his office.

Solar collectors have been used extensively to heat both domestic water and buildings throughout the world. Summer cooling with the sun's energy is also a great idea. Up until now, there hasn't been an efficient way to harness solar energy for cooling. You can do the job with PV modules, but the cost of modules along with refrigerated air conditioning can be very expensive. The Double Play system doesn't really use the sun for cooling, but it uses solar heating equipment to do the job, making it much more cost effective than other schemes.

Scientific Basis

In wintertime, dark, south-facing surfaces grow warm in the sun. On summer nights, these surfaces drop below ambient temperature. Few people realize just how strong night sky radiation is. Outer space is really cold. Our atmosphere is like a blanket, thick enough that we can survive the night, but still so thin that radiation from most surfaces pours through it on clear nights, lowering surface temperatures below air temperatures. Shiny metal surfaces will remain close to air temperature because they can't radiate heat. All painted surfaces, dark or light, radiate heat very well.

A plain black surface, if insulated beneath, will rise more than 100°F (56°C) above ambient air temperature, facing clear January sun in Albuquerque, New Mexico. Dark green gets almost as hot. At night, surfaces that are insulated below and face the sky regularly fall 10°F to 15°F (6-8°C) below air temperature. Under optimum conditions, it can be as much as 20°F (11°C).

Heat & Cool with Your Roof

Over much of the United States, roofs can be used to both heat and cool. It isn't a big step from a warm roof to a warm house; you merely add flat plate collectors to the roof (see *HP84* and *HP85*) and collect the heat for use in the house. Or make the roofing itself the collector. Most people are comfortable with an indoor temperature of about 70°F (21°C). A dark-colored, insulated roof can generate temperatures that will heat a building even at ambient temperatures near 0°F (-18°C) if it is sunny and calm.

For radiative nighttime cooling to work well, it's best if the nights are cloud free so that the ambient temperature drops accordingly. The same solar collector that does the heating can cool in the summer, and could also be a conventional roof. Maybe it's a triple play—heating, cooling, and roofing, all in a single system.

The Overall System

OK, we have flat plate collectors, or a dark-colored roof with waterways embedded to make the roof a collector—what now? The heating and cooling systems use the roof in a different way in different seasons. The two systems are themselves quite different.

The winter heating system is a classic drainback system as described in *HP87* and *HP97*. A pump with a high enough head overcomes the elevation difference in the piping to the top of the collectors, and is turned on when energized by a differential control or PV module. The water circulates through the collectors while the sun is shining, and is stored in a tank or other suitable, cosmetically acceptable storage vessel. When the sun is no longer shining, the water drains back into the storage tank, leaving the collectors empty in the event of freezing nighttime temperatures.

Water in the system should be at a level below the ceiling in the home when the system is not running. The storage tank serves as a drainback tank, the heat storage, and a passive radiator to deliver the heat to the home.

The summer cooling system is completely passive—it requires no moving parts or additional energy from another source. Warmer water rises, cooler water falls. At night, the collectors become cooler than the water in the storage tank. The water rises to the collectors, is cooled, and falls back to the storage vessel. Overnight, the water stored becomes close to the temperature of the radiating collectors. This type of passive flow of liquids is called "thermosyphon." For the cooling system to work, the system needs to be completely filled with water.

We have not had any problems with the water in the collectors boiling in summer. Albuquerque is more than 5,000 feet (1,525 m) in elevation and water boils here at 200°F (93°C). In summer, the collector surface is much less likely to rise 100°F (56°C) above ambient than in winter.

The system requires a little work for seasonal changeover. To change from summer to winter, we drain the water to below the roof level and connect the pump to the electricity. To change from winter to summer, we disconnect the pump and fill the system to the top of the panels. You can fill it with a garden hose if you have plumbed in a boiler drain valve. If not, you need a funnel and a fitting you can open at the top of the system to pour in the water or put it in

The author and Dave Harrison next to the storage/radiator that heats and cools their offices. The storage pipes also serve as a divider for the two offices.

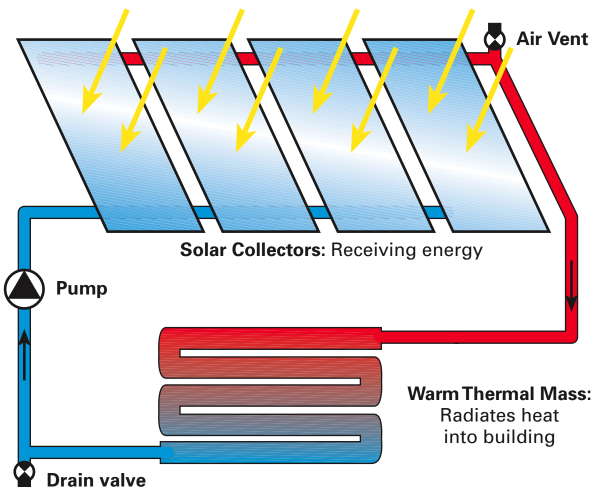
with a hose. There should be a coin vent or a fitting you can crack at the top of the system to let the air out. A boiler drain valve down below makes it easy to drain a little water in the winter to switch the system back to drainback mode, with no mess.

Thermal Storage

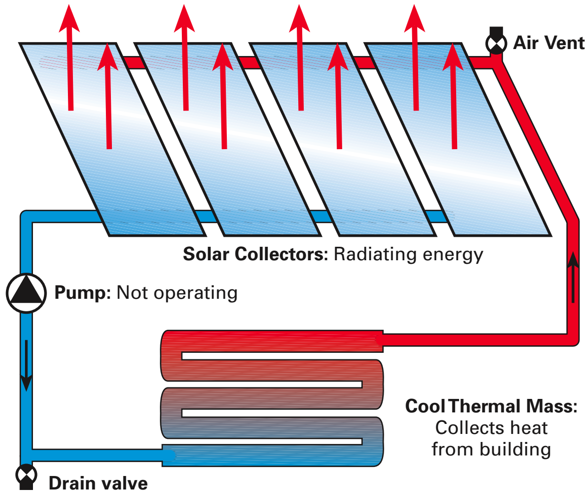
The thermal storage of the heat and cold can be configured in many ways. It must conform to a couple of rules. The storage needs to be of sufficient size and it must be able to perform as a kind of radiator. Storage heats the building on winter days because the water is warm, and cools the building on summer nights because the water is cool.

Our two installations use PVC pipes for the storage vessel/radiator. One is a long, 260 foot (79 m) spiral of 4 inch vent pipe. The other consists of ten, 7 foot (2.1 m) long, 8 inch, thin-wall PVC irrigation pipes. The PVC pipes have worked well, but storage could be better concealed

Winter Day Heating



Summer Night Cooling



The Andy Shack, where most of the R&D data has been collected on the Double Play system.

in interior walls and still be large enough to act as a good radiator. The simple systems where the storage and radiator are the same component are ideal for off-grid homes, since no extra electricity is needed to deliver the heat to the home.

Double Play Performance

We have two operational systems at Zomeworks—Dave Harrison's and my offices, and a building we call the Andy Shack in honor of the builder. The Andy Shack is the older installation and the one on which we have the most data. We have found that the system on the Andy Shack does not need to be turned on at the first hot weather. The overhead thermal mass in the PVC pipes makes it comfortable. It is the same in the fall. For a few weeks each fall and spring, we neither heat nor cool.

The most dramatic effect of the Double Play system is cooling. People are amazed on hot afternoons when they step into the Andy Shack. Good cooling requires keeping the room close to the temperature of the water cooled at night. This requires large surface areas for heat transfer by radiation and convection (natural or fan forced). Overhead or wall pipes are excellent heat exchangers, but their unconventional appearance is not cosmetically acceptable to some people. Radiant slabs could be used for both heating and cooling, as could radiant panels on ceilings and walls. However you handle the storage and delivery of heat, the roof is the natural place to gather or dispose of it.

July of 2003 was one of the hottest months on record in Albuquerque. It didn't cool at night. It reached 86°F (30°C) one day in the Andy Shack (usually, it never goes above 80°F; 27°C). We wondered if we should install a backup cooler. During very hot weather, we can sprinkle the radiator at night. This dramatically increases cooling, and sprinklers are cheap and easy to install. Notice that inside humidity is not increased as with evaporative coolers. Ceiling fans may be preferable to sprinkling, or can be used in conjunction with it in very hot climates. We don't know the limits of the Double Play roof. We may be able to cool in Tucson, though Phoenix is probably too hot.

System Sizing & Siting

The Andy Shack is 77 square feet (7 m^2) and is our main R&D building for the Double Play system. It contains 200 gallons (760 l) of storage in the 77 lineal feet (23 m) of 8 inch PVC pipe. Three, 4 by 8 foot (1.2 x 2.4 m) collectors have a total surface area of about 90 square feet (8.4 m^2). This approximate ratio of 1 square foot (0.09 m^2) of collector/radiator to 2 gallons (7.6 l) of water seems to work well.

Our 400 square foot (37 m^2) office has 180 gallons (680 l) of storage in 250 feet (76 m) of 4 inch PVC pipes. The plastic collector mat measures 125 square feet (12 m^2) on the roof. This system would perform better with additional storage. If the ceiling height of a well insulated home is an average of 8 feet (2.4 m), the roof collection/radiation area needs to be about half of the total square footage of the home.

Integrated Collector

There is no glass over the flat plate collectors that we are using. Glass costs extra money, is delicate to store and handle, and is the weakest part of any collector or module after it is installed. Without it, collectors are lighter, cheaper, and there is little fear of boiling temperatures.

We've been playing with collector construction at Zomeworks, our 35-year-old solar manufacturing company. The installations here have plastic and copper absorbers racked above the roof. At some point, we intend to make the roof and collector one piece, also without glass. One idea is a simple roll-formed aluminum or copper panel that snaps over riser tubes ending in top and bottom headers. Steel isn't a good option; it's a poor heat conductor compared to copper and aluminum. Roofing made of 0.020 inch copper and 0.032 inch aluminum are excellent heat conductors that have long life spans. The standard copper or aluminum roof is also a near perfect medium for a radiant heat exchanger for night cooling.

The south-facing slope should be dark if you intend to gather heat in winter. It will enhance summer cooling too. The roof should be at about the same angle in degrees as your latitude if oriented to the south, or you will miss a lot of winter heat. In climates that demand a steep pitch, the collectors are not as effective for cooling, but this problem is usually forgiven by cooler summers.

The south wall of a cool cell electronics room that Zomeworks manufactures with the Double Play cooling technology. This doesn't need much radiator surface area since it is designed to keep the room under 100°F.

The Double Play system is ideally suited for arid desert climates. It will work in other climates, but not as well. Desert climates usually have good sunshine in the winter and predominantly clear summer nights. These are the best conditions for maximum efficiency of the system. This is probably no surprise, since other solar energy systems work better in desert environments too. Each region where Double Play roofs are suitable must adapt the system to the specific climates.

Payback & Prospects

The payback in energy savings on heating and cooling is about US$1 per square foot of collector per year, where propane or electricity are the alternatives. This is certainly enough of a bonus to make you consider buying a superior copper or aluminum roof, and incorporating piping into it so it becomes a large collector. If pipes are run every 8 inches (20 cm) through either 0.02 inch copper or a 0.032 inch aluminum, the roof can be an effective radiator or absorber.

Even very good ideas, because they lack a powerful advocate, are often slow to find their way into widespread use. The Double Play system does add to the cost of buildings, but considering the fact that a copper or aluminum roof is an excellent investment to begin with, the one time use of the resources needed to build the system is better than burning twice as much in hydrocarbons each year.

The Double Play system for heating and cooling with the sun is still in an early stage of research and development. Many ideas from numerous sources are incorporated into the system design. The beauty of this solar heating/cooling system lies in its simplicity.

Access

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What the Heck? 14

Tempered glass etched with the manufacturer's info.

Edges of low-iron glass (clear) and window glass (green).

Low-Iron Tempered Glass

Used In: PV modules, solar thermal (heating) collectors

AKA: LIT glass, solar glass, Solite

What It Is: High transmittance tempered glass

What It Ain't: Moody glass that needs a vitamin supplement

Tempered glass is special. Sometimes called safety glass, it breaks into hundreds of small, relatively harmless pieces instead of long, sharp shards. Tempered glass is much stronger than regular window glass, and is required in building codes for patio and shower doors. It is etched in one of the corners by the tempering plant, as shown in the photo. Tempered glass cannot be cut with any conventional glass cutter.

Taking the iron out of the glass gives it a light transmittance of about 91 percent. Regular glass has a transmittance of about 83 percent. This 8 percent difference can be very significant over the thirty to fifty year life of a solar collector or module. Solar collectors and PV modules operate at efficiencies directly proportional to the amount of light that gets through the glass—hence the widespread use of low-iron tempered (LIT) glass in the solar industry.

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Maximum Power Point Tracker Project

Tim Nolan

If you're interested in helping create this technomadic machine, please reply…. We still offer our 'geek's vacation' package, with free Spartan room and board to anyone who wants to move in for a while and get a lot accomplished [on the Microship project]."

The Microship Status Reports 3/14/97 (Issue #118) by Steven K. Roberts Nomadic Research Labs • www.microship.com

I was surfing the Web a few years ago, looking for links to interesting solar-electric projects when I ran across this intriguing offer from Steve Roberts on his wonderful Web site: www.microship.com. I am an electrical engineer by training, working in an unrelated field, but I have always been interested in solar electricity and renewable energy.

Microships

I read on Steve's Web site about his Microship project. He is building two small sailboats that are powered by solar electricity. Since I'm also a sailor, and I was going to be traveling in the Pacific Northwest, I decided to take Steve up on his offer to spend a week on Camano Island working on his Microship project. Steve and I worked so well together that I ended up designing the solar-electric system controls for the Microship.

The Microships are basically small, one-person trimarans. More details can be found on Steve's Web site. In addition to sail power, the Microships have a pedal/propeller drive and a solar-electric drive. The electric propulsion motor is powered by the main 12 V battery, which is charged by the PVs.

The power control system monitors the current into and out of the main battery. It also adjusts the speed of the propulsion motor to equalize the power being used and the power being generated by the PVs. This keeps the electric propulsion motor from quickly draining the main 12 V battery, and maybe encourages Steve to do a little more sailing or pedaling on cloudy days. The maximum power point tracking part of the power control system increases the efficiency of the PVs by converting the higher PV voltages (17–21 V) to the 13 to 15 V needed to charge the main battery.

MPPT

After designing the power control system for the Microship, I thought others might be interested in applying the same maximum power point tracking techniques to their own solar-electric (PV) systems. So I designed the smaller, simpler maximum power point tracker (MPPT) presented in this article.

To understand why the MPPT can increase the efficiency of your PV charging system, a closer look at the electrical characteristics of a PV module is necessary. PVs convert photons from the sun striking their surfaces into electricity of a characteristic voltage and current. The PV's electrical output can be plotted on a graph (opposite page) of voltage vs. current—it's called an IV curve.

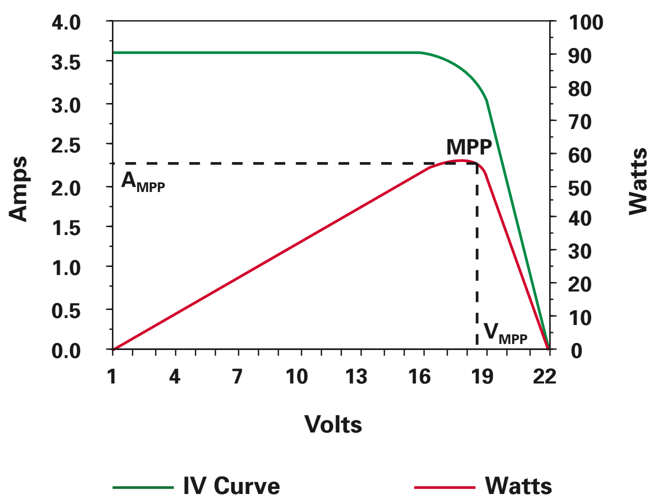
I represents the current in amps and *V* represents the voltage in volts. The resulting line on the graph shows the current of the PV for each voltage at a specific light level and temperature. Current is constant until reaching the higher voltages, when it falls off rapidly. This is applicable to the electrical output of all PVs, although each specific module will have its own individual IV curve.

Graphing the output of a PV shows an interesting characteristic. For most 12 VDC nominal PVs, the maximum output (watts) is produced at a panel voltage of about 18 V. This value is called the maximum power point or MPP. Operating the PVs at roughly this voltage is optimal.

However, when a PV is used to charge a 12 V battery directly, the battery pulls the operating voltage of the PV down near to its own voltage of 12 V (nominal). As shown on the graph, the PV is producing significantly less power (watts) at 12 V than at 18 V. So you can get more charging capability out of the solar-electric panel if it continues to

The Microship's power control system.

PV Panel IV Curve



operate at 18 V while charging a 12 V battery. (Batteryless inverters have MPPT built in.)

To gain the efficiency of maximum power point tracking, the 18 V of the PV must be converted to the lower voltage of the battery. This can be accomplished by using an electronic circuit called a DC-to-DC converter. A DC-to-DC converter is a very common device found in most DC power supplies in some form. It is the basis of the MPPT.

The DC-to-DC converter changes the PV's higher voltage and lower current to the lower voltage and higher current needed to charge the battery. Because the DC-to-DC converter is a low-loss device (90%+ efficient), it outputs almost the same wattage as is input, but at a different voltage and amperage.

In a power supply, simple feedback is used to set the DC-to-DC converter to a fixed output voltage. This is done by controlling the ratio of the input voltage to the output voltage. In the PV example, the above ratio would be 18 V ÷ 12 V or 3:2.

Moving Target

However, for any PV, the maximum power point is not fixed. Consider the IV curves for any PV. These curves change with the amount of light and the temperature of the panel. They also change for each individual type and brand of PV. As the curves change, the MPP changes for the different temperatures and light levels. If the MPP changes, the conversion ratio of the input voltage to output voltage of the DC-to-DC converter must also change to keep the PV voltage at the MPP.

Climbing Hills

The maximum power point tracker described here uses an iterative approach to finding this constantly changing MPP. I call this iterative method a hill-climbing algorithm. Examining the curve on the graph of the PV wattage, it looks like a hill with the MPP at the summit. The MPPT uses a microprocessor to measure the watts generated by the PV. It then controls the conversion ratio of the DC-to-DC converter to implement the hill-climbing algorithm. The software in the microprocessor works like this:

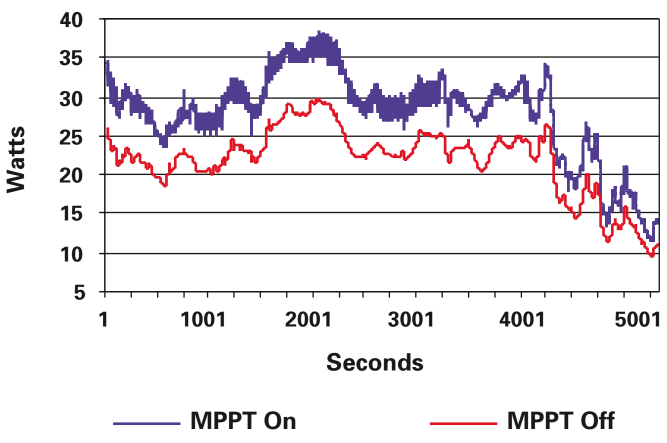
1. Increases the conversion ratio of the DC-to-DC converter;
2. Measures the PV watts;
3. If the PV watts are greater than the last measurement, then it is climbing the front of the hill—it loops back and does it again; or
4. If watts are less than the last time measurement, then it is on the backside of the hill—it decreases the conversion ratio and loops back to try again.

This hill-climbing algorithm occurs about once a second in my MPPT design, and it does a good job of keeping the PV operating at its maximum power point.

The basis for a maximum power point tracker is that the DC-to-DC converter changes the higher voltage/lower current PV input to the lower voltage/higher current battery charging power. The microprocessor controls the conversion ratio of the DC-to-DC converter, keeping the PV operating at its MPP. Obviously, a lot more details go into this design. For a clearer understanding of the process, look at the schematic and software listings for the MPPT on my Web site and on the *Home Power* Web site.

With an understanding of how the maximum power point tracker works, the next question is—how well does it work? The MPPT output graph on the next page illustrates data collected from the prototype MPPT connected to two, 50 watt PVs on my roof. In this example, the MPPT was charging a 12 V battery. The data from the MPPT was output by its serial port once per second, and collected, stored, and graphed on my laptop PC. (See my previous article, "Knowledge is Power," in *HP74*.)

MPPT Output for Jan. 3, 2003



Performance

On the graph, the line labeled "MPPT On" shows the watts generated by the PVs when the MPPT was running the hill-climbing algorithm. Every 10 seconds, the MPPT set the DC-to-DC converter to a 1:1 ratio, simulating a direct connection between the PV and the battery. The watts are measured and plotted on the graph as "MPPT Off," showing the power that would be generated by the PV array if it was directly connected to the battery. The difference in watts between "MPPT On" and "MPPT Off" is the power gained by using the MPPT. In this case, the battery is being charged with about 20 percent more power when the MPPT is on.

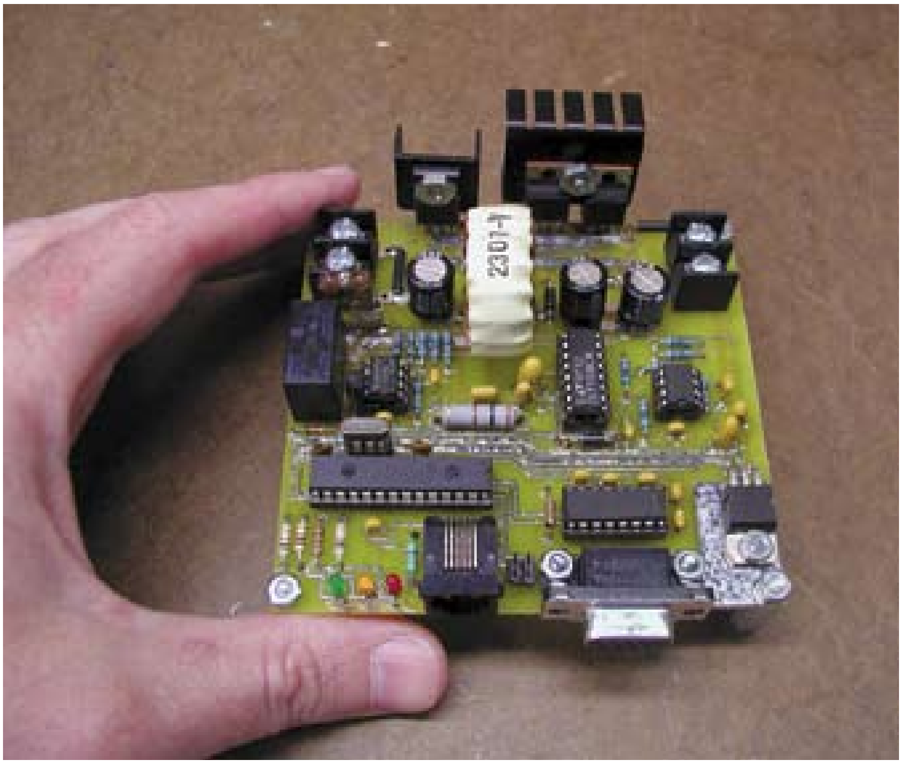
Gains of more than 30 percent are attainable when using the MPPT, but this is the exception, not the rule. The MPPT works because of the difference between the PV's MPP voltage and the battery's charging voltage. The IV curves for an actual PV (remember that the MPP is right at the knee of the curve) show that the MPP voltage goes down as the temperature of the PV goes up. This means that the difference in voltage between the PV MPP and the battery is lower as the panel temperature rises.

With a lower voltage difference, the MPPT will show a lower power gain compared to a direct connection between the PV and the battery. The factors that decrease the difference in voltage between the PV MPP and the battery will cause the MPPT to show a lower power gain. These factors include decreasing PV MPP voltage at higher temperatures, increasing battery voltage during charging, and voltage drop over long wire runs.

On the other hand, if the temperature of the PV is low and the battery is mostly discharged, the MPPT will show higher power gains. The graph was generated when the outside temperature was around 5°F (-15°C)—winter in Wisconsin! I was using a mostly discharged 12 V battery to maximize the gain of the MPPT system.

My experience with maximum power point tracking has shown that large gains (greater than 25 percent) are possible only under ideal circumstances. If the PVs are cool, the batteries mostly discharged, and voltage drops in the system are low, then maximum MPPT gains should occur. Under other conditions, the MPPT gains will be lower, especially if the PVs are being used in hot conditions.

The maximum power point tracker prototype.



Applications

So who should add an MPPT to their solar-electric system? Most PV battery charging systems include a charge controller to keep the batteries from overcharging. My MPPT prototype also includes a charge controller function in the software. In most cases, using a charge controller with MPPT capability increases the cost only slightly. Generally, the power and efficiency gains will easily offset this increase.

Another application for the MPPT is solar powered water pumping. I have run experiments pumping water in varying conditions. When a PV is connected directly to an electric water pump in low light conditions, the PV does not generate enough current to run the electric motor. Linear current boosters are sometimes used to change the high voltage/low current electricity from the PV to low voltage/high current electricity for the electric water pump. Since this is exactly what the MPPT does, it works very well in this application.

The author working on the maximum power point tracker.

To test this application, I used a small water pump. With the PV connected directly to the pump, there was not enough power early in the morning to pump water. Under the same conditions, the MPPT was able to boost the current to the motor so the pump would run, albeit at a slower speed than in full sunlight. Also, because the MPPT maximizes the power output of the PV, the water pump will receive more energy throughout the day than when it is connected directly to the PV. So using the MPPT in solar water pumping applications gives a net gain of more water pumped during the day.

Experiment & Improve

Maximum power point tracking is an advantage in many solar-electric applications. Because other people may be interested in experimenting with MPPT, I decided to write this article and release my work into the public domain. By providing this information with no strings attached, I'm hoping other people will build this design, experiment with it, improve it, and share their results.

Through this process, the technology will quickly improve. I'm willing to post any improvements that people make to the MPPT technology on my Web site. I would also like to hear how you're using the maximum power point tracker, and how well it works for you. The schematics, software, parts list, PCB files, and everything else needed to build this unit are available on my Web site and the downloads section of the *Home Power* Web site.

By developing this project, I've found that the maximum power point tracker does offer significant improvements in solar-electric systems, especially when it replaces the battery charge controller. I hope others will help me contribute to the promise of solar electricity and renewable energy in our future.

Access

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"Maximum Power Point Tracking," Bradley E. O'Mara, *HP29*, page 34

The following information on DC-toDC converters is available from Linear Technology • www.linear.com/pub/doc_group.html?pub_type=app

"LT1070 Design Manual,"#19, Jun. 1986

"Switching Regulators for Poets," #25, Sep. 1987

"Step Down Switching Regulators," #35, Aug. 1989

"Power Conversion from Milliamps to Amps at Ultra-High Efficiency (Up to 95%)," #54, Mar. 1993

The 2004 Toyota Prius

Allen Patterson

Inside the Prius–driver's view of the dash.

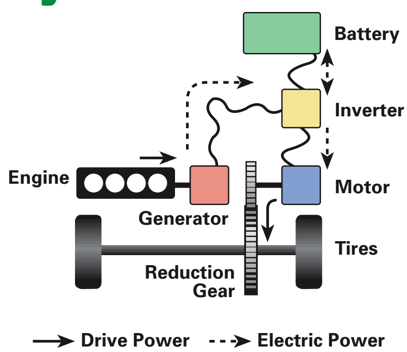
A redesigned mid-sized enviro-car is on the block—the 2004 Toyota Prius. The Prius has become very popular with people concerned with the environment. This is due in some part to the environmental impact of emissions, increasing fuel prices, potential gas shortages, and our dependence on foreign sources of fuel. The engineering crowd likes it for its design and technical excellence, and the wealthy and famous have embraced the Toyota Prius as well.

This new vehicle is the first to employ Toyota's hybrid synergy drive, a third generation, electric-gas, hybrid powertrain technology. Both the gasoline engine (76 hp) and the electric motor (67 hp) produce more power than previous versions (70 hp and 44 hp). It can accelerate from 0-60 mph (0–97 kph) in about 10 seconds compared to 12.7 seconds for the previous model (see reviews in *HP83* and *HP85*). For people worried about battery life, Toyota guarantees the batteries (201.6 VDC, 21 KWH) for eight years or 100,000 miles (160,000 km). The car has a suggested price of US$19,995. It offers an EPA rating of 60 mpg (3.9 l/100 km) in the city and 51 mpg (4.6 l/100 km) on the highway, compared to 52 and 45 mpg (4.5 and 5.2 l/100 km) for previous versions.

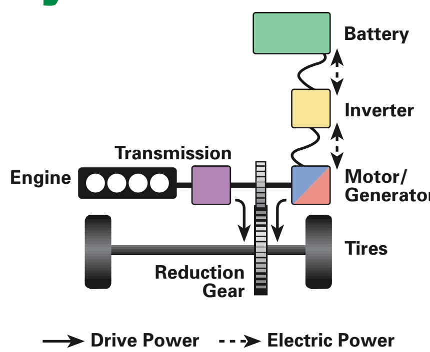
Three Types of Hybrid Systems

Hybrid systems come in three major types. The versions described below are being used in the hybrid vehicles

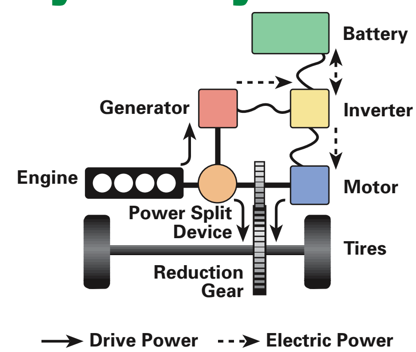
Series Hybrid System



Parallel Hybrid System



Series/Parallel Hybrid System



The Toyota Prius uses the series/parallel system for maximum efficiency and power.

currently on the market, although other configurations of these three types are possible.

Series Hybrid System

In a series hybrid system, the engine drives a generator. This generated electricity is used to charge the battery, as well as to power an electric motor to drive the wheels. Energy flows to the wheels in series—from the gas engine through the electric motor. A series hybrid system can run a small-output engine in the efficient operating range relatively steadily, generate and supply electricity to the electric motor, and efficiently charge the battery. This system is being used in the Coaster hybrid, which is marketed in Japan.

Parallel Hybrid System

In a parallel hybrid system, both the engine and the electric system drive the wheels, and the drive power from these two sources can be used according to the operating conditions. This is called a parallel hybrid system because the energy flows to the wheels in parallel from either or both sources.

In this system, the battery is charged by switching the electric motor to act as a generator, and the electricity from the battery is used to drive the wheels. Although it has a simple structure, the parallel hybrid system cannot drive the wheels from the electric motor while simultaneously charging the battery, since the system has only one motor. This system is used in the Honda hybrids—Insight and Civic.

Series/Parallel System

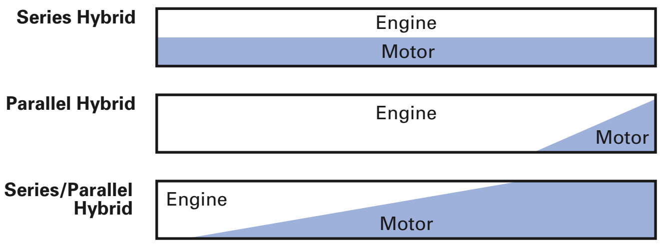
A series/parallel hybrid combines the series hybrid system with the parallel hybrid system to maximize the benefits of both systems. Depending on the driving conditions, it uses only the electric motor or the driving power from both the electric motor and the engine, to achieve the highest efficiency level. When necessary, the system drives the wheels while simultaneously generating electricity using a generator. This is the system used in the Estima hybrid, which is marketed in Japan, and in the Prius.

Engine & Motor Operation

Since a series hybrid uses its engine to generate electricity for the motor to drive the wheels, the engine and motor do about the same amount of work. A parallel hybrid uses the engine as the main energy source, with the motor used only to provide assistance during acceleration. Therefore, the engine is used more than the motor.

In a series/parallel hybrid (such as the Prius), a power splitting device divides the power from the engine, so

Relationship of Engine & Motor Operation in Hybrid Systems



the ratio of power going directly to the wheels and to the generator is continuously variable. Since the motor can be run on the electricity as it is generated, the motor is used more than in a parallel system.

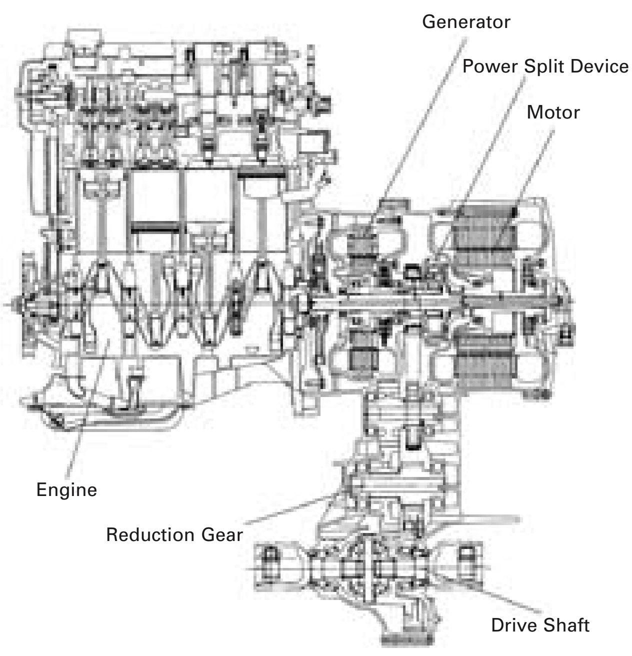
Characteristics of Hybrid Systems

Hybrid systems possess the following four characteristics:

Energy-loss reduction. The system automatically stops the idling of the engine, reducing energy waste. It's like a portable computer managed by an energy conservation system that shuts down the microprocessor between keystrokes, shuts down all drives when they are not needed, and keeps the display at only the brightness needed, saving energy incrementally whenever possible.

Energy recovery and reuse. Some energy that normally would be wasted as heat during deceleration and braking is recovered as electrical energy, which is then used to power the starter and the electric motor.

Engine & Motor Cross Section



Under the Prius hood.

Motor assist. The electric motor assists the engine during acceleration.

High-efficiency operation control. The system maximizes the vehicle's overall efficiency by using the electric motor to run the vehicle under operating conditions in which the engine's efficiency is low, and by generating electricity under operating conditions in which the engine's efficiency is high.

The series/parallel hybrid system has all of these characteristics, so it provides both superior fuel efficiency and driving performance.

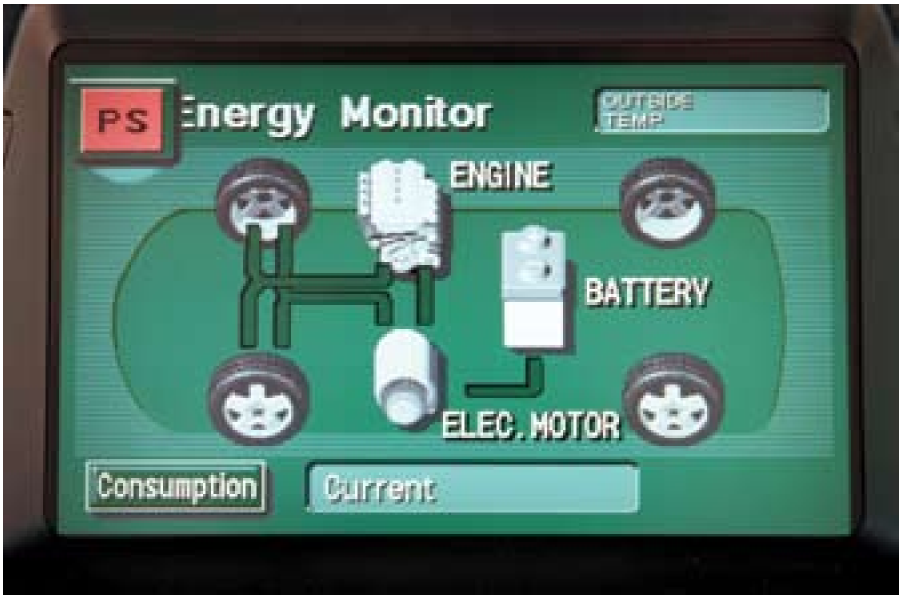
Objectives & System Configuration

Toyota's objectives in the development of the Prius' drive system were compatibility of environmental concerns and performance, pursuit of the highest fuel efficiency possible, and providing an innovative hybrid vehicle driving experience.

The system consists of two kinds of motive energy sources—a high-efficiency gasoline engine, as well as a permanent magnet, AC, synchronous motor with 1.5 times more output than the original Prius motor, a generator, high-performance, nickel-metal hydride (NiMH) battery pack, and a power control unit. Other key components include a power splitting device, which transmits the mechanical motive forces from the engine, the motor, and the generator by allocating and combining them.

System Operation & Control

The system control maintains the vehicle at its maximum operating efficiency by managing the energy used by the entire vehicle. This includes the energy for moving the vehicle as well as the energy used for auxiliary devices, such as the air conditioner, heaters, headlights, and navigation systems. The system monitors the requirements and operating states of hybrid system components. These include the engine, the generator, the motor, and the battery. It also receives braking information being sent via the vehicle's control network, as well as instructions from the driver, such as throttle opening and shift lever position.



The Prius energy monitor emphasizes efficiency.

must be switched is large, minimizing heat generated is important. Toyota developed a unique transistor finely tuned down to the crystal level. This device is 20 percent smaller than the device used in the earlier Prius, and has achieved low heat generation and high efficiency.

Hybrid Battery & Regenerative Braking System

In the new Prius, further enhancements were made to the compact, high-performance NiMH battery. The internal resistance was reduced by improving the electrode material and by using an entirely new connection structure between cells.

The new battery's energy density (output per unit of weight) is 35 percent better than the previous world record for a battery. To maintain a constant charge, the battery is discharged or receives charging energy from the generator and the motor, so it does not require external charging, as do electric vehicles.

During engine braking and braking using the foot brake, a regenerative braking system operates the electric motor as a generator, converting the vehicle's kinetic energy into electrical energy, which is used to charge the battery. The system is particularly effective in recovering energy during city driving, where the driving patterns of repeated acceleration and deceleration are common.

When the foot brake is being used, the electronically controlled braking system (ECB) for the Toyota Hybrid System II coordinates between the hydraulic brake and the regenerative brake. It preferentially uses the regenerative brake, recovering energy even at low vehicle speeds. This increases overall efficiency and, thus, fuel economy.

The optional vehicle stability control restores traction when wheel slippage on a snowy road is detected, for example, and informs the driver of the slipping situation. The basic requirement for safe vehicle operation is firm traction between the tires and the road surface. Motor traction control helps the driver maintain this state.

Another feature is uphill assist control, a driver assist function that is unique to the Prius. It prevents the vehicle from sliding downward when the brake is released during startup on a steep slope. Because the motor has a highly sensitive revolution sensor, it senses the angle of the slope and the vehicle's descent, and ensures safety by increasing the motor's torque.

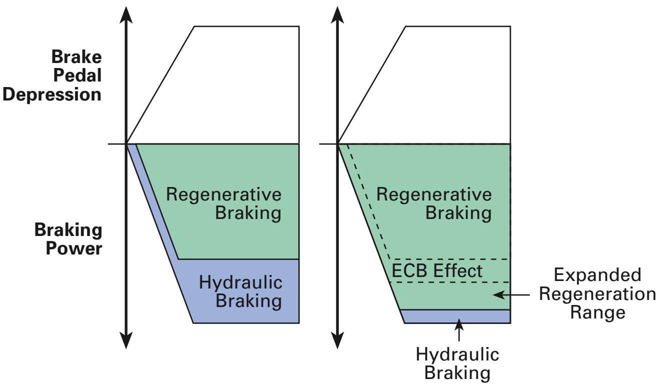
Power Supply & Control

The power control unit uses a new technology that increases the voltage of the motor and the generator from 274 VDC in the previous version to a maximum of 500 VDC. As a result, electricity can be supplied to the motor using lower current, contributing to an increase in efficiency. Doubling the voltage reduces the current by half, and reduces electrical distribution losses to one-quarter by comparison, resulting in higher efficiency.

The power control unit contains an inverter that converts the DC from the battery into AC for driving the motor, and a DC-to-DC converter for conversion to 12 V. The high voltage power circuit mentioned earlier also makes it possible to reduce the size of the inverter. Because the control circuits have been integrated, the size of the power control unit itself has remained almost the same size as in the earlier Prius.

A semiconductor switching device (based on IGBTs; insulated gate bipolar transistors) boosts the voltage from the battery and converts the boosted DC electricity into AC electricity for driving the motor. Since the current that

Improved Regenerative Braking



Hybrid Transmission

The hybrid transmission consists of the power splitting device, the generator, the electric motor, the reduction gears, etc. The output from the engine is split into two by the power splitting device. One of the output shafts is connected to the motor and the wheels, and the other is connected to the generator. In this way, the motive power from the engine is transmitted through two routes—a mechanical route and an electrical route.

The electronically controlled, continuously variable transmission can change speed while continuously varying the rpm of the engine and the rpm of the generator and the electric motor (in relation to vehicle speed).

By reducing the friction loss in the drive system and transmission, more of the energy that used to be lost during acceleration is now sent to the wheels, significantly increasing the vehicle's overall efficiency.

A Pleasure to Drive

What's it like to own and drive? Before I bought my Prius, I drove a large, 4,000 pound (1,800 kg) car with 295 horsepower. So I had some trepidation about switching to a smaller vehicle. The adjustment was actually swift and pleasing, and I felt like I was driving a precision piece of machinery. The Prius is a pleasure to drive, and with the side curtain air bags, I feel enveloped in safety. I do have to discipline myself to not get distracted by the energy display—it's enticing to watch it, which takes my eyes off the road. The noise level is higher than a Lexus, but I have no trouble having a conversation while driving along at 70 mph (113 kph).

I had expected to feel the switching back and forth between the engine and electric motor, but it is seamless. The only way you know it is happening is to see it displayed on the energy monitor. I understand that this is an improvement over the previous Prius models. It is especially satisfying to see the battery charge every time you release the accelerator.

The acceleration is better than I had expected, and I have plenty of steep hills to climb where I live. When you start up, you are strictly on the electric motor unless you shove the pedal to the metal, which will force both the electric motor and the engine into action. I get requests for rides all the time because the car is especially popular in the times we live in. I have also been offered more than I paid for it, but it is not for sale.

Access

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Toyota Motor Sales, U.S.A., Torrance, CA • 800-468-6968 • www.toyota.com • Prius: www.toyota.com/vehicles/2004/prius/ • Environmental technology: www.toyota.co.jp/en/tech/environment/

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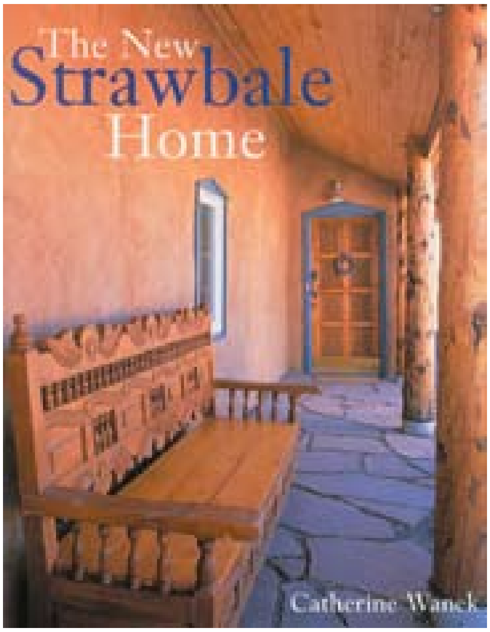
The New Strawbale Home

By Catherine Wanek
Reviewed by Rachel Ware & Laurie Stone

A home purchase may be the largest investment you ever make, both financially and emotionally. Building, buying, remodeling, decorating, and improving houses have become the all-consuming livelihood and pastime of millions of people. Houses are also what consume 40 percent of all natural resources and produce more than 20 percent of total U.S. carbon dioxide emissions. In our quest to house our growing population, our homes have become what David Eisenberg calls "resource sinks and waste generators."

However, there is a growing consciousness in the home building community. An attentive audience of designers, builders, and homeowners are looking to create homes that manifest dreams, beauty, and environmental awareness. People are expressing themselves not just with the objects put in, around, and on their homes, but with the actual walls themselves.



In *The New Strawbale Home*, author and photographer Catherine Wanek has skillfully captured this growing consciousness. Straw bale building began out of necessity in the treeless landscapes of Nebraska. A century later, straw bale construction is now entering the mainstream. Proponents of straw bale construction point to the low embodied energy, high R-values, and user-friendliness of the material.

Those who have been inside a straw bale building can also attest to the comfort, beauty, and calmness the walls can invoke. However, this book is not just for the converted strawbaler. It is for everyone from the skeptic to the designer, builder, or homeowner who wants to create homes that are comfortable, beautiful, and resource efficient.

It is much more than a coffee table book with pretty pictures. This book is appropriate for a broad audience. If you pick up the book with a skeptic's eye, you'll first be won over with the photos—"A straw bale home can look like that?!" People will open the book to a random page, surprise themselves, and then start over from the beginning and not miss a page. For those who envision a straw bale home in their future, the photography will leave you yearning for a time when you can build a home that will exemplify the same warmth and dignity as the homes presented.

The book is also a great resource for those in the design phase. Forty homes are featured, complete with floor plans, climate considerations, and design details. All types of homes are highlighted, from a 450 square foot cottage in sunny California to a 2,000 square foot urban home in downtown Montreal, to a post-and-beam home in the rainforest of the Pacific Northwest. Any designer or owner-builder will find great practical advice from the lessons learned, inspiration, and ideas in this well-organized book.

The New Strawbale Home is also an invaluable resource for sustainable building advocates, educators, and do-it-yourselfers. That's why you should keep a copy on the coffee table, right next to the latest issue of *Home Power!*

Access

The New Strawbale Home, Catherine Wanek, 2003, Hardback, 188 pages, ISBN: 1-58685-203-5, Gibbs Smith, Publisher, US$39.95 from Black Range Films & Natural Building Resources, 119 Main St., Kingston, NM 88042 • 505-895-3389 • Fax: 505-895-3326 • blackrange@zianet.com • www.strawbalecentral.com • Books & videos about natural building

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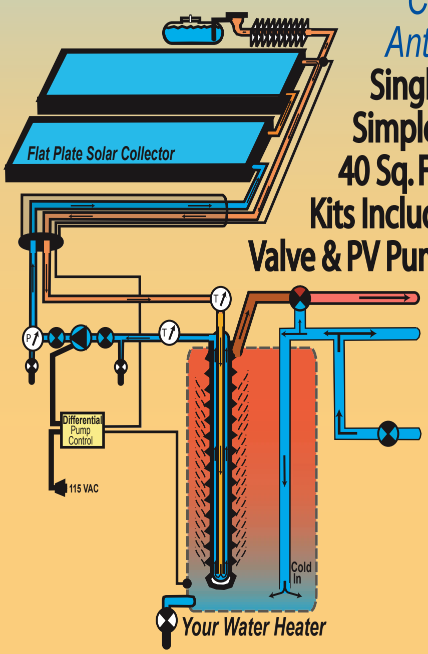
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PV Array Grounding

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

Nearly all electrical systems in the United States are solidly grounded to limit and stabilize the voltage to ground during normal operation, and to prevent excessive voltages due to lightning, line surges, or unintentional contact with higher voltage lines. The grounding requirements in the *NEC* have been developed through the school of hard knocks. For a detailed history on the arguments for and against grounding, see the International Association of Electrical Inspectors (IAEI) *Soares Book on Grounding*.

PV systems need to be grounded just like other electrical systems. PV arrays are usually mounted away from tall objects that could shade the array. In these exposed locations, PV arrays with metal module frames, metal mounting racks, and conductors connected to grounded electrical systems (for utility-interactive systems) are subject not only to induced electrical surges, but to possible direct lightning strikes.

With the increasing numbers of utility-interactive PV installations in urban environments, PV systems are being located in close proximity to high voltage transmission lines. In the event of high winds, earthquakes, or accidents, there is a remote possibility that high voltage lines may come into contact with PV arrays. In dry climates, high winds can build up high static electric voltages on large PV arrays. Utility-interactive PV systems are subject to the same line surges that affect other line-connected devices.

Necessary But Difficult

Grounding PV modules to reduce or eliminate shock and fire hazards is necessary, but can be difficult. Systems typically use copper conductors for electrical connections, and the module frames are generally aluminum. Copper and aluminum don't mix, as was discovered in numerous fires in houses wired with aluminum wiring in the 1970s.

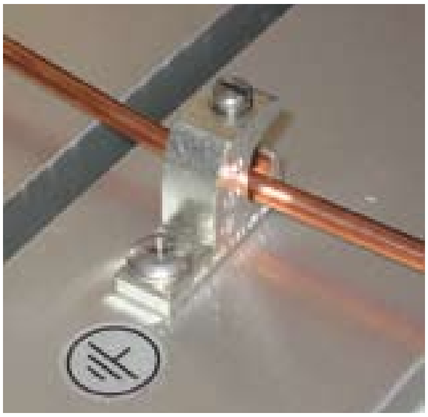
Most PV modules have a mill finish, some are clear coated, and some are anodized for color. Mill finish aluminum and any aluminum surface that is scratched oxidize quickly. This oxidation and any clear coat or anodizing form an insulating surface that makes it difficult to achieve long lasting, low-resistance electrical connections (such as frame grounding). The oxidation/anodizing is not enough of an insulator to prevent electrical shocks, but it is enough to make good electrical connections difficult.

Underwriters Laboratories (UL), which tests and lists all PV modules sold in the U.S., requires very strong mechanical connections between the various pieces of the module frame to ensure that these frame pieces remain mechanically and electrically connected over the life of the module. These low-resistance connections are required because a failure of the insulating materials in the module could allow the frame to become energized at up to 600 volts (depending on the system design). The *National Electrical Code (NEC)* requires that any exposed metal surface be grounded if it could be energized.

Code Requirement

The installer of a PV system is required to ground each module frame. The *NEC* and UL Standard 1703 require that the module frame be grounded at the point where a designated grounding provision has been made. The connection must be made with the hardware provided and using the instructions supplied by the module manufacturer.

The designated point marked on the module must be used, since this is the only point tested and evaluated by UL for use as a long-term grounding point. UL has established that using other points, such as the module structural mounting holes, coupled with typical field installation techniques do not result in low-resistance, durable connections to aluminum module frames for the long term. If each and every possible combination of nut, bolt, lock washer, and star washer could be evaluated for electrical properties and installation torque requirements *and* the installers would all use these components and install them according to the torque requirements, it might be possible to use the structural mounting holes for grounding.



An Ilsco GBL-4DBT lug is attached to the module frame with a 10-32, thread-forming, stainless steel screw.

Most U.S. PV module manufacturers are providing acceptable grounding hardware and instructions. Japanese module manufactures are frequently providing less-than-adequate hardware and unclear instructions. Future revisions of UL 1703 should address these issues. BP Solar is to be congratulated for getting their module listing to include making new grounding points at other locations than the marked points.

Grounding Hardware Option

In the meantime, installers have to struggle with the existing hardware and instructions, even when they are poor. The Southwest Technology Development Institute has identified suitable grounding hardware, and provides that information when installers ask about grounding—a frequent topic. For modules that have been supplied with inadequate or unusable hardware or no hardware at all, here is a way to meet the intent of the *NEC* and UL Standard 1703.

When mechanical protection is necessary or the magnitude of the short-circuit current requires it, conductors larger than #10 (5 mm^2) may be required. A 10-32, thread-forming, stainless steel screw can be used to attach an Ilsco GBL-4DBT lug to the module frame at or adjacent to the point marked for grounding. A #19 drill bit is required to make the proper size hole for the 10-32 screw. The 10-32 screw is required so that at least two threads are cut into the aluminum (a general UL requirement for connections of this kind). The thread-forming screw is required so that an airtight, oxygen-free mating is assured between the screw and the frame to prevent the aluminum from reoxidizing.

It is not acceptable to use the hex-head green grounding screws (even when they have 10-32 threads) because they are not listed for outdoor exposure and will corrode eventually. The same can be said for other screws, lugs, and terminals that have not been listed for outdoor applications. Hex-head stainless steel "tech" screws and sheet metal screws do not have sufficiently fine threads to make the necessary low-resistance, mechanically durable connection. The only thread-forming, 10-32 stainless steel screws that have been identified so far have Phillips heads.

The Ilsco GBL-4DBT is a lay-in lug (see photo at left) made of solid copper, which is then tin-plated. It has a stainless steel screw to hold the wire. The lug accepts a #14 (2 mm^2) to #4 (21 mm^2) copper conductor. It is listed for direct burial (DB) and outdoor use and can be attached to aluminum structures (the tin plate). The much cheaper Ilsco GBL-4 lug looks identical, but is tin-plated aluminum, has a plated screw, and is not listed for outdoor use. I have not been able to identify an alternative to the GBL-4DBT, but continue to search.

If the module grounding is to be done with a #14 through #10 conductor, the Ilsco lug is not needed. In that case, two, number 10, stainless steel, flat washers can be used on the 10-32 screw, and the copper wire can be wrapped around the screw between the two flat washers that isolate the copper conductor from the aluminum module frame.

Yes, we would all like to use the module mounting structure for grounding. The *NEC* allows metal structures

The right parts used improperly—copper wire in contact with an aluminum module frame is a recipe for corrosion.

to be used for grounding and even allows the paint or other covering to be scraped away to ensure a good electrical contact. We see numerous types of electrical equipment grounded with sheet metal screws and star washers. This works on common metals like steel, but not on aluminum, due to the oxidation.

Unfortunately, many PV systems are being grounded improperly, even when the proper hardware has been supplied. The photo above shows that even the proper hardware can be misused. Here, the stainless steel isolation washer has been installed in the wrong sequence, and the copper grounding wire is being pushed against the aluminum frame, a condition sure to cause corrosion and loss of electrical contact in the future.

Access

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The Grid of the Future

Don Loweburg

In *IPP* in *HP99*, I wrote about the connection between electricity trading and recent grid failures. Michael Golay, professor of physics at Massachusetts Institute of Technology echoes one of the column's conclusions when he states in a recent study:

We have a highly complex, poorly designed and controlled macroeconomic experiment (deregulation) being performed using an electric power system in ways for which it was not designed (electricity trading).

My column closed with a quote by David Morris from his article "Blackout: Repeating Energy History."

We need to adopt a bottom-up approach. We need to establish rules that will channel entrepreneurial energy, investment capital, and scientific genius toward building a two-way electricity system, one in which millions of households and businesses become producers as well as consumers. We need to develop the rules that will enable and encourage a distributed, decentralized, democratic electricity system.

What could the electricity system of the future look like? How could it be different from the grid we have today?

A Work in Progress

First, we should keep in mind that the grid we see today was not designed at one time, but rather, it grew ad hoc. It has always been somewhat of a patched together network of wires connecting users to centrally located, large generating facilities. The term "transmission" is applied to those wires that carry high power, high voltage electricity from those large, central generating sources to switching yards close to metropolitan areas.

The wires that carry electricity from the switching yards to the users are termed "distribution." In more recent years, lateral interconnections between utility systems, usually at the transmission level, have been built. The intended purpose of these interconnections was to increase system reliability by allowing utilities to share electricity as needed. These "bridges" worked well until recently, when electricity trading began stressing the grid. A consequence of that kind of stress was the blackout on the East Coast of the United States in August 2003.

Certainly the physical structure of the grid is important, and it will be adapted as needed in the future. But it is the behavior of users, producers, and marketers that impact the performance of the grid the most. The grid of the future will be fundamentally different than today's grid, not just because of technical advances (there will be many), but primarily because the relationship between users and producers will change. These relationship changes will be driven by the availability of new technology, such as on-site PV and other distributed resources.

Like Other Networks

We might compare the electricity network to another pervasive network, the Internet. The grid consists of nodes, connections between nodes, and of course the rules and protocols that determine the relationship between the nodes. The traditional electricity grid is very simple. It consists, for the most part, of passive users and active producers. It's a one-way connection.

Contrast the electricity network to the information network available on any continent. A PC or local network can connect, using the Internet, to any other node in the world. The information flow is two-way and access is open. The information network is peer to peer.

The electricity network of the future will have strong peer-to-peer elements. The end user, rather than being a passive customer, will be adaptive and interactive. The end user may have any number of distributed resources available. These might include things like on-site PV generation, battery storage, flywheel storage, fuel cells, engine generators, smart house technology, and smart appliances accessible via the Internet.

Much of this is already here! Hospitals, factories, data centers, homes, and businesses use these technologies. Utility customers have chosen these options to either control energy costs or to increase reliability. These distributed resources used at the point of load require no modification of the grid. The wires of the future grid may be the same wires that we have today. The real shift from old grid to new grid will be the relationship between the users and the network provider.

RE Drives Change

The end user might be considered the last node in the distribution-transmission network. From this perspective, the existing, large, central generating plants form the foundation or base node of the distribution network. These base load plants will continue to be a fundamental element in the electricity system. But over time, we can expect the rate of growth of these base load plants to decrease, and distributed generation to increase.

Extending the distribution-transmission model to include other generation, we can identify smaller plants downstream from the base load plants. Often called merchant plants, these facilities include peaking plants, usually gas fired, and renewable generation, such as wind farms.

From a physical perspective, the grid of the future will be much like the old grid. However, superimposed on the framework of the transmission-distribution system will be elements of storage and renewable generation. The most radical changes will be at the points of use. Distributed resources applied here will have the most impact and highest value. Ultimately, it will be the availability of distributed energy technology that drives the relationship changes mentioned earlier.

The relationship between the utility and customer will shift in ways that allow the customer to be more in control. The customer will become more interactive. For example, the customer might curtail load in response to price spikes or another customer-generator may choose to sell stored electricity during these price spikes. Interactions such as these require real-time price signals from the utility (most likely delivered over the Internet) on which the customer can act. The relationship here is more like a partnership, with the utility and customer both acting in their own best interest for the common good.

Utilities can build positive customer relationships by easing interconnection restraints, supporting net metering, and dropping exit fees and departing load fees that punish on-site renewable generation. The ratepayer must be treated like a customer rather than like a captive cash cow.

The grid of the future will really be the combination of two grids. One is the electricity distribution network discussed above, and the other the Internet or another information network. With the energy network coupled to the information network, distributed energy technologies that transform ratepayers into customer-generators will change the relationships between the utilities and their customers.

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U.S. PV Module Shortage

Michael Welch

The latest rumor: sometime this summer, the U.S. supply of photovoltaic modules will not be able to meet demand. Is it true? If so, what is behind this situation? Is this a good thing, or is it bad?

Some major PV manufacturers have let their distributors know that PV modules may soon be hard to come by. As of mid-May, according to some renewable energy (RE) dealers, there is a two to three month wait for modules, even for long-standing dealers with preferred status.

It is true that a couple of U.S. PV manufacturing facilities have been closed in recent years. But those have been more than made up for by other manufacturers bringing new facilities on-line or increasing production at their old ones, and by new foreign facilities. That means that something else must be driving the shortage.

Demand on the Increase

Demand for PV modules and balance of system equipment has been on the increase in the U.S., so that can explain at least some of the shortage. This demand has been partly driven by a general increase in awareness by the public. We are seeing more and more articles in local papers about RE homes in our communities, and that helps a lot. So does news about steady increases in utility-scale RE projects, especially big wind.

But what has increased U.S. demand the most are the incentives that many states are putting in place to encourage homeowners to install rooftop PV and backyard wind generators. Several states offer incredible cash incentives, up to half of the total system costs. (A handful of smaller programs in the U.S. have incentives that will end up paying more than the system costs, but these programs are rare enough to not have a big influence on U.S. demand.) But are these incentives enough to cause a shortage?

There really isn't too much that the major PV manufacturers could not predict and be prepared for. Demand projections are based on closely watched trends, and trying to predict with some certainty what the various state and federal incentives will be. State incentives are the biggest factor in increased U.S. demand, though there is also the general trend of more folks being interested in having a PV system.

But incentives usually take quite a while to put into place, making them predictable, so PV manufacturers can more reliably work to increase production in advance of the demand. Further, seasonal demand switches between the southern and northern hemispheres, which helps in allocating manufacturing resources where they are needed the most each season.

Rate-Based Incentives

So, if increases in U.S. demand should be able to be met predictably by increasing manufacturing for U.S. markets, what exactly is causing the demand to outstrip the supply?

The answer is that the German government has recently recommitted to and improved old programs that offer large rate-based incentives for installing grid-tied, rooftop, solar-electric systems (see *HP45 Power Politics* for more info and a call to action for rate-based incentives). As of this writing, they are paying 57.4 Eurocents (US$0.70) per KWH for solar electricity! The payments are promised for 20 years and decrease at a rate of 5 percent each year.

Here is an example of how big this subsidy really is. Take a 1 KW PV system on a moderate solar site, making 1,500 KWH per year. Our German friends would be paid back more than US$1,000 the first year, and payments over the full twenty years will total more than US$12,800. If you add in the savings on their utility bills, it totals almost US$15,000 into the pocket of the homeowner, for a system that costs less than US$10,000.

That is some real money. With the German government behind these programs and guaranteeing the payments, loan companies are setting customers up with low-interest loans (under 2% APR for 10 years) for installation costs, which run about the same as in the U.S. As of 2002, KfW Bank Group, a quasi-governmental lender that works for the public good, has made more than €1 billion in loans for systems with a minimum peak size of 1 KW.

The Germans are serious about global warming and cutting dependence on fossil fuels. They also are sick and tired of nuclear energy, which has been a mainstay of their electrical system for a long time. Their Green Party is very influential, and energy and the environment are among the key platforms of the party. Despite a modest solar resource in much of Europe, the German demand for solar-electric panels is outstripping their supply, and beginning to affect supplies elsewhere, including the U.S.

Any Left for Us?

Reports are that German dealers and distributors have already gotten commitments for all the modules that they can get from the major manufacturers, and are now making cold calls to U.S. distributors to get more—and offering premium prices, to boot. This not only adds to the U.S. scarcity, but it also could increase the price of modules in the U.S. And this may just be the beginning, as similar incentive programs and their accompanying low-interest loans get going in Italy and other European nations.

According to PV market researcher Solarbuzz.com, as of May 2004, U.S. prices have not increased yet. But some individual dealers are reporting that they have seen increases, and that some distributors are demanding payment up front from their dealers. These are both serious impediments to the U.S. solar-electric industry. After seeing prices decline for a long time, the May survey prices held steady compared to April, which may be indicative of the turn-around point in price trends that would be expected from diminished supply.

Many U.S. dealers are buying all the modules they can get their hands on. Dealers who sell systems right now may not be able to receive modules for those systems for three or more months, according to industry experts. Some manufacturers are preparing their customers for the worst, as more and more modules head to Europe. Other manufacturers are maintaining their commitment to the U.S. market, but no one is predicting that this problem will be corrected in the next few months.

In the manufacturers' viewpoint, the U.S. is small potatoes for PV installations. According to last year's statistics, Japan is the leader with 39 percent of the market, and Germany is next with 25 percent. The U.S. follows at 11 percent (other European nations total 9%, and the rest of the world totals 16%). The manufacturers need to satisfy their major markets first, and the U.S. and other countries in a similar boat won't see supplies go up until more PV manufacturing comes on line.

Good or Bad News?

So, is this shortage and its results a good thing, or is it a bad thing? From a U.S.-centric, short-term viewpoint, there is nothing good about it. Folks in the U.S. who are ready now for home-scale RE may have to wait a while, and you know how impatient we can be. Many RE dealers, except the best established and largest, will suffer cash crunches as their installation plans drag out, waiting for PV modules. Some less established dealers may have troubles surviving, or may need to take other jobs until things get better.

But taking the world perspective, even in the short term, it does not really matter where PVs get installed. In any country, grid-tied PV is going to quietly do its job of offsetting polluting, resource-intensive energy production technologies. So from that perspective, it's a wash—neither good nor bad.

From the long-term viewpoint, I see good coming from this. PV manufacturers are going to benefit financially as high demand drives the prices up. That means a higher profit margin for the solar-electric industry, which looks most excellent in the board rooms, and will result in more PV manufacturing capacity—we hope enough to satisfy every country's demand for PV and enough to continue the decreasing price trends that we have seen for a long time.

Effective Incentives

In this increased demand, you see verification of the effectiveness of rate-based incentives, a concept introduced to *HP* readers ten years ago by Tom Jensen and Bob Johnson in *HP44*. It was pretty darn obvious to us then that the European style of PV incentives was going to be successful. Some of us tried to get these kinds of incentives implemented in California and other states that wanted to promote RE. But the utilities were fearful of competition from solar-electric systems, and the governments did not have the guts to stand up to the utilities on behalf of the rest of us.

It is hard to avoid drawing comparisons between what is happening in the smaller nations like Germany, Japan, and Italy and what is happening in the U.S. In those nations, there are strong commitments by their governments to make energy production from renewables a priority. In the U.S., we don't see this strong commitment.

The U.S. needs sound energy policy. We still have some excellent folks in Congress who are working hard to get an acceptable, if not good, energy bill. Let's keep plugging away at these things, folks. Maybe some day our little nation of 291 million of the richest, most resource-consuming people will begin to catch up with Japan (127 million) and Germany (82 million) in total number of annual installed PV systems.

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Writing for *Home Power*

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

Informational Content

Write from your direct experience—*Home Power* is hands-on and how-to! Articles must be detailed enough that our readers can actually use the information. Name names, and provide us with actual numbers, product names, and sources. We like to keep the body of our system articles human-interest focused for newer, nontechnical readers. We include more technical system information in sidebars and tables.

Don't forget to tell readers "who" and "why"—the people and motivations are important parts of *HP* articles. Highlight what's different in your system from other *HP* articles, what you've learned, and how RE changed your life. Whenever possible, "show" rather than "tell." Instead of spending an extra hour (and 500 words) describing something in writing, devote that same hour to thoughtfully composing a photo, diagram, or illustration that accomplishes the same result. Visual aids like this go a long way toward making your article inviting to readers.

Have you submitted your article or a similar one for publication anywhere other than *Home Power*? If so, please let us know. *Home Power* only uses original, unpublished material. If you are writing about someone else's system or project, we require a written release from the owner before we can consider publishing the article.

Article Style & Length

Home Power articles range from 350 to 2,500 words. Length depends on what you have to say. Say it in as few words as possible. We prefer simple, short declarative sentences (fewer than twenty words). We like the generous use of subheadings to organize the information. We recommend writing from within an outline. Browse a few articles in *Home Power.* After you've studied a few, you'll get a feeling for our style.

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

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System articles must contain a schematic drawing showing all wiring. Our art department can make gorgeous diagrams, charts, and schematics from your rough sketches. If you're interested in creating a computer file of a schematic or other line art, please contact us first.

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

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Photography is one of the most important components of your submission. While our staff can be enormously helpful when it comes to editorial content, there is very little we can do about so-so photos. Thoughtful, well-composed photos will significantly improve your chances of being published, or may even win you the cover spot! If you're not particularly confident or capable with a camera, don't hesitate to invite a more experienced friend or relative to help out. Whoever winds up with camera in hand, consider these suggestions.

- Thoughtful composition is the key.
- Avoid "busy" backgrounds (audiences, traffic, etc.).
- People are nice in photos; a fuse box is only so interesting, even to solar nerds.
- Potential cover shots are vertically oriented and leave ample room for the *Home Power* masthead.

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Computer Talk

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

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

- Clearly written, well organized, and complete text, with a strong introductory paragraph, subheads for each major section, and a strong closing paragraph
- Plenty of well-composed photos with comprehensive captions
- Cost table (if applicable)
- Load table (if applicable)
- Technical specifications sidebar (if applicable; see templates on the *HP* Web site, www.homepower.com)
- System schematic (if applicable)
- Other tables, charts, and diagrams as appropriate
- Complete access information for author, installers, consultants, suppliers, manufacturers, and other recommended resources.

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

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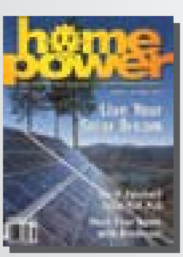

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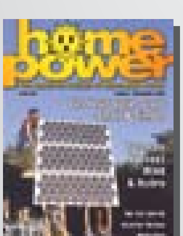

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Conservation—

Saving Energy

Ian Woofenden

Derivation: From Latin conservare, *to preserve.*

Last column, I talked about efficiency, the ratio of energy out to energy in. Energy efficiency makes sense no matter what you're doing, and it's easy to sell. It gives you more bang for your energy buck, and is the best first investment if you're planning to generate your own renewable electricity. Energy efficiency means doing whatever job you want to do with a minimum of energy waste.

Efficiency is one piece of a larger pie called conservation. Conservation includes not only energy efficiency, but also changing your habits, doing with less, and even doing without. In today's consumer society, this is definitely harder to sell. Too many folks want it all and want it now. Technology can be addictive, and can overpower our ethics (see *Ozonal Notes* in this issue).

Personally, I think we should all focus not just on energy efficiency, but also on conservation. But I also respect human choices, and feel that people have to come to their own conclusions in their own time. So I shy away from preaching about conservation in general, and instead emphasize how energy efficiency can save natural resources and dollars no matter what you're doing.

When it comes to transportation, conservation can include asking yourself how many vehicles you really need, and how many trips you take in them. This can get pretty personal! It's easy to criticize others, but more to the point to examine our own transportation lifestyle. Carpooling, using mass transit, bicycling, walking, and just staying at home can be conserving options.

Putting on a sweater instead of cranking up the temperature in your home can conserve a lot of energy. Your home needs a "sweater" too—making sure you have adequate insulation is a smart move. And consider the size of your home and appliances too. A key component of conservation is using less. Smaller homes, smaller appliances, and smaller vehicles tend to be more conserving to make and use.

Before finding the most efficient appliances you can buy, you can ask yourself whether you really need all of them. Choices vary, but I know people who do without a dryer, many small appliances, and even a refrigerator, preferring to use less energy intensive means to do the jobs these appliances do.

Conservation also includes thinking about when and how you use appliances. Doing full loads of dishes and laundry can save a lot of energy and water. Even simple things like heating up a single cup of tea instead of a whole teakettle's worth can make a difference. And turning off the lights when you're not using them is an obvious move. It's more conserving to turn lights off when you leave the room and on when you enter the room than to leave them all on all the time, just in case you need them. And adjusting your energy usage to not coincide with times of utility peak demand can decrease the need for new generating plants, which conserves energy on several levels.

On a family level, I find that building conservation and efficiency into our home's infrastructure is usually easier than building it into my family's habits. After the light on our shop porch was left on several times, I installed a timer, so even I can't leave it on for more than 15 minutes. Using super-efficient lightbulbs means that when they are left on, they are using a quarter of the energy a cheap incandescent would use.

Conservation can take some unusual twists too. For years, I've heard and preached that you can't heat with

Author Ian Woofenden cooking lunch on a solar powered hot plate (made by Cadco), while wearing his favorite sweater (made by his wife).

solar electricity—no electric stoves or dryers in off-grid homes! But our PV system runs a large surplus for most of the summer, so I recently bought an electric hotplate so we can do some of our cooking with solar electricity. This saves propane, and keeps our solar electricity from being wasted.

For lots of good information on conserving energy in your life, I recommend the American Council for an Energy Efficient Economy (www.acee.org), and the Rocky Mountain Institute (www.rmi.com)—especially their book *Homemade Money: How to Save Energy and Dollars in Your Home*.

Every situation is different, but all of us have many opportunities to conserve energy. Even solar energy is not without its impact, and it just makes common sense to lighten up our load on the planet and on our own personal energy and financial reserves.

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Different Sameness

Kathleen Jarschke-Schultze

Several people who have visited our off-the-pavement, renewable energy powered home have made the comment, "If you hadn't told me, I wouldn't know this was an off-grid home." You would think that our lifestyle is unique enough that someone would notice right away. I pondered this. What do we do that is actually different from a utility-dependent home?

First Impressions

When you first walk into our house, there are no immediately obvious clues that we are using renewable electricity. Computers, desks, printer, and fax machine wrap two walls of the office/dining room. (Our friend Ernie says it looks like a NASA control room, with our office chairs lined up at the computer monitors.) So, we have a typical home office.

The half wall between the dining room and kitchen displays three digital meters. That might be the first clue that this is not an ordinary house. We have an Outback Mate, a TriMetric 2020, and a Xantrex Link 10. If possible, we like to incorporate the products that we sell into our own renewable energy (RE) system. This allows us to see how they perform in daily use. By glancing at the meters, I can tell the battery bank state of charge. If the batteries are at 100 percent, I do laundry or run the dishwasher—my biggest energy loads. To a degree, weather determines my housework schedule.

The fridge might be your next clue that our house is off-grid. If you look to the third wall of the room, you will see my 14-year-old, hedgerow green, Sun Frost RF-16 refrigerator/freezer. When I bought my fridge, I found out that you could choose from about a hundred different colors besides white for no extra charge. That's pretty unique, and so is the color of my Sun Frost. It is in the dining room because the only space for it in the kitchen was right next to the stove. Hot box next to cold box—not a good idea.

The Sun Frost is 34.5 inches wide, 62.5 inches tall and 28 inches deep (88 x 159 x 71 cm). It is so tall because it sits on a matching 13 inch (33 cm) base cabinet. It has an imposing presence. It is a 12 volt model because our RE system used to be 12 volt. When we acquired a wind turbine and a Trace SW4024 inverter (serial #37), Bob-O changed the system voltage to 24 volt (see *HP41*). Our system changes often as Bob-O tests new equipment, but the availability and quality of our electricity has always been good and keeps getting better.

A big difference from other refrigerators is the uncluttered outer appearance of the Sun Frost. Since it is covered in Formica, it will not hold refrigerator magnets. I really wanted some poetry magnets when they came out. But, alas, it was not to be.

Down in the basement, where it is perpetually cool, I have a white Sun Frost F-10 freezer. A 24 V model, it has 10 cubic feet (0.28 m^3) of space. Bob-O built a base for it. Since the motor and compressor are on top, the F-10 is very low to the floor without a stand of some kind.

La Cucina

In the kitchen, everything looks like a regular home. Scatterings of fridge magnets are displayed on the front of my black Asko automatic dishwasher. The dishwasher is Swedish. It is very efficient, with low electricity and water consumption.

It contains its own heating elements for the water, as do most European appliances. It has manual switches for using the water temperature boost and heated fan drying options. I mostly leave both of those switches off. This dishwasher could easily be in a utility-dependent home. It is not a specialty item for the RE market. Its uniqueness is in its efficiency, not its appearance.

We have a mid-sized microwave oven. Again, it is an off-the-shelf model. I believe we found it on sale. Nothing noteworthy there. My black enamel range is a propane Peerless Premier. It looks and is quite normal. There are four burners with a griddle in the middle. A really nice feature is that by taking out the griddle and its cover, I can replace it with a fifth burner setup. That comes in handy during canning season or when I'm using the big wok.

Again, the special attributes of my stove are not immediately apparent. It is one of the few brands of ranges that do not have a glow bar to light the oven. (A glow bar is an electric element for preheating a thermocouple. The thermocouple regulates the flow of gas—off or on. Once the thermocouple is warmed by the glow bar and the gas is on, it is lit by electronic ignition.) Unlike most stoves today, the oven can be lit with a match. I do not use matches. I use the electronic ignition. It is a gas range, but the clock, timer, and ignition are electric. The range electrical consumption totals about 2 watts while on.

I only turn on the stove when I cook. Between the microwave and the range is a wall-mounted plug strip.

Plugged into this are the range, the microwave, and a fluorescent light strip. When I am cooking, I turn on the plug strip. The light comes on automatically and all the features of the range and microwave are available to me.

Curse of the Phantom

This brings us to the subject of phantom loads. Anything in our home with a clock or "instant-on" feature is on a plug strip. That means the two TVs, DVD player and VCR, stereo system, the microwave and range, the three computers, printer, and satellite connections.

Our two wall clocks and my bedside radio are battery powered. Any appliance that has a rechargeable battery is unplugged after it is charged. We use them until the battery has completely discharged, and then plug them in again for full recharge. These include an electric toothbrush, the camera and drill battery rechargers, and a small electric broom. Many of these appliances have nickel cadmium (NiCd) batteries in them with a charge memory. If you recharge them before the battery is fully discharged, they may charge only to the level of the previous charge.

Water Course

Some special instructions come with using water in our house. We use a Myson, on-demand, tankless water heater. It uses propane and has a pilot light. Our large water heater tank also uses any extra electricity to heat water when our batteries are full. When water flows from the tank through the demand heater, it is checked for temperature. If the water is above a certain temperature, the demand heater does not turn on. The flow rate must also be above a certain rate for the burners to light.

What this means is that during some periods of the year (times with lots of sun and wind), the water can be very hot coming from the faucet. At other times of the year (when sun, wind, and water in the creek are not so available), the demand heater kicks in every time.

The upshot of this is that when you want hot water, you turn the hot water tap (in the shower, or any of the sinks) all the way on and use the cold water tap to regulate the heat.

Guests need a few more instructions before using our bathroom. We use a Sealand one-pint flush toilet. It is a ceramic toilet with a trap door. It is a type used most often in RVs. After you flush, the trap door closes and a pint of water is released into the bowl. A foot pedal on the side of the toilet opens the trap door. By raising the foot pedal, you can fill the bowl with water to the desired amount.

Sometimes a pint works; sometimes you need more. I have a framed set of instructions above the toilet. When you are standing, looking at the toilet, they are at eye level.

Wash Day

I have had a Staber washing machine for ten years or so. It was the first top-loading, horizontal-axis washing machine available. It is very efficient on electricity and, just as important for us, on water. It uses very little soap and does a really swell job. It is rather loud, but it is in the basement, so I don't care.

Kathleen with her trusty, 14-year-old Sun Frost fridge.

My clothes dryer is a Frigidaire Gallery. It is gas (propane) powered. It needs electricity for the timer, tumbler motor, and inside light. It has a glow bar to ignite the gas, but it only comes on long enough to heat the thermocouple that starts the gas flow and lights it. In the summer months, I use my solar clothes dryer (clothesline).

Light Lite

Of course, all of our lighting is compact fluorescent bulbs. We have been using CFs since they were big bulky things that wouldn't fit in a regular lamp. Now we see them everywhere. Stores, motel rooms, and many people's homes sport these efficient lights. We've found that a selection of compact fluorescent lights is a perfect housewarming gift for on or off-grid friends.

So What's Different?

After all this pondering, I have come to the conclusion that it is not obvious that we are off the utility teat. Everything we do can be done in a utility-dependent home. No magic here—we are just efficient with our energy use.

I'm sure some people are thinking right now that we have a lot of appliances and electronic gear. Couldn't I really just wash the dishes in the sink like I did every other day in my childhood? (My sister Mary washed them the other days.) Sure I could. And if we are low on energy, I do. But if we produce electricity and I don't use it, the fact is, I am wasting it. I don't like wasting energy.

Off & On

Energy efficiency is an integral part of an RE system. If you are on-grid and wanting RE, train yourself to be as efficient as possible. It's good practice, and the money you save is like not paying interest on your credit card.

Turning out the lights or TV when you leave a room is a simple habit to acquire. Turning on a plug strip before you turn on the appliance becomes second nature. Gazing out the window at the weather before deciding a course of action is a good thing. Energy conservation is the key to a successful renewable energy system. Go with the flow—of electrons, that is.

Access

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

Moving On

Eric Grisen, one of *Home Power's* graphic designers and our article submissions coordinator, is leaving the computer and headed to the field. Eric is pursuing a career as an RE system designer/installer in Southern Oregon's Applegate area. He's been with *Home Power* for four years plus, and his enthusiasm for RE, and life in general will be missed. Best of luck with the new gig, E!

— Joe Schwartz for the *Home Power* crew

Use of Service Entrance Raceways

I want to call attention to a potentially serious error in *HP100*, in Bernd Geisler's "Simple Wind Grid-Tie" article on page 24, second column. It is a violation of the *National Electrical Code* 230.7 to use service entrance conduit for any other than service entrance conductors. The only permitted exceptions are grounding and bonding conductors and load management conductors having overcurrent protection. No electrical inspector I know of would have approved this installation.

This is with good reason. Service entrance conductors normally have no overcurrent protection other than the downstream main circuit breaker or fuses. The utility transformer typically has overcurrent protection only on the high voltage primary side. Thus, in the event of a fault, current is limited only by the tranformer's and service drop/lateral conductors' impedance. Even a modestly sized transformer can supply ten or more times the current rating of the conductors of a typical home service until the primary fuse opens.

When an initiating event, such as a lightning strike, causes an arcing fault, I have seen conductors, KWH meters, sockets, and disconnects incinerated by this high current. This could likely cause severe damage or even fires if inverters or photovoltaics are involved. Speaking of photovoltaics, *NEC* 690.4(B) requires that photovoltaic source circuits and output circuits not be placed in the same raceway, fitting, etc., with feeders or branch circuits of other systems. I know boring concrete may not be simple, or elegant, but it would be vastly preferable to the consequences. Sincerely, Jeff Miller, Rapid City, South Dakota • jjmiller@actcom.net

Breaking into the RE Industry

Dear *Home Power*, As an avid reader of the magazine, and a true believer in green power, I need some professional advice. How does someone, like me, recently laid off from the electronics industry after 20+ years, go about getting an entry level job working in the RE field?

I have taken both Internet-based and formal courses for PV installation and design, and have been certified by New Jersey's clean energy program as a trained installer. I have also designed and installed a small PV grid connected system, with battery backup for my own home, generating about 3 KWH per day. The problem is, I don't have enough experience and confidence under my belt to work as an independent PV installer. I need to get into a position where I can learn the various aspects of actually working in the business from the ground up. Maybe a few good-sized installs will get me on my way.

It's one thing to be designing an RE system for my own personal use, but when it comes down to all of the potential liabilities of providing these services as a consultant, it's another matter. I have been looking for potential employers, but haven't been able to establish any real contacts other than those individuals also seeking to get experience. Do you have any advice? Organizations to contact? Groups to become affiliated with? Special training that's desirable? Volunteer organizations?

I am willing to do whatever is necessary, including relocating, volunteer work, or perhaps a partnership involving investing my own funds. But somehow, I need that first important position as an entry level wrench. I have much respect for the professional installer and feel up to the challenge. And thanks to the *HP* crew—you guys are doing great! Regards, John Anderson • john.k.anderson@comcast.net

Hi John. Thanks for your compliments, and I think it is great that you want a career as an installer. You should read Richard's article in HP89 *that we published for folks in your situation, though it sounds like you have taken the first steps.*

One other thing I can recommend is that you take advantage of the RE Directory on our Web site to search out and contact folks that might be able to give you a job or an apprenticeship. Check out www.homepower.com/community/directory/.

Also, if you can't immediately find a position in an RE company, you might consider getting an apprenticeship with an electrician, even if it means not working directly with RE for a while. It would be great experience to help you find a job in the RE industry, and who knows, you might even get your boss interested in RE installation. Michael Welch • michael.welch@homepower.com

Independence Day: Richmond, Virginia

The desire to financially justify a home power system is only one reason for investing the time and money needed to install one. Let me give you another reason, one that is far beyond the calculations of financial payback. And for those of you who are having difficulty persuading your spouse that you really do need a home power system, this letter is for you.

Solar electricity has always appealed to my independent nature. I am, however, limited to solar electricity in the suburbs. Sure, I dream of the backwoods—total independence, passive solar home, panels on the roof, amateur radio to reach the outside world, and a bold stream coming down from the mountain with 300 feet of fall for serious hydro power generation, or a tall wind generator turning out nature's watt-hours. But living sometimes gets in the way of our dreams, and we settle for the next best thing.

Solar energy has been a hobby for many years. I own and have read every *HP* magazine ever printed. Over the years, I've collected six, 120 watt panels, a C60 controller, an old Ananda Power Center, a 3,600 watt Vanner inverter, 40 amp StatPower charger, 100 amp transfer switch in the power shed for the 3,500 watt Honda backup generator, 2,800 pounds of Liberty 2000 batteries, and a 200 amp transfer switch in the house. Finally, two years ago, with e-mail and telephone advice from the good folks at Backwoods Solar Electric Systems, Northwest Power Company, and Earth Solar, the system was installed.

But, in September 2003, independence was no longer a hobby. Hurricane Isabel raged in from the south and struck Richmond. It had been one of the wettest summers on record. The ground was soft from the excess rain, and the high winds blew down scores of trees in every block. Power lines were a tangled mess. The telephone lines were down in many areas. Streets were absolutely impassable. There was no cable for the TV and the computer. It was a war zone. The apocalypse had arrived in Richmond, Virginia.

People who had depended on the local utility were in trouble. No one had electricity—even many hospitals, all schools, and most stores were closed. Anyone who waited until after the storm to obtain a generator was in deep trouble. The roads and highways were impassable. Even if the person was somehow able to reach a store, it was either closed or, if open, sold out of anything remotely resembling a generator.

At my home, my hobby had suddenly become priceless. That night, as the winds moaned and trees crashed around me, the lights went out. They stayed out. I took my flashlight, walked downstairs to the big 200 amp transfer switch, smacked that lever down, and there was light. I could hear the TV as it came back on, and the announcer giving emergency instructions. I went to the front porch, turned on the floodlights just in time to see a giant oak tree fall.

Early the next morning, the storm had passed. It was still dark when I went outside. It was eerie to be surrounded by homes, and see nothing but blackness. Without city lights, the stars above in the clearing sky were bright. Far in the distance, there was the sound of a generator running. There were oak trees on my lot that had been there for a hundred years. The one I saw fall now lay across my driveway. Another lay across my neighbor's car and home. I looked at that storm-tossed mess in the morning light, got out my chain saw, and joined my neighbors in the exhausting job of cutting our way out.

For six days, my home was an oasis of light and sound in a world of darkness. For three days, I ran the home on batteries. Then, when they were about 50 percent exhausted, I ran the generator during the day to charge the batteries and power the home. Family and friends moved their frozen foods to my home. Friends moved in for the duration. In the midst of the devastation, neighbor helped neighbor. When my saw became jammed in the tree across my driveway, my neighbor came to help. Later, when the roads were somewhat passable, he brought his construction crew to my place and hauled away the debris from the storm—at no charge.

I must confess that I felt pleasure in being able to cope, to have my hobby justified, and to be needed by others. While running on the silent batteries, it felt good to be able to turn the front porch light on (fluorescent, of course), when that was the only light to be seen for blocks. For me, it was a light of independence that represented the possibility of a better future for this great country. Dick Leatherman, N4SRC, Richmond, Virginia • RWLCEO@aol.com

Single-Wall Heat Exchangers

Hello, I have a technical question regarding heat exchangers because I plan to use a single-wall heat exchanger in a water-only drainback system. In your article, "Heat Exchangers for Solar Water Heating" in *HP92*, you say that a single-wall heat exchanger is not suited for heating potable water because of a risk of mixing. So my question is: The drainback system is an unpressurized system and the water supplied by the municipality is pressurized at something like 70 psi, so how can it be possible for the unpressurized water of the drainback circuit to enter the pressurized potable water circuit?

If a leak happened on the drainback circuit inside the heat exchanger itself, I think it's the potable water from the municipal supply system that will enter the drainback system circuit, so there is no risk, even if nontoxic propylene glycol is used. Am I right or have I missed something in the concept? I know that safety comes first, but especially with a water-only system, double-wall is maybe overkill. Thanks for your attention. Robert Lefebvre, Montreal, Canada • lefebvrerobert@yahoo.com

Hello Robert, It is OK to use a single-wall exchanger in a drainback system with water as the collector loop fluid (pages 69 and 75 of the article in HP92*). This is the only exception in the Uniform Solar Energy Code that allows single-wall exchangers when used with potable water. I personally agree with you about the safety requirement of double-wall exchangers when using nontoxic propylene glycol as the collector loop fluid.*

These health and safety codes are published by the International Association of Plumbing and Mechanical Officials (IAPMO). I wonder if this group has paranoia as the number one qualification for membership. As you state, even if a wall is breached in a single-wall exchanger, the most likely possibility is the potable water (higher pressure) leaking into the collector loop fluid (lower pressure). Even in the unlikely event that the collector loop was at a higher pressure than the potable water and someone had mistakenly added ethylene glycol (toxic) to the system and the exchanger then developed a leak—who drinks hot water anyway? And, wouldn't a more reasonable requirement be a big red sign reading something like "Caution! Use only nontoxic propylene glycol in this system!"

This is my opinion only and perhaps I am not paranoid enough to fully understand IAPMO rules, but I don't think you're missing anything, and I think it's overkill too. Cheers, Chuck Marken • chuck.marken@homepower.com

Things that Work!

Please bring back "Things that Work!" For instance, I was glad to read the article where someone used a turbine from African Windpower. If this owner spent two years collecting data on it, he could write a "Things that Work!" Mallory Hinkly, Allegan, Michigan

Hi Mallory, Coincidentally, your comment came in just in time for this issue, in which we are publishing my review of the AWP 3.6 wind turbine. We have retired the "Things that Work!" format in favor of our new "REview" format. Our goal with this format is to review products in specific applications and conditions, and avoid blanket endorsements. We know that our readers want more information on RE gear, and we have some other new plans on that front—stay tuned for more in future issues of HP. *Ian Woofenden • ian.woofenden@homepower.com*

Switched Outlets, Etc.

After my article in *HP97*, in which I described converting my on-grid home office to off-grid, I received the most responses and inquiries about those "single-plug switched outlets" I used to disable all my phantom loads. Most of you received a response from me something like this, "Look for a package labeled 'attachment plugs with switch.' They are sold under the GE brand. The stamped part number is 'GE5365,' rated 15 amps 120 VAC, UL-listed. The only other info stamped on the subswitch is 'not for use with motor loads.' I bought them at a local construction supply store."

My switches are not three-wire grounded outlets, as many have asked. But while shopping yesterday, I found a new part, GE5368-71D, which is a 3-wire outlet with a switch, in the same size and format as the nongrounded models shown in my article. I bought three on the spot, for US$3.44 each before tax. I'd recently bought another notebook computer and a couple other devices, which, unlike my older notebooks, had standard 3-wire plugs. Since I'd given up hope of finding 3-wire individual switches, I'd either isolated them on their own switched multi-outlets or simply unplugged them when not in use (the majority of the time). Now everything's plugged in on my desktop switched multi-outlets, with all phantoms on their own mini-switches—no more plugs sitting loose on the tables! These are expensive little switches, but a nice and neat outcome, and I think worth the high price. When people visit my office, I want them to see stuff that looks under control, not messy or too manual.

By the way, this week I finished my 29th consecutive month running my office on 100 percent PVs and batteries, with no backup or failures to report as of yet. Impressive!

A couple of follow-up points: Replacing equipment in an intentionally fixed energy-availability situation always presents difficulties in today's upwardly-mobile energy market. For instance, my newest notebook, a 750 MHz PIII Dell with a 14 inch screen, uses about double the average energy (34–35 W) that my old 166 MHz PI Dell with 12 inch screen does (15–17 W). I bought the more powerful notebook to handle weightier picture files and computerized slide presentations, but the older models still do fine for most routine office applications like CAD, e-mail, and calcs of all sorts, including hour-by-hour simulations.

I've balanced the newest notebook's increased energy demands by using it sparingly for those applications needing more power and screen, while down-watting some of my primary lighting. For instance, I found that I can often get equivalent light from one of those mini-book lights, usually 2 or 3 watts, instead of the 15 watt under-counter lamps about 30 inches above the table top. Makes sense, since light diminishes by the square of the changed distance from source to use.

I was shocked last summer when Energy Secretary Abrahams reported that U.S. grid-electricity demand went up 35 percent from 1992 to 2002. I was shocked because of all the efficiency and renewables that became available and more affordable during this same timeline. However, with so many appliances and devices offering more energy-consuming features, and more people buying more than one of everything, this has apparently more than offset many of our efficiency gains. So I believe our bigger tasks as energy experts and RE advocates is talk about restricting growth in our energy demand, not simply implementing new supplies whether conventional or renewable. This is part of my stump speech this year during Earth Day celebrations. And it sure is convenient to use my own office experiences to show how this can be accomplished. Most people I meet believe growth in energy supplies is essential to our future, like Abrahams and Greenspan, so I hope my contrary message with offered proof gets at least some people thinking. If only we could get this kind of discussion into this year's electoral politics... John F. Robbins • jrobbins@queencity.com

Doubt Factor

Dear *Home Power*, As one of the largest PV energy producers in my tiny city, I feel that a major hindrance to the adoption of renewable energy is the "doubt factor." The doubt factor is, will I be able to find a truly competent and honest installer who will give me an optimally performing system and will not con me out of my hard-earned dollars? The knowledgeable consumer is always wary, and even more so with new, somewhat complex technologies. There are a hundred ways things can go wrong. Though some fiascoes might be anticipated, like the job taking four times longer than what was originally promised, other debacles are beyond what even the most cautious homeowner could imagine. Will the state run out of rebate money after I sign a contract for the job? Will the company's chief installer fall off a roof, leaving me with the dregs of the contractor's crew (yes, a rough approximation of this particular scenario actually happened to me!). Will I find out after the concrete has been poured and the system installed that my 10 KW ground-based system is shaded two hours earlier than the company's solar engineer predicted? Will I find out four years later that the financial predictions of a five-year payback turn out to be fudged, with 15 years being closer to the truth? Will a miraculous new improvement in efficiency make my $100,000 (before rebates) initial investment become a huge investment folly?

For the consumer, there is a huge leap of faith involved in installing renewable energy now. This doubt factor mostly revolves around what I feel is a shortage of honest, competent, well-capitalized installers. J. Block • blytheblock@hotmail.com

Hello J, It's disappointing to hear about your botched PV system design and installation. I've been working in the construction trades off and on since I spent high school summers apprenticing with a master carpenter in Massachusetts. I've seen my share of shoddy workmanship as a result. PV and other renewable energy systems are significant investments, and home and business owners need to proceed with the same caution they would when undertaking any significant home improvement project, or substantial purchase. Obtain more than one bid for the job, have the contractors provide you with customer references, and make sure the contractor is licensed and insured.

The RE installer base in the U.S. has grown rapidly in recent years, and many areas now have more than one RE installer to choose from. This is obviously good for the customer, since competition raises the bar in terms of the quality of workmanship. I'm in regular contact with RE installing dealers across the country. While there are a handful of incompetent installers out there, people should rest assured that there is a very high quality network of RE contractors across the country that's growing every day. Best, Joe Schwartz • joe.schwartz@homepower.com

Straw Bale

Happy Birthday, *HP!* Congratulations and salutations on hitting triple digits. We are all the better off for it; and for the thousands of lives you've improved, trouble you've helped shoot, electrons you've helped flow, people you've empowered, connections you've helped make, tons of CO_2 you've helped save, and on and on. I thank you for providing your service.

I have a couple of comments to make on Laura Struempler's recent article on straw bale construction. I greatly appreciate your inclusion of green building technologies in your magazine; it is related directly to RE promotion in the shared goals and visions of the two fields. There were a couple of inaccuracies I noted in the article, however.

One, the author presents only load-bearing bale walls or post-and-beam frames as structural options for the support of the roof. While these are certainly very popular systems, they are not the only systems. Straw bale buildings are straw bale only by their inclusion of straw in the wall system, not inherently by their structural design. Bale houses can be held up by bales, post and beam frames, traditional stud wall frames, steel frames, and hybridized with numerous wall systems including earthbag, rammed earth, straw-clay, and other natural building systems. The room for creativity is great, and it should be noted that stud wall frames (balloon or platform), if detailed correctly, can be integrated nicely into a bale home, either as new construction or as a retrofit.

Two, the author includes a photo of a "nicely detailed stucco stop" on a building seemingly completely covered in metal lath. While this is appropriate for a building to be finished in a cement stucco, it would be an inappropriate approach for a building to be finished with an earth or lime-based plaster, which all straw bale buildings should receive. The lath, while critical for stucco, would be an interference for natural plasters, and would weaken the plaster-wall bond. Cement stucco should not be used on straw bale walls, for its lack of vapor permeability, its low hydroscopic properties, its high embodied energy, and the need to buy, use, and install all of that lath. Thanks for a great publication. Warmly, Jacob Racusin, Montgomery, Vermont • smallfrog@peoplepc.com

Dear Jacob, Thanks for your comments on my article, "Meeting Design Goals with Straw Bales" in HP100. *I appreciate the chance to discuss both points. Even though this was an introductory article, a comment on the creative structural options and hybrid opportunities is clearly something that would have been useful to include.*

Also, your assessment of the "stucco stop" is good. Had the ACES duplex been plastered with an earthen or lime finish, there would have been no need for metal lath. (The building, by the way, was covered in lath only where absolutely required by our code official or common sense.) Earthen and lime finishes still benefit by having a stucco stop or capillary break in almost all climates and sites.

The prevailing wisdom among straw bale folks and building scientists alike is that natural plasters are far better for covering natural walls for vapor permeability as well as embodied energy. However, cement was used quite often during the earlier years of the straw bale renaissance for its durability and familiarity. Cement is still favored in rare cases such as in high seismic areas for its shear strength. For the latest test results regarding straw bale construction, see The Straw Bale Test Program at www.ecobuildnetwork.org. You will find helpful and detailed structural, moisture and fire test results. Thanks again, Laura Struempler • struempler@sopris.net

WindShrub

Hi Folks, Thank you so much for the excellent articles. We will soon be installing solar-electric panels and a well pump rather far from the grid for our new home. We enjoy staying informed about off-grid living. We have used solar electricity for four years on our cabin, and it has worked very well.

We are interested in a wind generator for the cloudy winter times. We've heard of a model that is barrel shaped and spins on a vertical axis, like a coffee can with air scoops. The promoters, EcoQwest, say that it is being tested in Europe now, and claim that it generates a *lot* of energy at low wind speeds. Any future information on this type of wind generator will be appreciated. The low wind speed needed would eliminate the need to put it very high to get any energy, thus making servicing it a lot easier. It's supposed to be quiet too. Sincerely, Carol Fugitt, Holland, Michigan

Hi Carol, I'm glad to hear that your cabin PV system has been working well, and that you are going for more. Unfortunately, I don't have any cheerful words on the EcoQwest wind generator (WindTree is the brand name). I'm not even convinced that it *actually exists. It has been at least two years that these promoters have been saying that this machine "will be out in a few months," and we still don't see a product.*

The promotion for this machine is full of hype and misinformation as well. The fact is, there just is not very much energy available in low wind speeds. And all wind generators should be on tall towers to get above ground friction and turbulence, just as PV modules should be sited in full sun. The claims for this machine exceed the physical possibility. See Hugh Piggott's article in this issue for a rough guide to calculating output from a wind generator.

I urge you to be very cautious about outlandish claims, especially with wind generators. The major manufacturers are building good quality machines that are representative of what is really possible. If the claims from folks with a new idea sound too good to be true, they probably are. Don't plunk your money down until you've seen one, heard one, and watched the kilowatt-hour meter… Best, Ian Woofenden • ian.woofenden@homepower.com

Question Authority

Dear Editor, Twelve years ago Larry Elliot, a writer to *Home Power*, said he liked the bumper sticker, "Question Authority." His letter was about overkill *National Electric Code (NEC)* regulations.

Twelve years later, things have gone from bad to worse. Simply follow the money. The excessive regulations benefit regulators, equipment manufacturers, electricians, testing laboratories, and government inspectors. All consumers are hurt by unnecessary and redundant regulations.

Government employees and most of their contractors create no new wealth for the nation. They simply stifle productivity. Nor does the country need real working people in the manufacturing sector turning out unnecessary widgets.

To be blunt, the safety excuse for regulations is a crock. Until regulators address other safety issues for themselves and their family, I feel they are hypocrites. Examples include home sprinkler systems or driving around in a safe one-ton pickup with aftermarket side impact airbags installed. Remember the sniper in Ohio. If one uses the extreme safety logic of the *NEC* regulations, then everyone should be driving armored cars.

Unless you have children playing cowboy and Indian and throwing real tomahawks in your power room, you don't need all the wire in conduit. Nor do you need a disconnect switch for your inverter on a low voltage system—simply pull a fuse if you want to isolate and service the inverter.

I am for safe alternative energy systems but strongly against the overkill regulations and an intrusive government babysitting our every move. Twelve years ago, Larry Elliot had it right, *Question Authority.* Steve Hicks, Mountain Pass Wind Co., White Sulphur Springs, Montana

RE happenings

INTERNATIONAL

Solar On-Line (SóL) Internet courses on PV, green building, & 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.

BELIZE

Dec. 6–10, '04; Basic PV; Toledo District. Hands-on workshop with lectures, labs, & installs. Info: hareef99@yahoo.com • www.thefarm.org/etc

CANADA

Alberta Sustainable Home/Office, Calgary. Open last Sat. every month 1–4 PM, private tours available. Cold-climate, conservation, RE, efficiency, etc. 9211 Scurfield Dr. NW, Calgary, AB T3L 1V9 • 403-239-1882 • jdo@ecobuildings.net • www.ecobuildings.net

COSTA RICA

Feb. 21–27, '05; Homebuilt Wind Generators workshop, Fundacion Durika, Costa Rica. Build wind generators from scratch with Hugh Piggott. Info: see SEI in COLORADO listings. Coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Mar. 7–13, '05; RE for the Developing World-Hands On, Rancho Mastatal, Costa Rica. Solar electricity, hot water, & cooking; & other RE technologies. Info: see SEI in COLORADO listings. Coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

CHINA

Oct. 31–Nov. 4, '04; Wind Energy Conf. & RE Exhibition; Beijing. Info: World Wind Energy Assoc., Charles-de-Gaulle-Str. 5, 53113 Bonn, Germany • +49-228-369 40-80 • secretariat@wwindea.org • www.wwindea.org

GERMANY

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

Jan. 26–27, '05; Clean Energy Power 2005; Berlin. Consumer & trade fair for RE, alternative mobility and energy efficiency. Info: www.energiemessen.de

Feb. 25–27, '05; Erneuerbare Energien 2005; Böblingen. Consumer & trade fair for RE & energy efficient building & reconstruction. Info: www.erneuerbareenergien.com

Mar. 21–23, '05; ENEX - New Energy 2005; Polen. RE trade & consumer fair. Info: www.enex-expo.com

HUNGARY

Sep. 27–29, '04; RE & Energy Efficiency Finance Forum / Green Power Central & Eastern Europe; Budapest. Finance forum followed by 2-day green power expo for business. Info: www.greenpowerconferences.com

ITALY

Sep. 30–Oct. 2, '04; Eolica Expo Mediterranean; Rome. Expo & conference on utility-scale wind power. Info: Solar Energy Group, Via Antonio Gramsci 63, 20032 Cormano (MI), Italy • +39 0266301754 • info@eolicaexpo.com • www.eolicaexpo.com

KENYA

Sep. 18, '04 in Mombasa & Dec. 18, '04, place TBA. Regional energy fairs. Info: Solarnet, PO Box 76406-00508, Nairobi, Kenya • 254-20-572656, 565027 • david@solarnet-ea.org • www.solarnet-ea.org

UNITED KINGDOM

Sep. 20–21, '04; RE Finance Forum; Kensington, London. Info: Tanya Mayrhofer, • 020 7779 8103 • Fax: 020 7779 8946 • tmayrhofer@euromoneyplc.com • www.coaltrans.com

Apr. 18–21, '05; Int. Power Sources Symposium & Exhibit-STORE 2005; Brighton Corn Exchange. Storage of RE. Info: Int. Power Sources Symposium • www.ipss.org.uk

U.S.A.

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

Info on state & federal incentives for RE. North Carolina Solar Center, Box 7401 NCSU, Raleigh, NC 27695 • 919-515-3480 • www.dsireusa.org

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

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

ARIZONA

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

CALIFORNIA

Aug. 5–8, '04; Eco Wave 2004; Oakland. Green architecture conf. Info: San Francisco Institute of Architecture, Box 2590, Alameda, CA 94501 • 510-523-5174 • SFIA@aol.com

Aug. 14, '04; Southern California RE Expo; Pomona, CA. RE booths, workshops, & demonstrations. Info: Solatron Technologies, Inc. • 888-647-6527 • www.socalenergyexpo.com

Aug. 23–24, '04; Solfest RE & Sustainability Fair; Hopland, CA; Exhibits, workshops, music, speakers. Info: 707-744-2017 • www.solfest.org

Oct. 2–15, '04; Green Building For A Sustainable Future; Garberville, CA. Workshop covers ecological design, green building, RE, grey water, sustainable forestry, & indoor air quality. Info: Heartwood Institute, 877-936-9663 • hello@heartwoodinstitute.com • www.heartwoodinstitute.com

Oct. 18–21, '04; Solar Power 2004; San Francisco. Conf. & expo for all forms of residential and commercial solar applications. Info: SEIA, 202-628-7745 • ebrown@seia.org • www.solarpower2004.com

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

Hopland, CA. Ongoing workshops, including beginning to advanced PV, wind, hydro, alternative fuels, green building techniques, & more. Real Goods SLI, 13771 S. Highway 101, Hopland, CA 95449 • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO

Aug. 29–Sept. 3, '04; World RE Congress; Boulder. Forum for energy suppliers, consumers, governments, industry, academia & financial institutions on RE. Info: Nancy Jo Wiggin • 203-925-2102 • nwiggin@infinityexpo.com • www.energytechexpo.com

Sep. 27–Oct. 5, '04; Sustainable Resources 2004: Solutions to World Poverty; Boulder. Grassroots conf. on sustainable development, technology, & use of resources. Info: Sustainable Resources Conference, 717 Poplar Ave., Boulder, CO 80304 • 888-317-1600 or 303-998-1323 • info@sustainableresources.org • www.sustainableresources.org

Camp-Us; RE camp for teens. Jul. & Aug. sessions. Lectures, labs, hiking, & more. Apprenticeships available, campers & volunteers wanted. Info: Ed Eaton, Our Sun Solar, PO Box 1876, Paonia, CO 81428 • 970-948-5304 • hareef99@yahoo.com • www.youthcamp-us.org

Carbondale, CO. SEI hands-on workshops & online distance courses on PV, solar pumping, wind power, micro-hydro, solar H2O, alternative fuels, green building, women's courses, & online distance courses. Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

ILLINOIS

Aug. 7–8, '04; 3d Annual IL RE Fair; Ogle County Fairgrounds; Oregon, IL. Exhibits, workshops, & booths. Info: IL RE Assoc. • 815-732-7332 • www.illinoisrenew.org

IOWA

Jul. 31– Aug. 1, '04; Solar Domestic Hot Water Workshop; Garrison, IA. See below for IRENEW access.

Sep. 11–12, '04; 13th Iowa Energy Expo, Prairiewoods Franciscan Center, Hiawatha, IA. Workshops, exhibits, Electrathon, alternative vehicles, straw bale building, passive & active solar, biomass, & solar-powered music. See below for IRENEW access.

Prairiewoods & Cedar Rapids, IA. Iowa RE Assoc. meets 2nd Sat. every month at 9 AM. Call for changes. IRENEW, PO Box 3405, Iowa City, IA 52244 • 563-432-6551 • irenew@irenew.org • www.irenew.org

KENTUCKY

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

MICHIGAN

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

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

NEW MEXICO

Sep. 25–26, '04; Solar Fiesta; Albuquerque. RE fair, incl. solar, wind, passive solar and green building, solar cooking, water harvesting, & recycling. Also, kids' area & solar entertainment. Info: NM Solar Energy Assoc., 505-246-0400 • info@nmsea.org • www.nmsea.org

NEW YORK

Aug. 8–11, '04; Energy 2004: Energy Efficiency Workshop & Expo; Rochester, NY. EE for all professionals. Info: 410-997-0763 • energy@epponline.com • www.energy2004.ee.doe.gov

NORTH CAROLINA

Aug. 27–29, '04; Southern Energy & Environment Expo; Etowah, NC. RE, green building, & sustainable living exhibits, workshops, & talks. Info: S.E.E. Expo, PO Box 1562, Etowah, NC 28729 • 828-696-3877 • 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

Oct. 2, '04; Green Energy Ohio Solar Tour. Sustainable, energy efficient, & RE technologies at homes, businesses, & public places. Guidebook. Info: See GEO below.

Oct. 9–10, '04; Athens Area Sustainability Festival; Athens, OH. Recycling, solar, wind, watershed restoration, organic farming, alternative transportation, local arts, music, theatre, jugglers, food, education, etc. Info: AASF, PO Box 58, Amesville, OH 45711 • 740-448-2696 • media@susfest.org • www.susfest.org

Nov. 9–10, '04; Ohio Wind Power Conference; Cleveland. Educational seminar on wind development for Ohio & Lake Erie. Info: Green Energy Ohio, 866-GREEN-OH • geo@greenenergyohio.org • www.GreenEnergyOhio.org

OREGON

Sep. 18, '04; Solar Cookery Equinox Extravaganza & Potluck; Morning Hill Forest Farm, Seneca, 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

TEXAS

Sep. 24–26, '04; Texas RE Roundup & Green Living Fair; Fredericksburg, TX. Speakers, workshops, demos, family activities, alternative vehicles, & natural food. Info: 877-3ROUNDUP • 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: e-mail for meeting times: HREG • hreg@txses.org • www.txses.org/hreg

WASHINGTON STATE

Oct. 16, '04; 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. 18–23, '04; 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

Oct. 25–30, '04; 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

WISCONSIN

MREA workshops: Aug. 25–26, Gurnee, IL, Basic PV; Aug. 27–28; Gurnee, IL, Int. PV; Jul. 30–Aug. 1, St. Cloud, MN, Straw Bale Constr; Sep. 19–25, Custer, Tilt-Up Tower Wind Install. Also, Alternative Construction, Solar Domestic Hot Water, Solar Space Heating, & more. Info: MREA, 7558 Deer Rd., Custer, WI 54423 • 715-592-6595 • mreainfo@wi-net.com • www.the-mrea.org

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

Technology & Change

Richard Perez

Technology is now a major force driving change in human society. Technology is so powerful that it now modifies our natural environment in addition to our human society.

I beg your indulgence for this short history and analysis of social change. I don't have the space to develop and document the ideas I'm going to present. This is a seat-of-the-pants historical reflection. This is one person's impressions, gathered in a half century's intense interest in social change.

We humans have always been a busy lot. We're never satisfied with the status quo. We always seek to make change and to improve our conditions. For millennia past, religion provided the ideology that structured change in human society.

Within the last few centuries, newer rules and nonsecular ideals were developed by what we call "politics." Politics is an ideology, a structure, for governing and ordering human society. Change in human society was always directed by religious or political ideas. All this has changed. We now have a new factor structuring human society—technology.

As I look back on the last century, I find that neither religion nor politics were the major forces that drove social change. Religious states became rare. Major political revolutions took place and failed—witness the communist revolutions in the Soviet Union and China. Democracies became mechanical in their support of the status quo—the business of government became business. Religion became a private affair. Politics stagnated.

During the last century, people discovered and began to popularize technology. Machines amplified our labors. Technology allowed us to do things that a century before would have been considered magical marvels. Almost without realizing it, we allowed technology and engineering to become the factors that shaped our lives.

Instrument of Social Change

I realize that many of you may scoff. Technology is just gadgets and machines, you may say. We humans still order our societies by our politics and religions, you may claim. I offer three very distinct examples of my claim that technology now primarily directs our societies—transportation, especially the automobile; telecommunications, especially the Internet; and electricity. These are all technological mass developments within the last century.

Transportation. At the turn of the last century, the automobile was considered a curiosity. This play toy for the rich would never replace our traditional beast of burden, the horse, as our mode of moving ourselves and our necessary supplies. As the century wore on, the automobile gained acceptance and became more common—we made millions of them.

Soon we were building roads and highways especially for automobiles and definitely not useful for horses. We mined minerals to make these steel transportation machines. We pumped the eons-old richness of the Earth's oil to fuel these mechanical vehicles. No longer were we limited to what we could walk or ride a horse to in a day or two. We could span vast distances, and we could haul goods over hundreds, even thousands of miles. We changed. Our culture changed.

Let's shift gears from the macro to the micro for a moment. Karen and I lived for six years on our homestead on Agate Flat, Oregon, without a motor vehicle. Everything we needed from the "outside world" had to be either backpacked or horse-packed six miles from the nearest automobile accessible road—this was 19th century living.

We could, and did, employ ourselves at home, but any outside labor for money meant a journey by either foot or horse of many hours before we could reach the site of our employment. A journey to town for supplies took several days, even with the charity of our automobile-owning neighbor who ferried us to town and back. For us, a journey to town was an experience in culture shock. We were living in a previous century and visiting a new world that we neither were part of, nor could afford. I experienced, first hand, the change that the automobile had made to our culture.

The automobile, and its larger cousin the truck, shaped 20th century life. These mechanical conveyances gave us the ability to work many, many miles from where we live. It gave us the ability to centralize food production and manufacturing, and to ship these goods thousands of miles to where they were eventually consumed and used. It changed us in more practical ways than religion or politics ever did.

Communications. A century ago, most human communication was carried out by talking face to face. Letters were a rarity, and telegraphic communication just beginning. Technology limited communications to neighborhoods. News traveled slowly.

During the 20th century, radio communications became common. Everyone in an entire nation could listen to the same information at the same time. Telephones put us in communication with each other, regardless of distance. Televisions added moving pictures to the audio offered by radios. And recently, the Internet began spreading information, communications, and ideas worldwide.

What were local communications became national; national ideas became international. We entered the information age. Access to international and instantaneous communication changed every society it touched. Ideas and opinions became more homogenized.

The high degree of modern, interconnected, information interchange brought the peoples of the world closer together. We became more informed, and therefore more concerned about events outside of our neighborhood. We became more tolerant of different elements within our own society and those of different, international societies.

Once again, a personal digression from the macro to the micro. Karen and I lived for many years without a telephone. The nearest mailbox was a day's journey from our home. We didn't have a television or even a radio. We lived in a 19th century communications universe. We got the neighborhood news by visiting and talking with our neighbors, and by reading newspapers and magazines that were weeks and sometimes months out of date.

When we finally got modern communication devices at our home, we experienced a cultural shock. The world was ahead of us by decades, and we caught up in a matter of weeks. Even television commercials were an interesting window on a world that had passed us by.

Electricity. Perhaps no technology has more revolutionized human society than electricity. Technologies tend to spawn other, newer technologies. Without the technology of electricity, neither modern transportation nor communications would be possible. In modern America, electricity is considered a necessity—you simply cannot live without it.

For almost a decade, Karen and I lived without electricity. We lived in a 19th century combustion world. We used kerosene lamps and candles for light. We cooked our food and heated our home with a woodstove. We hauled our drinking water by hand. To say that we welcomed electricity into our home would be a huge understatement. It revolutionized our lives.

Not only has electricity made our homes more comfortable, it has also made modern mass production and manufacturing possible. Electricity spawned entire new industries that provide work for millions of people.

And now electricity itself is undergoing a revolution. The 20th century notion of making electricity in centralized power plants and shipping it vast distances on wires is changing. Once again, technology is making societies change.

Renewable energy, electricity made from solar, wind, and microhydro sources, is challenging the concept of centralized power plants. Electricity can now be made virtually anywhere. These natural sources offer freedom from monthly energy bills, freedom from the pollution caused by centralized electricity production, freedom to live in remote areas, and I hope eventually, freedom from energy-induced wars.

Two-Edged Sword

Technology is a two-edged sword—it can be used for good or for ill. The same transportation technology that makes air travel possible can also be used to drop bombs. The same communications technology that can be used to bring information to us all can be used for misinformation and propaganda. The same electric power technology that lights our homes and pumps our water can also be used to power an electric chair.

Technology is essentially mindless and without ethics or ideals. Social change comes from how we use technology and which technologies we use. When we adopt a new technology into our homes and lives, we are in essence voting for that technology and the changes it makes. With technology, we vote with our dollars, while in politics, we vote with a ballot.

When we choose to adopt RE technologies, we also choose the social changes that RE technology fosters. If we want a better and cleaner world, the place to start is at home. Each home that uses RE is a home that participates in the democratization of energy. Each home that uses RE is a home that helps to clean up our environment. Each home that uses RE is a home that fosters world peace. We vote with our bucks—the choice is up to us.

Access

Richard Perez, *Home Power*, PO Box 520, Ashland, OR 97520 • 541-941-9716 • richard.perez@homepower.com • www.homepower.com

questions & answers

Starting Surge

Hi *HP*, I have a question about power surge. In your Energy Master spreadsheet, you use starting power of about 2x for the refrigerator example. I tested the surge on my 14.5 cubic foot Whirlpool with a Watts Up? meter, and it registered starting power that is 17 times the normal power of about 100 watts. That must be instantaneous, since the Watts Up? graphed the surge at about 2x, which I believe is averaging the power over time. I have tested other appliances including pump motors with similar results. Is this high instantaneous surge not relevant to sizing the inverter surge requirements? In this case, what should I use for a starting power estimate? Thanks, Randy Sadewic • rsadewic@earthlink.net

Hi Randy, Starting surges can be measured over a variety of time periods—1 millisecond (ms), 10 ms, 100 ms, and one second. It is the 1 second surge we are interested in when sizing inverters. I suspect that you were measuring a 1 ms or 10 ms surge. This very high, but very short duration surge can be neglected when sizing an inverter. Richard Perez • richard.perez@homepower.com

Irrigation Pump

I picked up your magazine for the first time this past weekend and enjoyed reading the entire issue. I am planting blueberry bushes in a field that does not have water or electricity and want to install a drip irrigation system. I was thinking of placing a tank with water and a small pump to pressurize the system. Have you encountered a similar application? Would a solar-electric panel be able to power the pump? Any direction would be appreciated. Thanks, Rick Scherr • rscherr@catrock.net

Hi Rick, Yes, this sort of thing is commonly done, assuming you have a source of water nearby. You could run an array-direct solar pumping system that would pump when the sun shines. Or you could use a pressure pump run by a solar-electric module and battery to provide water all the time (within the limits of the system and source). Any dealer of RE equipment should be willing to help you design a system that will fit your needs. Michael Welch • michael.welch@homepower.com

GSHP vs. SHW

HP, I don't see ground source heat pump articles much in *Home Power*, but I thought I'd ask this question: Theoretically, what is the more cost and environmentally effective choice—a ground source heat pump (GSHP) or a solar hot water (SHW) system for heating a home in a cold climate?

You would have to hold some things constant (size of home, kind of backup heat, location, etc.) in the comparison, but I would guess a GSHP would use more electricity than a SHW system (increasing pollution in my coal heavy state) A GSHP may cost more, but it will also be more effective in winter when you need it. Any back-of-the-envelope calculations you can offer? Mike • mptaylor@hotmail.com

Hi Mike, Good question. There seems to be more than a little confusion about the different technologies. Ground (water) source heat pump performance is measured by coefficient of performance (COP), the ratio of energy out to energy in. The higher the COP, the higher efficiency and the more money saved and emissions avoided. Grid-connected electrical water heaters (and furnaces) have a COP of 1, the baseline. Ground source heat pumps have COPs of 3 to 4 in home heating applications. Because domestic hot water requires a higher temperature than needed for home heating, the COP of heat pump water heaters is closer to 2. A COP of 2 means the heat pump water heater uses half the electricity needed to heat the same amount of water using an electrical resistance water heater.

Passive solar water heaters and active water heaters powered by PV have an infinite COP—they do the same job with zero grid electrical usage and cost, and zero emissions. Active solar water heaters using a grid powered pump and control have COPs of about 8 to 20, depending on system type and the location of the installation.

A quick and rough calculation for a single pump active solar water heater using a Taco 006 pump and Goldline GL-30 control: The pump draws 60 watts and the control 3 watts when the system is on, an average of 6 hours, so about 380 watt-hours per day. In addition, the control uses about 1 watt on standby for an additional 18 watt-hours, so we can round up to 400 watt-hours a day. This system is located in a sunny climate and is capable of producing 40 gallons of hot water per day (60°F temperature rise). It takes about 20,000 BTUs to heat 40 gallons of water 60°F. A KWH of electricity will produce about 3,400 BTUs, so it takes 5.6 KWH to heat the 40 gallons per day. The COP of this solar water heating system would be about 14 (5.6 ÷ 0.4 = 14).

The initial cost of the system, the total life cycle cost, and the amount of the total energy load displaced are also important factors that you may wish to consider to decide what will be best for you. Cheers, Chuck Marken • chuck.marken@homepower.com

Initial Charge

I just ordered your CD-ROM special and hope to find answers there, but I have an immediate need that you may be able to help me with. I am installing my first RE system using Photowatt solar-electric panels, eight Trojan T-105 batteries and a Xantrex C40 charge controller wired in a 48 V configuration. My question is: How do I need to do my initial charge of the batteries?

Each battery has the same date code stamped on the terminals, so they should be from the same manufacturing lot. Should I charge each 6 V battery separately and then install them in my system, or should I just install them and let the controller perform an equalization charge after it initially charges them? It seems to me that I need to charge each one individually to ensure that they are close to the same charge level, but I have not been able to find any information to support this. Thank you for your time, Bill Settle • williamsettle@yahoo.com

Hello Bill, Just go ahead and install the entire system and let the PVs charge the batteries. It will take six to eight cycles before the batteries come up to full capacity. There is no need to charge each battery before installation. If the batteries are going to sit *around for more than a few weeks before installation, be sure to stick a trickle charger on them. A cheap-o car battery charger with the batteries wired in series-parallel for 12 V will do the trick. I hope you are including an amp-hour meter in this system so you can accurately monitor the batteries' state of charge. Richard Perez • richard.perez@homepower.com*

Array Placement

Hi *Home Power*, The roof of my house has all sorts of odd angles and tree shading at various times of the year. I had one PV provider suggest that I place half of a 2.5 KW system on an east-facing roof section and the other half on the west-facing roof section. Another guy (from the same company) said that such a configuration would cause trouble for the Sunny Boy 2500U grid-tied inverter. Does this make any sense to you? The second guy is suggesting that I split the system up on various south and west-facing sections, which he claims is nicer to the inverter. I'm thinking of ignoring both of these guys and installing a smaller 1.1 KW system on a single south-facing section that is shade-free for most of the day from April through September. This is when my utility has the greatest payback ($0.30 per KWH vs. $0.10 per KWH the rest of the year). With it on one section, I expect the installation to be simpler, too. I've downsized the system, since it looks like I really will have to return my electric car this summer. With this limited information, do you see any obvious flaws in my reasoning? Many thanks, Casey Hartman, Redwood City, California • robinandcasey@comcast.net

Hi Casey, I see no flaws in your reasoning, but I would not yet dismiss the idea of a larger array, even if it means splitting it up. It is weird that you are getting conflicting info from the same company. That would certainly make me think twice about things. This is from the Sunny Boy FAQ at www.sma-america.com:

Q: What is the best panel configuration to use with my Sunny Boy inverter?

A: Ideally, every PV panel connected to one Sunny Boy inverter should be installed in the same plane-of-array orientation (facing the exact same direction). You should not place PV panels in different orientations. Every module should also be installed in a location to avoid shading, no matter how small. If the orientation is mixed or partially shaded, the weakest panel(s) in the system will limit the output of the entire PV array. Other orientation considerations should be made to optimize time-of-day and/or time-of-year performance.

So, for multiple planes and/or shading situations, it would appear that multiple inverters are called for. If I were in your shoes, I would call up the folks at SMA-America and explain the situation to them. The more info you have about how much time each of the roof faces are in the sun, the better they will be able to advise you. Their reputation for helping customers is among the best in the industry. Michael Welch • michael.welch@homepower.com

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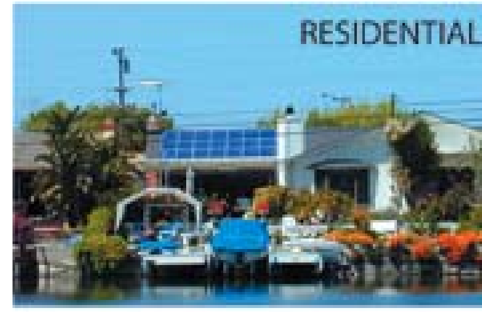

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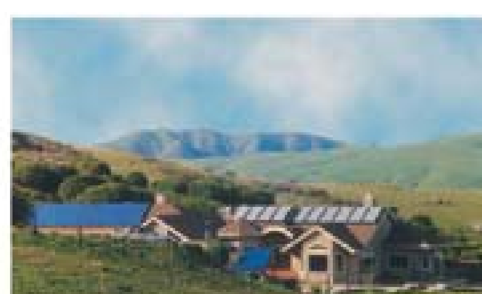

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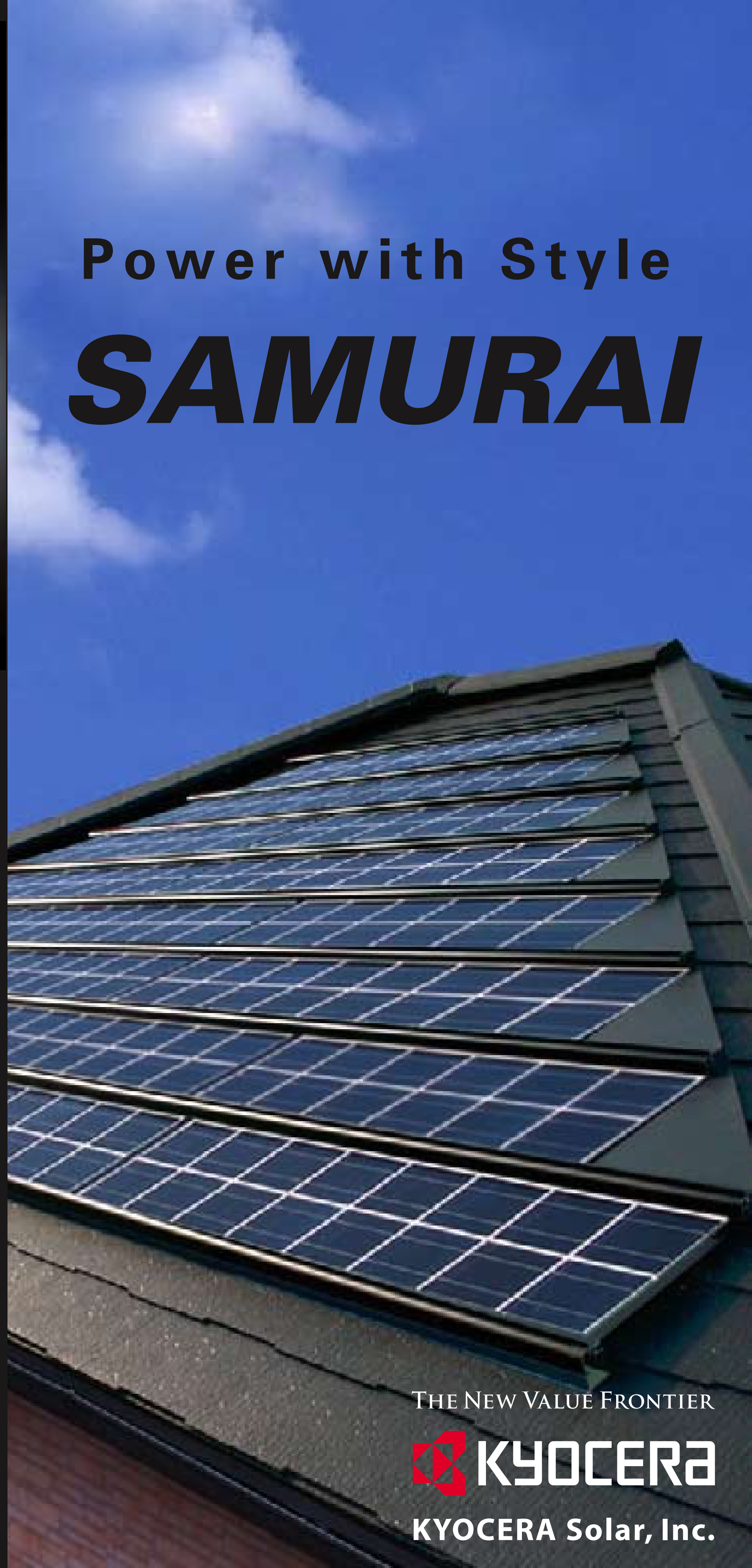

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Energy Survey

The following optional questions about your renewable energy use help us tailor the magazine to meet your needs. All information is kept confidential. We appreciate your input.

I use, or plan to use, renewable energy for:

Now	Future	
☐	☐	All electricity
☐	☐	Most electricity
☐	☐	Some electricity
☐	☐	Backup electricity
☐	☐	Recreational electricity (RVs, boats, camping)
☐	☐	Vacation or second home electricity
☐	☐	Business electricity
☐	☐	Transportation
☐	☐	Water heating
☐	☐	Space heating

My site(s) have the following renewable energy resources:

- ☐ Solar power
- ☐ Wind power
- ☐ Hydro power
- ☐ Biomass
- ☐ Geothermal power
- ☐ Tidal power
- ☐ Other (explain)

Electric utility grid use:

☐ I have the utility grid at my location.

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

______% of my total electricity is purchased from the grid.

☐ I sell my excess electricity to the grid.

The grid pays me ______¢ for electricity (cents per kilowatt-hour).

I use, or plan to use, the following renewable energy products (check all that apply):

Now	Future	
☐	☐	Photovoltaic modules
☐	☐	Wind generator
☐	☐	Hydroelectric generator
☐	☐	Battery charger
☐	☐	Instrumentation
☐	☐	Batteries
☐	☐	Inverter
☐	☐	Controls
☐	☐	PV tracker
☐	☐	Engine/generator
☐	☐	Methane digester
☐	☐	Thermoelectric generator
☐	☐	Solar oven or cooker
☐	☐	Solar water heater
☐	☐	Wood-fired water heater
☐	☐	Solar space heating system
☐	☐	Hydrogen cells (electrolyzers)
☐	☐	Fuel cells
☐	☐	RE-powered water pump
☐	☐	Electric vehicle

Feedback

Please write to us here. Tell us what you like and don't like about *Home Power*. What would you like to read about in future issues? Thanks for your attention and support.

☐ It's okay to print my comments as a letter to *Home Power.*

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