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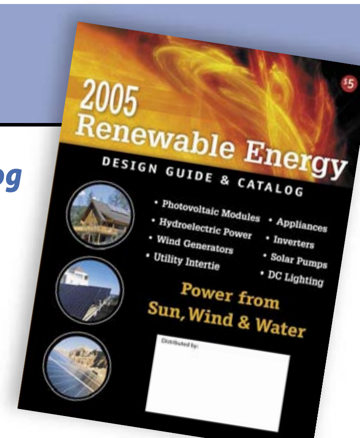

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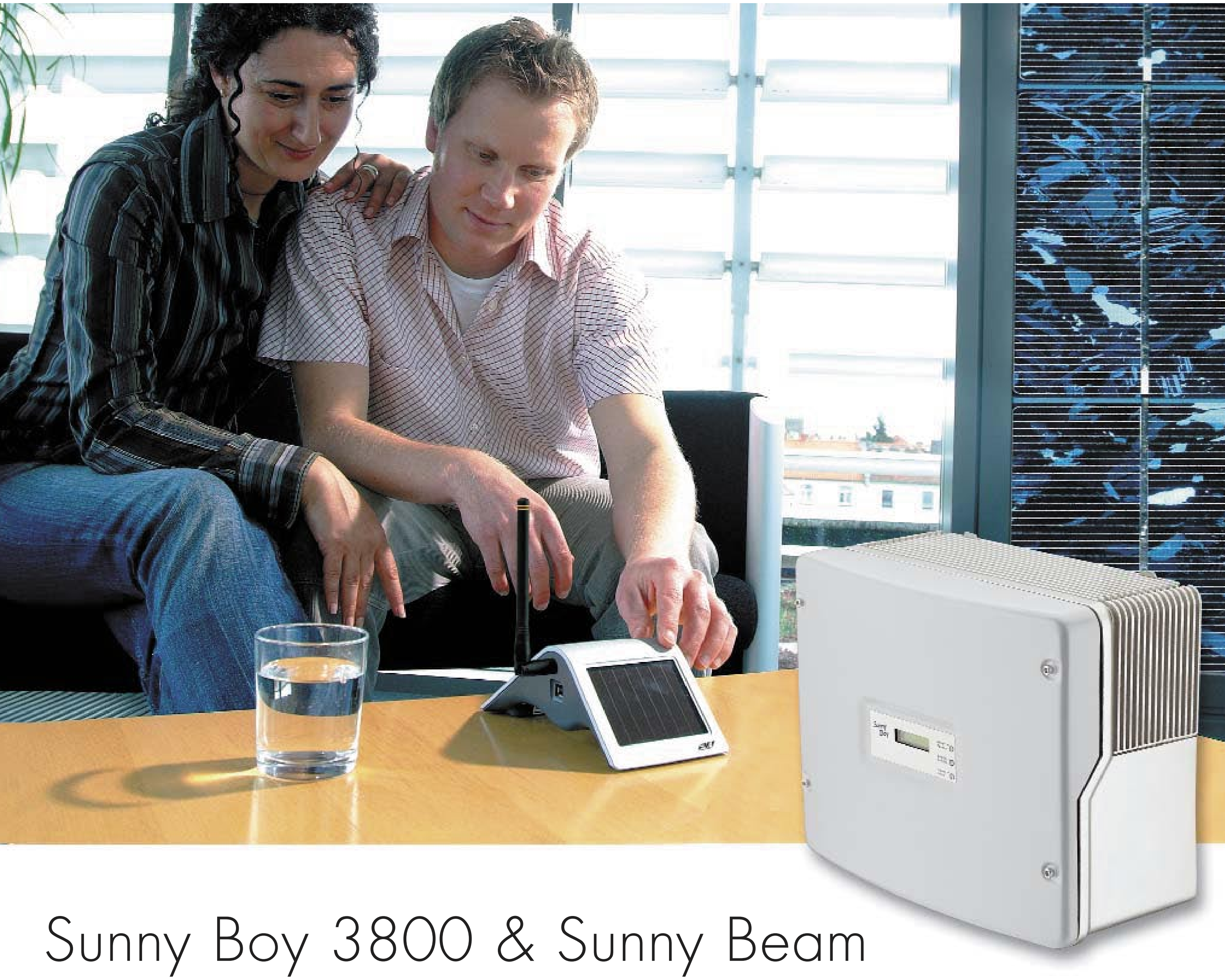

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HP110 contents

On the Cover

Tiffany Grisen fuels her Volkswagen Golf TDI with cleaner, greener, 100 percent biodiesel at Rising Phoenix Biodiesel in Phoenix, Oregon (phoenixorganics.com).

Photo by Shawn Schreiner

Regulars

Fueling Change

Recent high gasoline prices have surely changed our lifestyles in a number of notable and positive ways. Gas-guzzling SUVs are being traded in for sleeker, fuel-sipping vehicles in record numbers. Alternative fuels, such as biodiesel, ethanol, straight vegetable oil, and electric and hybrid electric vehicles are options that are suddenly becoming mainstream hot topics. Most of us are just driving "smarter," while paying very close attention to our gas gauges and the signs at the pumps.

To help our budgets survive, we are becoming more efficient by combining our trips, carpooling, or not using our cars at all in favor of entertaining ourselves at home. If we go out, more of us are riding the bus, walking, and bicycling. Being able to work from home or living close to our work are new factors to consider when choosing a job or housing. As a result of these changes, we lose nothing, but gain a better connection to our communities and greater quality time to spend with our families, while we engage in more healthful activities.

If we can learn anything from how high prices have affected our transportation habits, it will teach us what we can do to reduce our other energy needs and how those changes may make our lives better. High transportation costs foreshadow what's just around the corner with other fuels—heating oil, natural gas, and grid electricity. We will surely want to modify our use habits and make smarter lifestyle choices in our homes and businesses, just as high prices for gasoline have changed the way we use our cars.

This is the perfect opportunity to explore your options. Making energy efficiency a higher priority, trading up to Energy Star appliances, and taking advantage of the excellent tax incentives now being offered for implementing efficiency measures and renewable energy technologies can only improve your lifestyle, while saving you money.

As always, you can count on *Home Power* for the most up-to-date information on RE innovations, practical tips on how to get started with your efficiency projects, and the best ideas for making lifestyle changes to save energy and money. Just turn the pages…

—Linda Pinkham for the *Home Power* crew

Think About It…

"We're not there yet…"

—George W. Bush, President of the United States
(See *Letters to HP*, page 108)

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Wind-Electric Systems SIMPLIFIED

Ian Woofenden

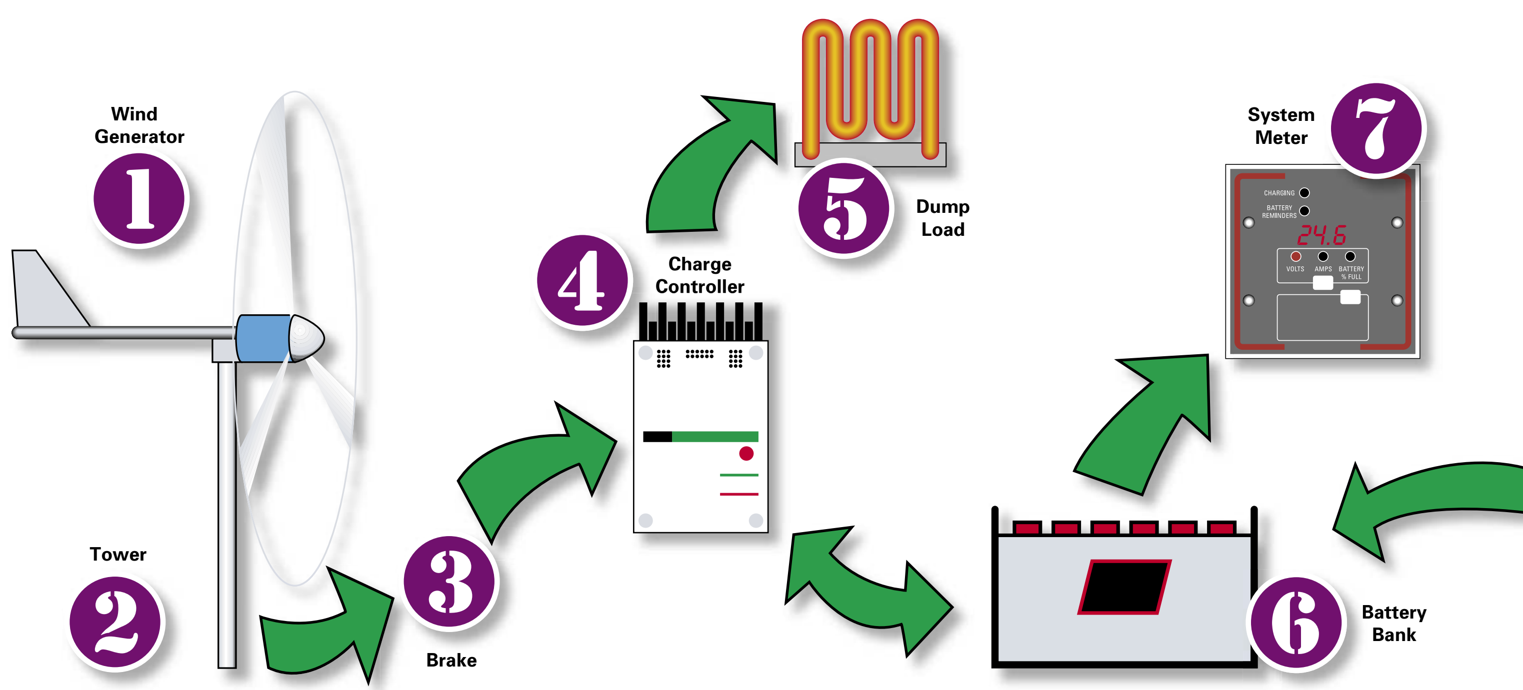
Wind-electric systems may be the most captivating of the three main renewable electricity technologies. Most of us just love to watch a wind turbine spin. But these systems are also the most prone to problems, and can be more complicated and expensive to install.

To get you started down the right road in using wind energy, this article will outline the basic system components and types. It will help you understand the systems better, so you will make better choices if you decide that wind energy is right for you.

Off-Grid Wind-Electric System

Off-grid wind-electric systems are battery based. People generally choose these systems because their home or other energy use is not connected to the grid, and connection would be expensive. Others prefer the independence of off-grid systems, or live where utilities and governments make it difficult to tie a renewable energy system to the grid.

Off-grid systems are limited in capacity by the size of the generating sources (wind turbine, solar-electric array, fuel-fired generator, etc.), the resources available, and the battery bank size. Off-grid homeowners have to learn to live within the limitations of their system capacity.



1 Wind Generator *AKA: wind genny, wind turbine*

The wind generator is what actually generates electricity in the system. Most modern wind generators are upwind designs (blades are on the side of the tower that faces into the wind), and couple permanent magnet alternators directly to the rotor (blades). Three-bladed wind generators are most common, providing a good compromise between efficiency and rotor balance.

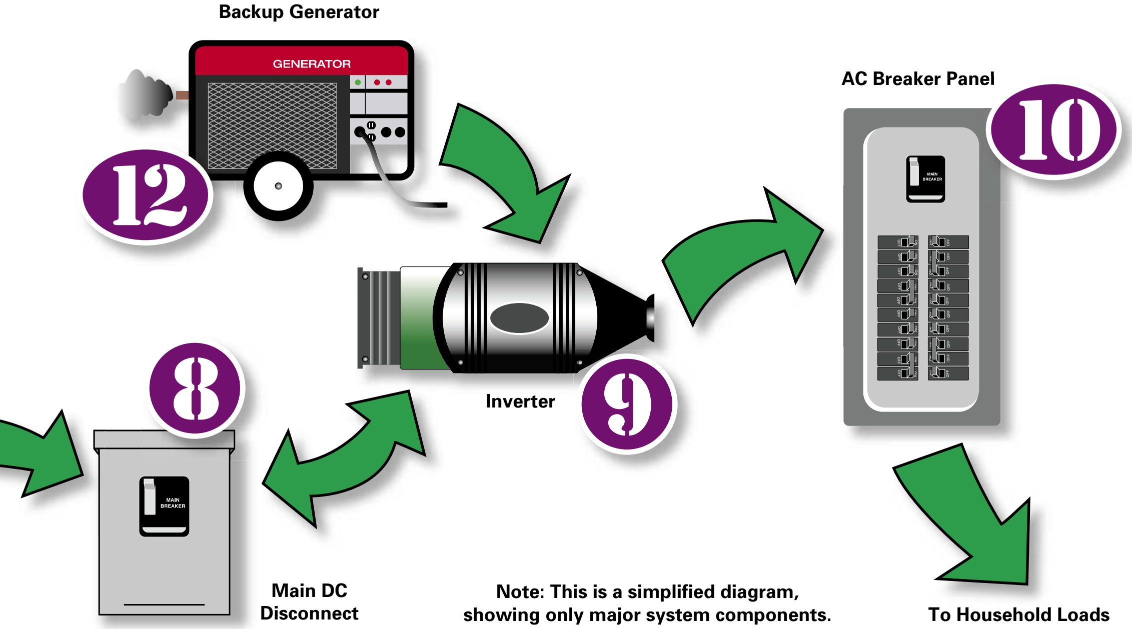
Small wind turbines protect themselves from high winds (governing) by tilting the rotor up or to the side, or by changing the pitch of the blades. Electricity is transmitted down the tower on wires, most often as three-phase wild alternating current (AC).

It's called "wild" because the voltage and frequency vary with the rotational speed of the wind turbine. The output is then rectified to direct current (DC) to charge batteries or to be inverted for grid connection.

2 Tower

A wind generator tower is very often more expensive than the turbine. The tower puts the turbine up in the "fuel"—the smooth strong winds that give the most energy. Wind turbines should be sited at least 30 feet (9 m) higher than anything within 500 feet (152 m).

Three common types of towers are tilt-up, fixed-guyed, and freestanding. Towers must be specifically engineered for the lateral thrust and weight of the turbine, and should be adequately grounded to protect your equipment against lightning damage. See my article "Wind Generator Tower Basics" in *HP105* for information about choosing a tower.



3 Brake

AKA: emergency shutdown mechanism

Most wind turbines have some means of stopping the turbine for repairs, in an emergency, for routine maintenance, or when the energy is not needed. Many turbines have "dynamic braking," which simply shorts out the three electrical phases and acts as a disconnect. Others have mechanical braking, either via a disc or drum brake, activated by a small winch at the base of the tower. Still others have mechanical furling, which swings the rotor out of the wind. Mechanical braking is usually more effective and reliable than dynamic braking.

4 Charge Controller

AKA: controller, regulator

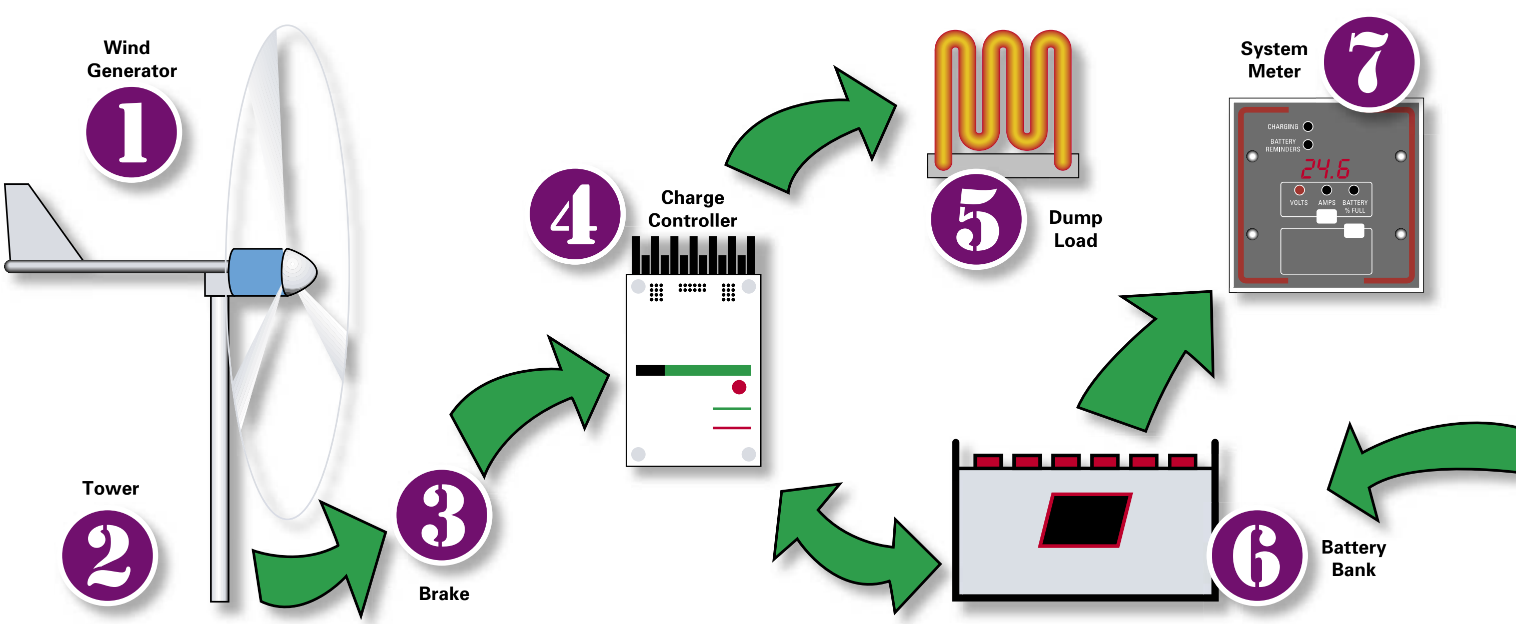
A wind-electric charge controller's primary function is to protect your battery bank from overcharging. It does this by monitoring the battery bank—when the bank is fully charged, the controller sends energy from the battery bank to a dump (diversion) load.

Many wind-electric charge controllers are built into the same box as the rectifiers (AC-to-DC converters). Overcurrent protection is needed between the battery and controller/dump load.

In batteryless grid-tie systems, there is no controller in normal operation, since the inverter is selling whatever energy the turbine is generating. But there will be some control function in the case of grid failure, and there may be electronics before the inverter to regulate the input voltage.

GRID-TIED WIND-ELECTRIC SYSTEM WITH BATTERY BACKUP

Connecting a wind-electric system to the utility grid with battery backup gives you the best of both worlds. You have the unlimited capacity of the grid at your disposal, and you can send your surplus wind energy to the grid. When the grid is down, you can still use your system, within the limitations of the battery bank and turbine. Wind-electric systems can be a much better match for utility backup than solar-electric systems, since many grid outages are caused by high winds. The drawback is that this is the most expensive type of wind-electric system you can install.



5 Dump Load *AKA: diversion load, shunt load*

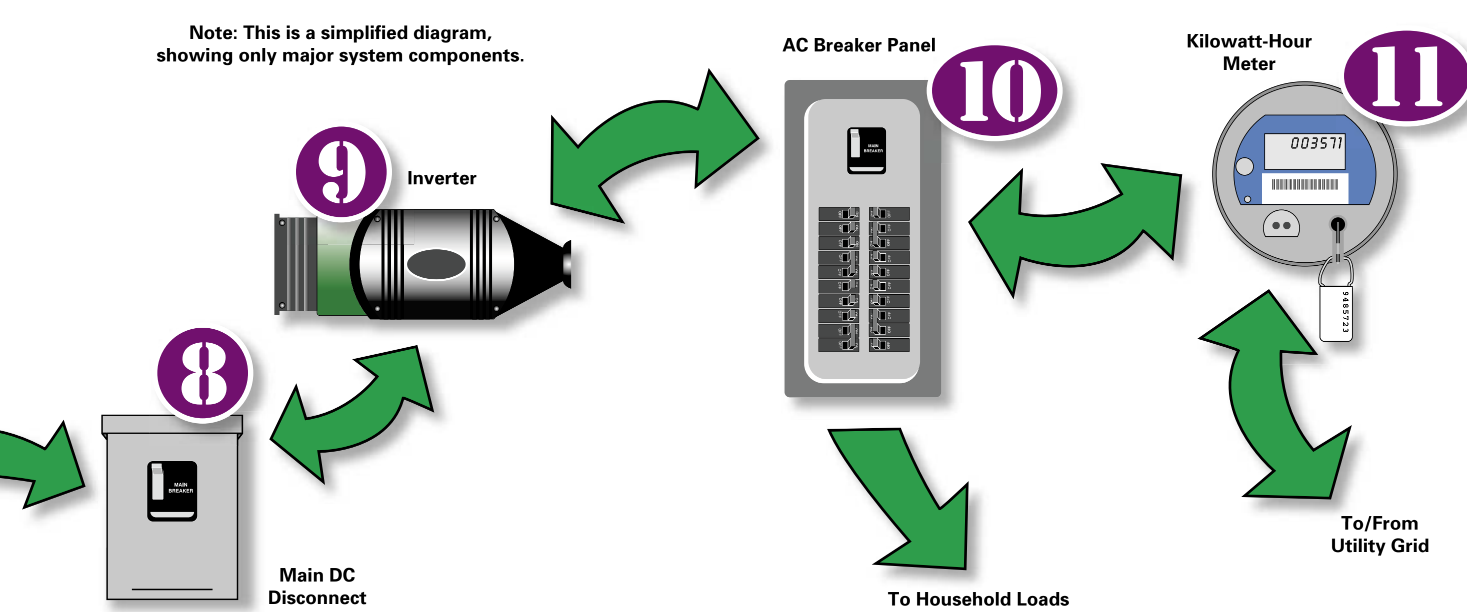
Solar-electric modules can be turned off—open circuited—with no damage. Most wind generators should not run unloaded. They will run too fast and too loud, and may self-destruct. They must be connected to a battery bank or load. So normally, a charge controller that has the capability of being a diversion controller is used. A diversion controller takes surplus energy from the battery bank and sends it to a dump load. In contrast, a series controller (commonly used in PV systems), actually opens the circuit.

A dump load is an electrical resistance heater, and it must be sized to handle the full generating capacity of the wind generator used. These dump loads can be air or water heaters, and are activated by the charge controller whenever the batteries or the grid cannot accept the energy being produced.

6 Battery Bank *AKA: storage battery*

Your wind generator will produce electricity whenever the wind blows above the cut-in speed. If your system is off grid, you'll need a battery bank—a group of batteries wired together—to store energy so you can have electricity when it's not windy. For off-grid systems, battery banks are typically sized to keep household electricity running for one to three calm days. Grid-intertied systems also can include battery banks to provide emergency backup during blackouts—perfect for keeping critical electric loads operating until the grid is up again.

Use only deep-cycle batteries in wind-electric systems. Lead-acid batteries are the most common battery type. Flooded lead-acid batteries are usually the least expensive, but require adding distilled water occasionally to replenish water lost during the normal charging process. Sealed absorbed glass mat (AGM) batteries are maintenance free and designed for grid-tied systems where the batteries are typically kept at a full state of charge. Sealed gel-cell batteries can be a good choice to use in unheated spaces due to their freeze-resistant qualities.



7 System Meter

AKA: battery monitor, amp-hour meter, watt-hour meter

System meters can measure and display several different aspects of your wind-electric system's performance and status—tracking how full your battery bank is, how much electricity your wind generator is producing or has produced, and how much electricity is in use. Operating your system without metering is like running your car without any gauges—although possible to do, it's always better to know how much fuel is in the tank.

8 Main DC Disconnect

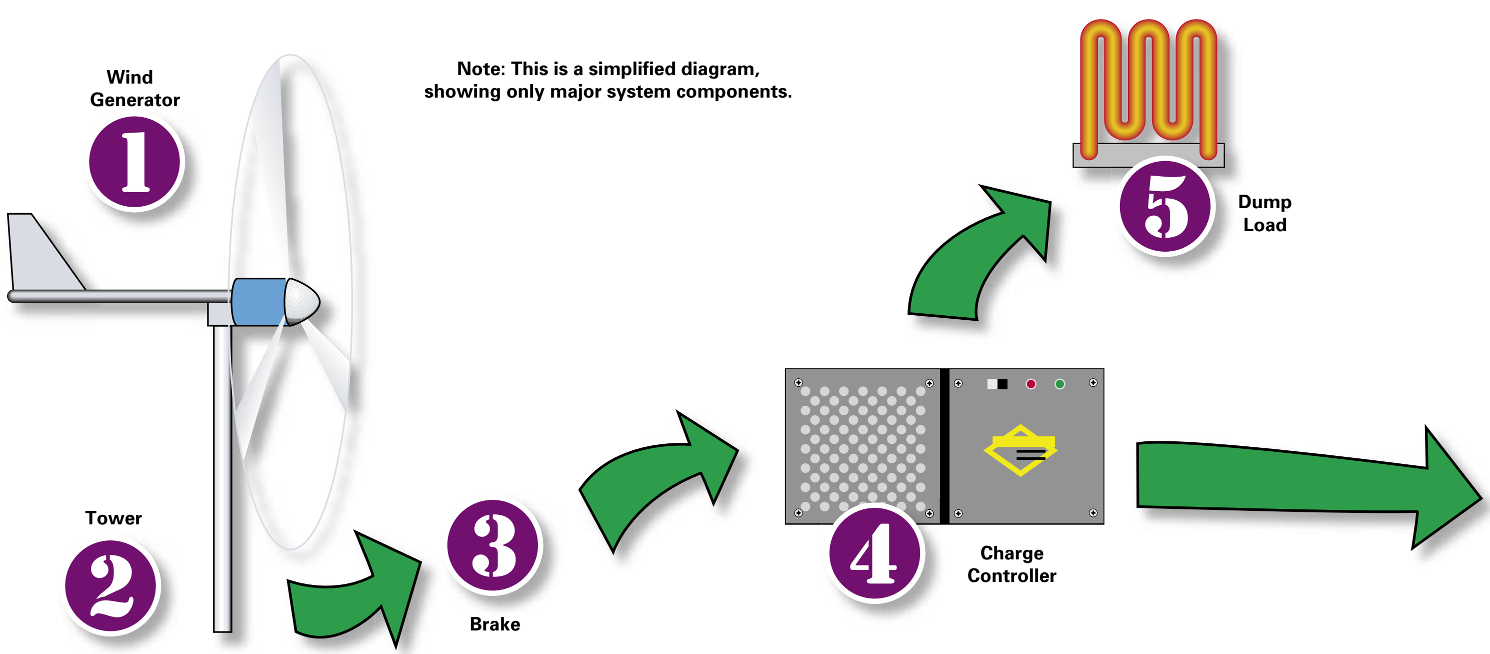
AKA: battery / inverter disconnect

In battery-based systems, a disconnect between the batteries and inverter is required. This disconnect is typically a large, DC-rated breaker mounted in a sheet metal enclosure. This breaker allows the inverter to be quickly disconnected from the batteries for service, and protects the inverter-to-battery wiring against electrical fires.

BATTERYLESS GRID-TIED WIND-ELECTRIC SYSTEM

Connecting to the grid without batteries is the most cost-effective and environmentally friendly way to go. You eliminate batteries, which are costly, require maintenance, and carry a significant efficiency penalty. The only drawback of batteryless systems is that when the grid is down, your system shuts down. But in most grid-serviced areas, utility outages are only a few hours a year—a small inconvenience to endure for the efficiency, environmental friendliness, and thriftiness of these systems.

Batteryless grid-tie systems may see increased performance (sometimes dramatically) from the wind turbine compared to battery-based systems. This is because the inverter's electronics can match the wind's load more exactly, running the turbine at optimum speed, and extracting the maximum energy.



9 Inverter

AKA: DC-to-AC converter

Inverters transform the electricity produced by your wind generator into the AC electricity commonly used in most homes for powering lights and appliances. Grid-tied inverters synchronize the electricity they produce with the grid's "utility grade" AC electricity, allowing the system to feed wind electricity to the utility grid.

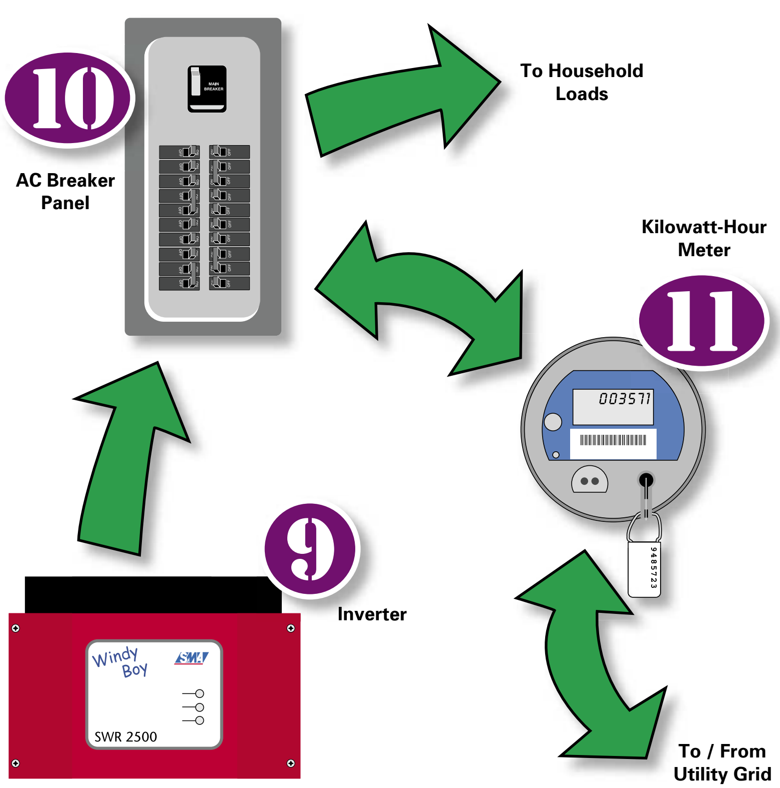
Grid-tie inverters are either designed to operate with or without batteries. Battery-based inverters for off-grid or grid-tie systems often include a battery charger, which is capable of charging a battery bank from either the grid or a backup generator during cloudy weather.

10 AC Breaker Panel

AKA: mains panel, breaker box, fuse box

The AC breaker panel, or mains panel, is the point at which all of a home's electrical wiring meets with the "provider" of the electricity, whether that's the grid or a wind-electric system. This wall-mounted panel or box is usually installed in a utility room, basement, garage, or on the exterior of the building. It contains a number of labeled circuit breakers that route electricity to the various rooms throughout a house. These breakers allow electricity to be disconnected for servicing, and also protect the building's wiring against electrical fires.

Just like the electrical circuits in your home or office, an inverter's electrical output needs to be routed through an AC circuit breaker. This breaker is usually mounted inside the building's mains panel. It enables the inverter to be disconnected from either the grid or from electrical loads if servicing is necessary. The breaker also safeguards the circuit's electrical wiring.



11 Kilowatt-Hour Meter

AKA: KWH meter, utility meter

Most homes with a grid-tied wind-electric system will have AC electricity both coming from and going to the electric utility grid. A bidirectional KWH meter can simultaneously keep track of how much electricity you're using and how much your system is producing. The utility company often provides intertie-capable meters at no cost.

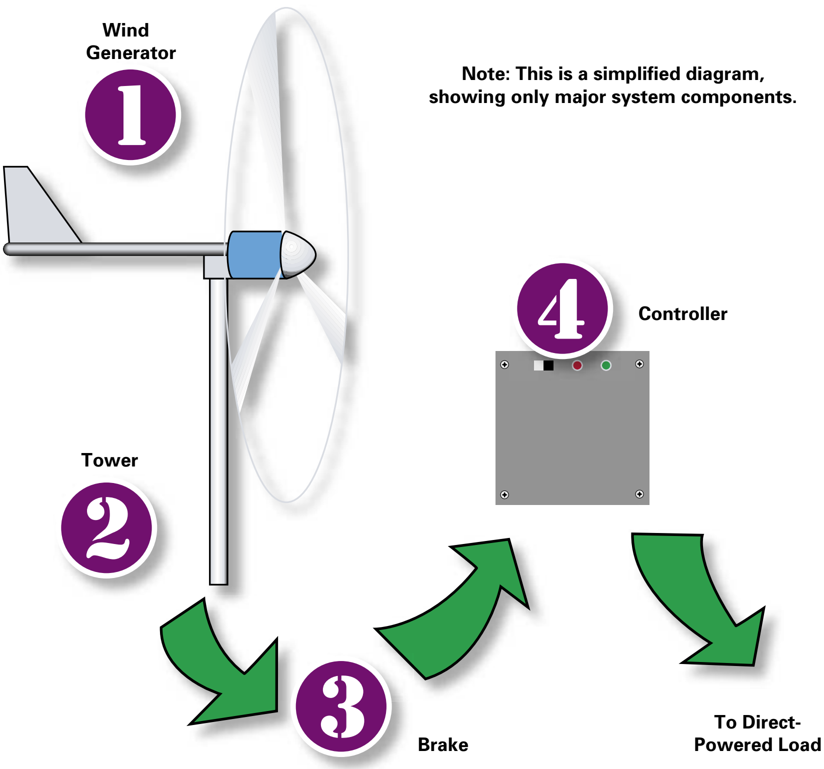
12 Backup Generator *AKA: gas-guzzler, "the Noise"*

Off-grid wind-electric systems can be sized to provide electricity during calm periods when the wind doesn't blow. But sizing a system to cover a worst-case scenario, like several calm weeks during the summer, can result in a very large, expensive system that will rarely get used to its capacity, and will run a huge surplus in windy times. To spare your pocketbook, go with at least two sources of energy. Wind–PV hybrid systems are often an excellent fit with local renewable resources. But a backup, fuel-powered generator still may be necessary.

Engine-generators can be fueled with biodiesel, petroleum diesel, gasoline, or propane, depending on the design. Most generators produce AC electricity that a battery charger (either stand-alone or incorporated into an inverter) converts to DC energy, which is stored in batteries. Like most internal combustion engines, generators tend to be loud and stinky, but a well-designed renewable energy system will require running them 50 to 200 hours a year or less.

DIRECT-DRIVE BATTERYLESS WIND-ELECTRIC SYSTEM

These are the least common wind-electric systems, typically used for water pumping. A turbine is matched to a pump, often through an electronic controller. When the wind blows, water is pumped to an elevated tank, a stock-watering tank, or directly to the land to irrigate. These systems can be simple and cost effective in the right situation. Direct-drive systems are also used for heating, which can be a good match, since it's normally colder when it's windy. But heating is a big load, so large turbines are needed.



Do It Right & Harvest the Wind

If you want a simple, reliable, maintenance-free renewable electricity system, buy solar-electric modules. Wind-electric systems are not for the faint-of-heart, and will probably never be a simple "appliance" that you can install and forget about. These are spinning machines in a very harsh environment. You don't expect your car to operate without maintenance, and you choose and drive it carefully to avoid accidents. The same is true of wind-electric systems—the renewable energy systems that take the most maintenance, and have the highest potential for problems. Wind-electric systems are very satisfying when they work, but very disappointing (and visible) when they don't.

Don't buy cheap equipment, and do buy a tall tower! Buy the best turbine for your site, regardless of price, and put it on the tallest tower possible. Investing in quality up front will pay off in the long term. Almost all of the disappointment I hear about from wind energy users is related to buying lightweight equipment for heavy-duty sites, or installing equipment on towers that are not well above surrounding obstructions.

If you do it right, wind energy can be the most satisfying of the renewable energy technologies. There's nothing quite like watching a wind generator spinning, filling up your battery bank or sending energy to the grid. When the wind blows, you may need to button up your overcoat, but you'll get a warm feeling, knowing that the wind is working for you.

Access

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

More reliable redundant architecture.

Efficiency & Solar Pay Off

System owner Ron Nichols throws the switch the first time, sending solar electricity to the utility grid.

Lori Hauser & Ron Nichols

By virtue of a long-held intrigue with solar energy, along with a conservationist attitude fostered by parents of the Great Depression, our attraction to renewable energy (RE) as a lifestyle felt like a natural fit. Personal choices include reducing our dependence on cars by walking, using public transportation, and riding bicycles as much as possible. We grow some of our food in an organic vegetable garden. These and other savings associated with our conservationist and energy efficient lifestyle made our financial investment in renewables a realistic and viable option.

Finding Phantoms & Improving Efficiency

Our active participation in RE began about three years ago when we invested in green electricity from Puget Sound Energy (PSE), the local utility. PSE allows its customers to choose renewable energy sources for their electricity by paying a small, additional cost per KWH. The US$3 to $4 more per month was worth it to know that all of the energy we were using was generated by renewable sources.

Then, through a class offered by the community college from locals who live off grid, we learned about general solar-electric system design and feasibility, along with principles of conservation. Attending the SolWest Fair in John Day, Oregon, exponentially expanded our interest in RE.

But we were limited by our budget, so before thinking about how to invest and what system to install, we studied our energy use habits to find out how we could reduce our electricity consumption.

Our home was built in the ’90s and has double-pane windows. We recently upgraded to a 96 percent efficiency,

Evacuated-tube solar hot water collectors maximize heat gain on overcast days that are common in the Pacific Northwest.

gas, forced-air furnace. We added insulation to the attic and to the crawl space under the house to reduce heat loss in winter and limit heat gain in summer. We diligently began pulling shades and blinds on the windows to preserve heat on cold winter nights and to prevent overheating on hot summer days.

We used a Kill A Watt watt-hour meter to measure the energy use of all our appliances and began to eliminate phantom loads—hidden loads from devices that continue to use energy even when you've turned them "off" or are not using them. We shut off the furnace at the electrical panel in summer to eliminate its phantom load, and use a multiplug switch for the TV, VCR, and DVD player. We replaced incandescent lightbulbs with compact fluorescents, which produce the same amount of light but only use about 30 percent of the energy.

SDHW System Tech Specs

Type: Evacuated tube, pressurized glycol

Location: Mount Vernon, Washington

Production: 99 percent, April–Sept.; 50 percent or more, Oct.–Mar.

Collector: Thermomax Solamax, 30-tube collector; 48 square feet

Collector installation: Wall-mounted at 62-degree tilt

Storage: Existing 50 gal. electric hot water tank

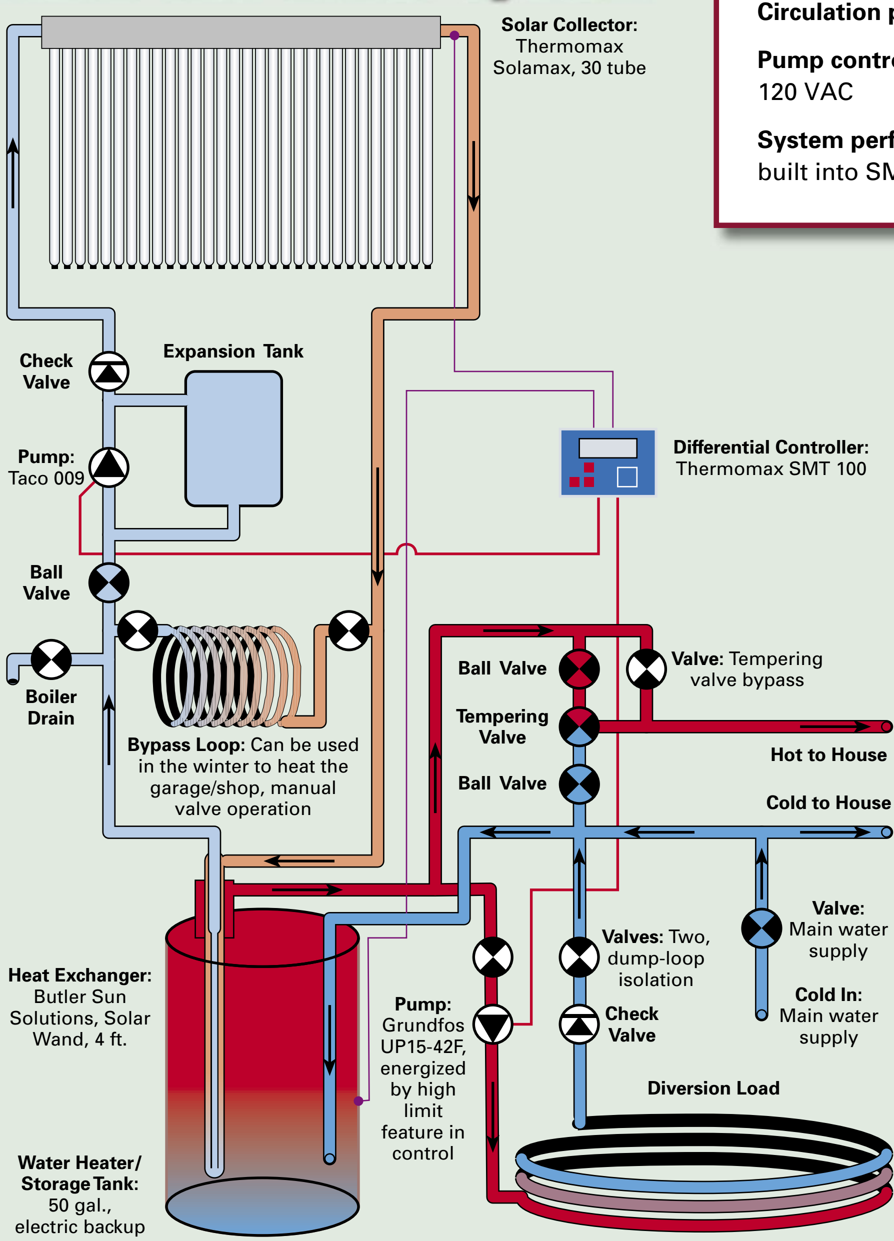
Heat exchanger: Butler Sun Solutions Solar Wand, 4 ft.

Circulation pump: Taco 009 solar loop

Pump controller: Thermomax SMT100 controller, 120 VAC

System performance metering: Thermometer built into SMT 100 controller (tank temp.)

Solar Hot Water System



Fortunately, we had made energy-wise choices in selecting a front-loading washer and electric dryer from Creda, and had the added benefit of a small and efficient electric oven and a gas countertop stove. We installed a clothesline or "solar dryer," and began to plan our clothes washing according to favorable days for outdoor drying.

We discovered that our electric water heater was the largest consumer of electricity. Although we would have liked to install an on-demand (tankless) gas water heater, our situation did not lend itself well to the outdoor venting that is required. Instead, we placed a timer on the existing water heater to coordinate hot water use for morning and evening, and insulated the tank and pipes to reduce heat loss. We also installed low-flow showerheads to reduce the amount of hot water used.

A little insulation and conservation is all it took for Lori and Ron to substantially reduce their energy use. Now, the renewable energy system that fit their budget also meets their needs.

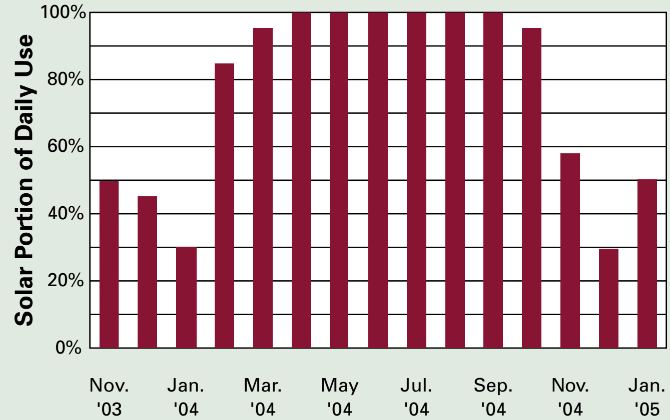
Conservation Becomes Participation

Our conservation paid off. With these simple strategies, we reduced our energy consumption by an average of 30 percent. We were excited about the way we were consuming energy thoughtfully, but without any hardship on our lifestyle. We now had a pretty good handle on what we would need for renewable energy production.

Ron attended a local hands-on workshop, and got to participate in installing a small, residential solar-electric system. Together, we visited several solar-electric and wind-powered systems throughout the Northwest as part of the American Solar Energy Society's National Solar Tour. It was now time to make the leap toward our own renewable energy production. We wanted to invest in a system that would be effective and efficient for our specific needs and situation. The savings associated with our lifestyle, and the knowledge of our energy needs, made the financial investment in solar energy and the goal of energy independence a genuine possibility.

We had saved for probably six or seven years, knowing we would be adding improvements to our home along the way. But our home was relatively new and other than cosmetic choices, we had already done the necessary structural improvements. Rather than change décor or aesthetic atmosphere, buy new cars, or spend money on other consumer garbage, we chose to invest in solar energy for the future.

Solar Hot Water Production



Solar Thermal Start

We decided to start with a solar thermal system, one of the most cost-effective uses of solar energy, to heat our water. Ron chose an evacuated tube system that performs well in the cold and overcast conditions common here in the Pacific Northwest.

Solar Hot Water System Costs

Item	Cost (US$)
30 Solamax tubes	$1,428
AST 30 solar manifold	628
Taco pump set, with expansion tank & plumbing	532
Labor	500
Solar Wand heat exchanger	275
Thermomax differential controller	267
Mount for collector & manifold	165
Misc. pipe, fittings, insulation	159
Misc. plumbing, valves, drain	112
Shipping	100
Kitec tubing & misc.	100
Grundfos UP15-42F circulating pump	88
Propylene glycol antifreeze, 1 gal.	16
C-H breaker, 20 A	6
Total	$4,376

Many Hands

Lori and Ron turned the installation of their photovoltaic system into an educational experience for others in their community. Through a Solar Energy International (SEI) workshop, two dozen enthusiastic students got hands-on experience installing a renewable energy system. See Access for info on how you can participate in a similar event.

Left: Laying out the mounting rack.

Right: Ron Nichols and an SEI student install the first PV panel.

Right: MC connectors make series wiring easy.

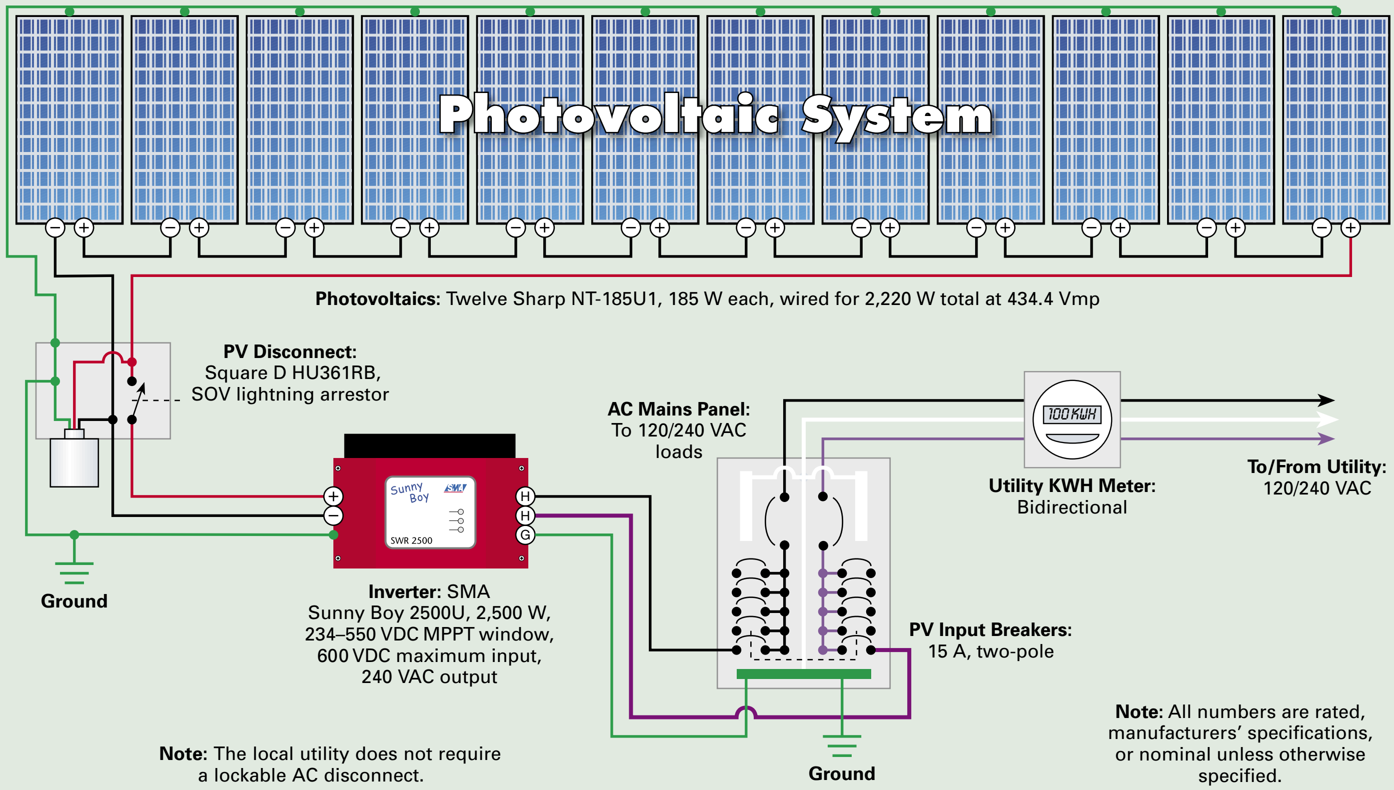
Below: Bolting down the PV array.

Left: Everyone helps.

Below: Testing PV array voltage.

Below Left: Lori and students watch the meter spin backwards.

Below: Success!



PV System Tech Specs

Type: Batteryless, grid-tie PV

Solar resource: 3.5 average daily peak sun hours

Production: 160 AC KWH per month average

Utility electricity offset: 100 percent

Photovoltaics

PV: Twelve Sharp NT-185U1, 185 W STC, 36.2 Vmp, 24 VDC nominal

Array: One, 12-module series string, 2,220 W STC, 434.4 Vmp

Array disconnect: Square D HU361RB

Array installation: UniRac SolarMount, 23-degree tilt

Balance of System

Inverter: SMA Sunny Boy 2500U, 2,500 W, 600 VDC maximum input, 234–550 VDC MPPT voltage window, 240 VAC output

System performance metering: Bidirectional AC KWH meter and Sunny Boy inverter display

Our Solamax 30-tube system is mounted on the south side of the house at a 62-degree angle—an optimal orientation that takes advantage of the sun's lower path in the sky during wintertime. In summer, we knew the system would be producing more hot water than we use, so we did not need to maximize summer exposure.

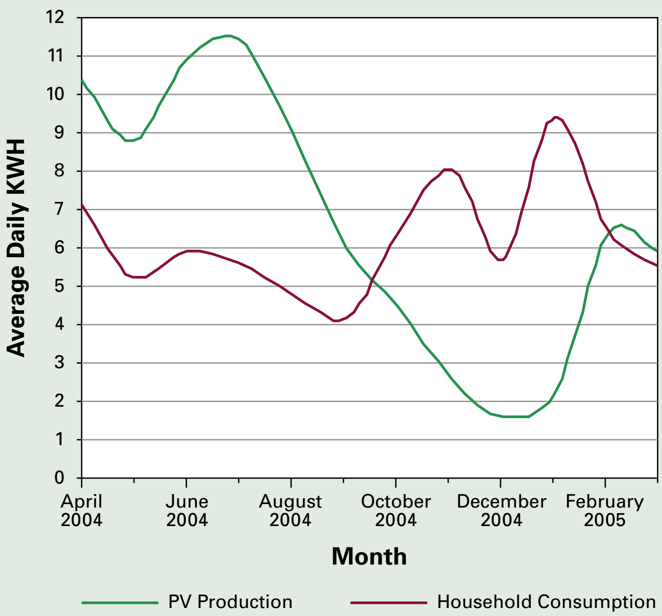
The existing electric water heater serves as the storage tank. A 4-foot-long (1.22 m) Solar Wand submerged in the hot side of the tank serves as a heat exchanger and uses propylene glycol to transfer heat. Given the high heat capacity of the glycol running through the tubes, there needed to be a way to accommodate overproduction during peak periods. We routed this "dump load" through Kitec PEX tubing—engineered composite pipe made from flexible aluminum and cross-linked polyethylene tubing—in the crawl space under the house.

Since its installation in November 2003, the system has impressed us. Between April 2004 and September 2004, it met almost 100 percent of our hot water needs, which average about 20 gallons per person, per day. During the fall and winter months, it meets about 50 percent of our demand.

Next Steps

Given the freedom from depending on electricity to heat our water, our electrical consumption was diminished to a manageable level (a monthly average consumption of 185 KWH) that could be met with a modest PV system. Through our good fortune, we had the opportunity to become a workshop site for Solar Energy International (SEI). With the

PV System Production vs. Consumption



help of SEI participants and instructors, we installed twelve Sharp 185 W monocrystalline modules on the south side of our roof, and tied the array to a Sunny Boy 2500 inverter. This project was the first grid-tied PV system in our town.

Because we have no batteries to baby-sit, the system is simple to use and maintain. Since April 10, 2004, when the installation was completed, the PV system has produced an average of 6.59 KWH per day. We've only used an average of 6.2 KWH a day. PSE allows us to "bank" excess energy we produce on an annual, rather than a monthly basis. This enables us to accumulate a surplus of stored kilowatt-hours during sunny months to help offset our electrical usage during cloudy months, when system production is lower.

PV System Costs

Item	Cost (US$)
12 Sharp NT-185UI PV modules	$9,528
SMA 2500U inverter, with display	2,950
UniRac module mounts	1,054
Shipping	319
Square D HU361RB DC disconnect	181
Misc. conduit & electrical	125
Scissor lift rental, 1 day	112
2 Multiconductor cables, 100 ft.	100
Electrical building permit	76
Delta lightning arrestor	42
C-H BR215 two-pole breaker, 15 A	9
Total	$14,496

Investing in the Future

There are many avenues to take in pursuing renewable energy, and we can all make a difference. One simple yet powerful way to invest in renewable energy is to buy green power from your local utility. Supply follows demand, and demand from enthusiastic, educated, and informed people will make a difference.

Investing in renewable energy is our way of investing in the future. Anything we do to reduce our dependence on nonrenewable energy sources is positive, no matter how small it may be to start—it goes beyond our own pocketbooks and into the preservation of the world's resources.

Access

Lori Hauser & Ronald Nichols, 524 Jefferson St., Mt. Vernon, WA 98274 • 360-336-1085 • lhauser@mv.k12.wa.us

Jeffrey Utter, Alternative Energy Solutions, 3231 Hillside Rd., Deming, WA 98244 • 360-303-5024 • Fax: 360-592-5166 • SDHW installation assistance

Butler Sun Solutions, PO Box 1666, Solana Beach, CA 92075 • Phone/Fax: 858-259-8895 • butlersunsolutions@adelphia.net • www.butlersunsolutions.com • Solar Wand in-tank heat exchangers & parts for solar-assisted hot water systems

Creda • www.creda.com • Horizontal-axis clothes washer, efficient electric clothes dryers (imported from the UK)

Delta Lightning Arrestors, PO Box 750, Big Spring, TX 79721 • 800-335-8252 or 432-267-1000 • Fax: 800-335-8227 • deltala@msn.com • www.deltala.com

Ipex Inc., 9940 E. 47th St., Denver, CO 80238 • 800-473-9808 or 303-754-0102 • Fax: 303-754-0109 • www.ipexinc.com • Kitec PEX tubing

P3 International, 132 Nassau St., New York, NY 10038 • 888-895-6282 or 212-346-7979 • Fax: 212-346-9499 • info@p3international.com • www.p3international.com • Kill A Watt meter

Jay Peltz, Peltz Power, PO Box 2391, Redway, CA 95560 • 707-923-3477 • jay@asis.com • SEI workshop instructor & PV system supplier

Sharp Electronics Corp., 5901 Bolsa Ave., Huntington Beach, CA 92647 • 800-SOLAR-06 or 714-903-4600 • Fax: 714-903-4858 • sharpsolar@sharpsec.com • www.solar.sharpusa.com • PV panels

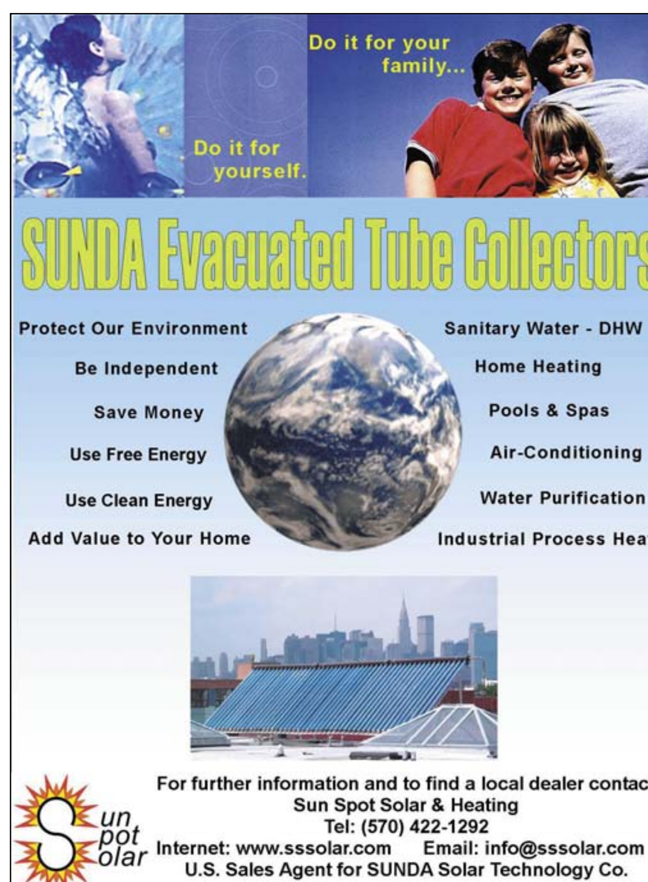
SMA America Inc., 12438 Loma Rica Dr., Grass Valley, CA 95945 • 530-273-4895 • Fax: 530-274-7271 • info@sma-america.com • www.sma-america.com • Sunny Boy inverter

Solar Energy International, PO Box 715, Carbondale, CO 81623 • 970-963-8855 • Fax: 970-963-8866 • sei@solarenergy.org • www.solarenergy.org • RE workshops

Taco Inc., 1160 Cranston St., Cranston, RI 02920 • 401-942-8000 • 401-942-2360 • marcha@taco-hvac.com • www.taco-hvac.com • SDHW circulating pumps

Thermomax Industries Ltd., 3181 Kingsley St., Victoria, BC, Canada V8P 4J5 • 888-923-9443 or 250-721-4360 • Fax: 888-923-9443 or 250-721-4329 • zev@solarthermal.com • www.solarthermal.com • Solamax evacuated tube collectors & controllers

UniRac Inc., 3201 University Blvd. SE, Ste. 110, Albuquerque, NM 87106 • 505-242-6411 • Fax: 505-242-6412 • info@unirac.com • www.unirac.com • Rack mounting system



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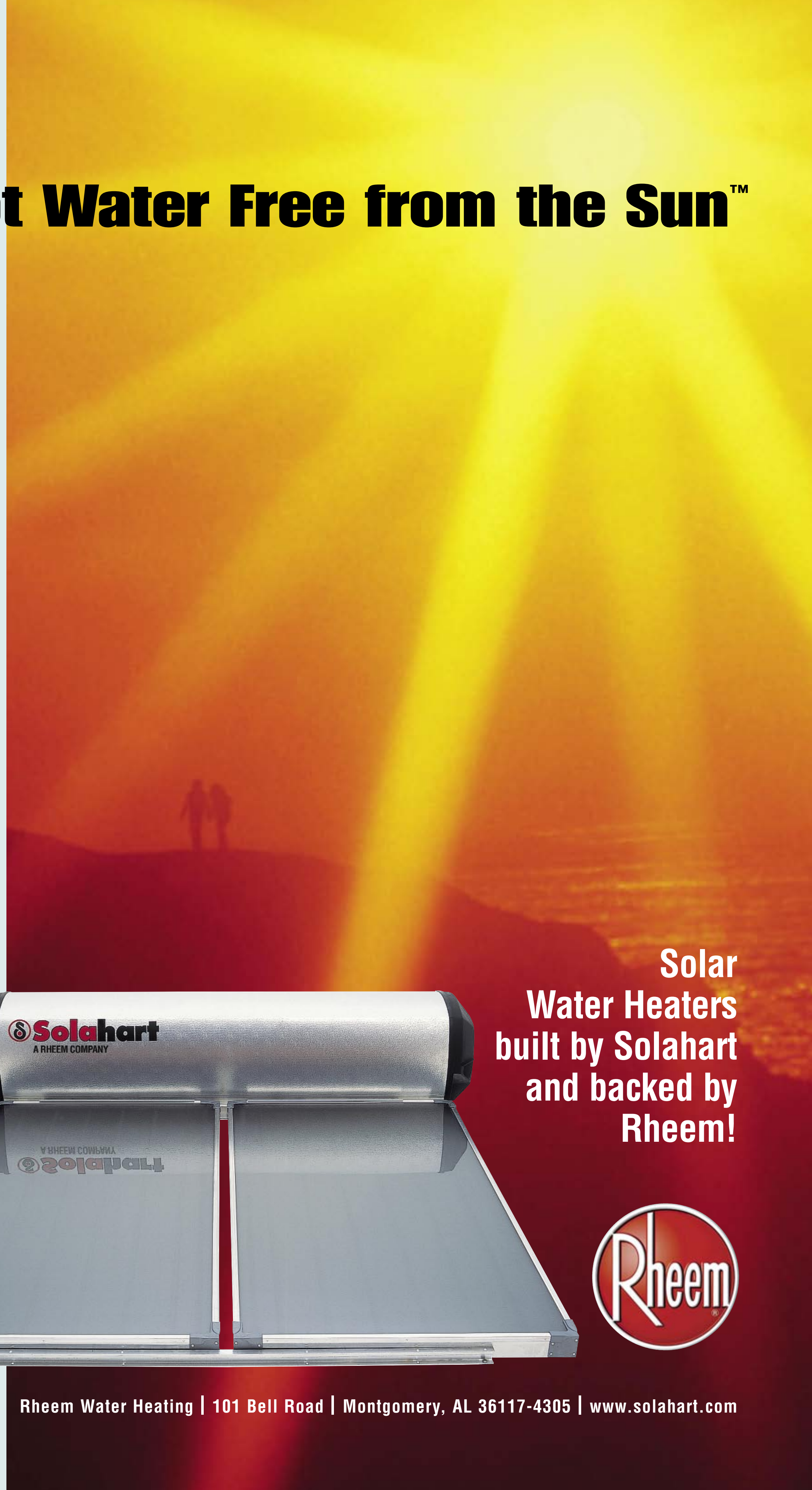

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Biodiesel & Ethanol

Sustainable Fuels for Your Car

Nick Janes

Like most people in North America, I like to drive. Recently I have begun to appreciate the real price that we pay for driving. It's not just the US$3 or more at the pump. People are giving their lives for our fuel. Air pollution is terrible. Something has to change.

Gasoline and diesel are the main fuels used for transportation around the world. But new alternatives are out there. I say "new," but these fuels are not really new. Rudolf Diesel's first diesel engine ran on peanut oil. Henry Ford had ethanol-fueled Model Ts. Electric cars were among the very first cars ever produced. Cheap petroleum replaced all of them. However, petroleum can't last forever.

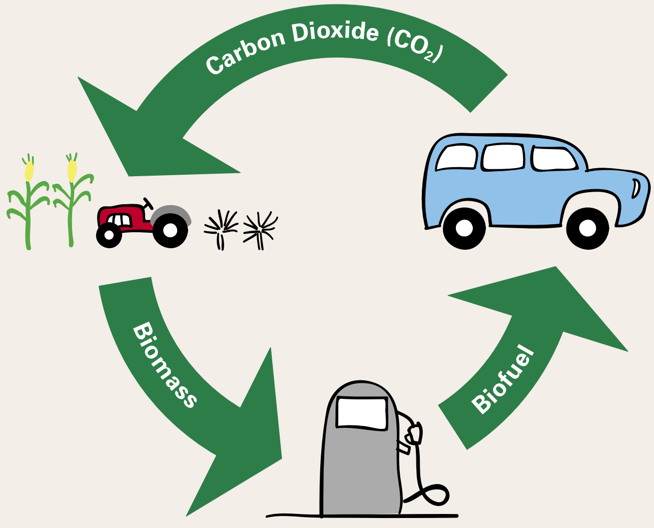
We need sustainable solutions to our transportation needs. This article focuses on two biofuels that are commercially available in the United States—biodiesel and ethanol.

Sustainability

Ideally, our fuel processes and materials should all be ecologically friendly. If we turn plants into fuel, we can make our fuel carbon-neutral. The combustion products are CO_2 and water vapor. A small amount of carbon monoxide (CO), unburned fuel, and nitrous oxides (NO_x) are released as well. We can combat most of these other emissions with various techniques. The big win is that the bulk of combustion products (CO_2 and water vapor) are absorbed by plants and recycled back into the growing process.

Many would argue that we can't grow enough plants to replace the fuel

Carbon Cycle



Carbon-Neutral Fuel

Biofuels are cleaner, greener, and becoming cost-competitive with fossil fuels.

that we burn. There are studies on both sides. The reality is that we cannot continue to rely solely on fossil fuels. Biofuels are an alternative that we can use today.

Energy Balance & Availability

Positive energy balance is necessary for a sustainable system. A sustainable fuel must provide as much or more fuel energy than it takes to produce. Many forms of energy are involved—fuel for the transport of the raw and finished products, electricity to run the processing equipment, and a heat source for processing.

For fossil fuel, a well must be drilled and the crude oil pumped out of the ground. It's then transported to the refining facility—sometimes halfway around the world. Then the refined fuel is transported to the retail station. Making a gallon of gasoline requires several gallons of fuel and a lot of electricity, creating a negative energy balance. Studies show that both ethanol and biodiesel have positive energy balances.

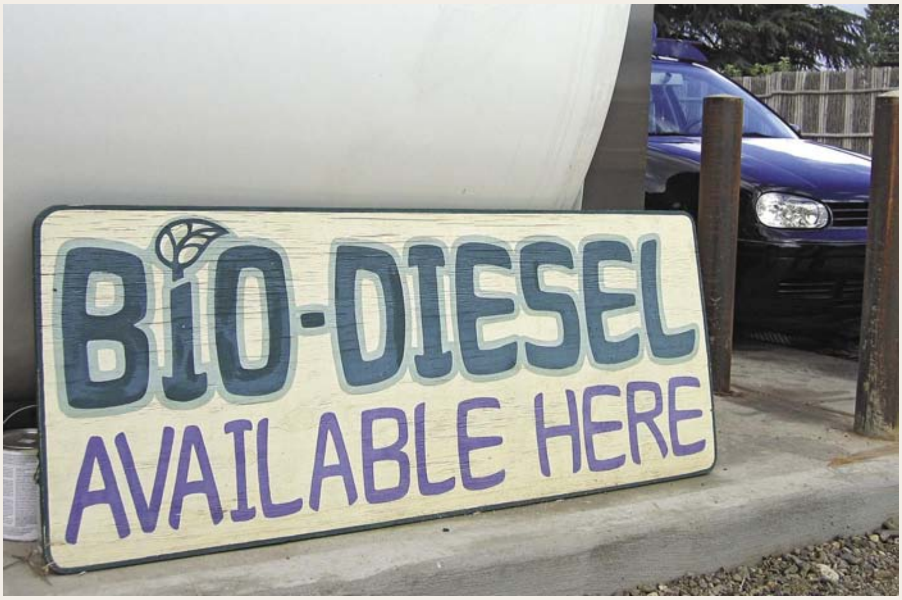
Another big challenge with biofuels is availability. About 170,000 retail gasoline stations are in the United States. Unfortunately, relatively few locations sell biofuels. But over the last few years, availability of biodiesel and ethanol-blend fuels has increased substantially.

Biodiesel

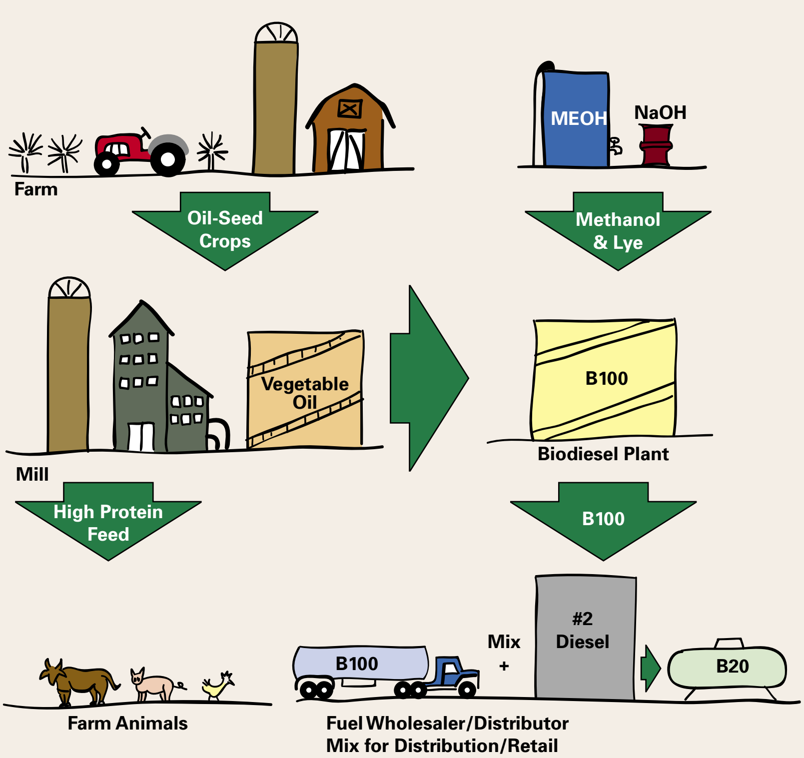
While the first diesel engine was made to run on plain vegetable oil, modern diesel engines run on a thinner fuel. When it's cold, a thicker fuel (like vegetable oil) can gel, blocking fuel flow, or it will not combust completely, leading to carbon buildup and eventual blockage of the fuel injectors. While biodiesel is most commonly made from soybean oil, the oil is thinned enough to run well in a modern engine through a process called transesterification—a reaction with sodium hydroxide and methanol. The glycerin by-product can be used in soaps and cosmetics.

Biodiesel is approximately 10 percent oxygen, which promotes more complete combustion, reducing soot and carbon monoxide. New federal regulations mandate that sulfur in diesel must be radically reduced over the next few

Biodiesel blends are premixed and ready to dispense.



Biodiesel Production



years to reduce smog production. Since soybean oil has no sulfur, the resulting fuel is also free of sulfur. Less sulfur and unburned hydrocarbons reduce ground-level ozone (smog) formation. Virtually all undesirable emissions and by-products are reduced. A possible exception is nitrous oxides (NO_x), which may be higher depending on the engine. But the lower sulfur content of the emissions can allow for the use of better NO_x controlling technologies. Other characteristics of biodiesel are:

- Improved engine lubrication
- Higher flash point
- High cetane rating
- Improved biodegradability
- Lower toxicity
- Higher cloud point
- Similar fuel value to diesel or heating oil
- Better smell and less harmful to breathe

In a diesel engine, the fuel itself is part of the lubrication. The enhanced lubricity of biodiesel helps to reduce wear and enhance performance. Many fleet vehicle operations report reduced maintenance costs with as little as 2 percent biodiesel. With a flash point of 260°F (127°C; twice that of diesel), biodiesel spills are less likely to ignite.

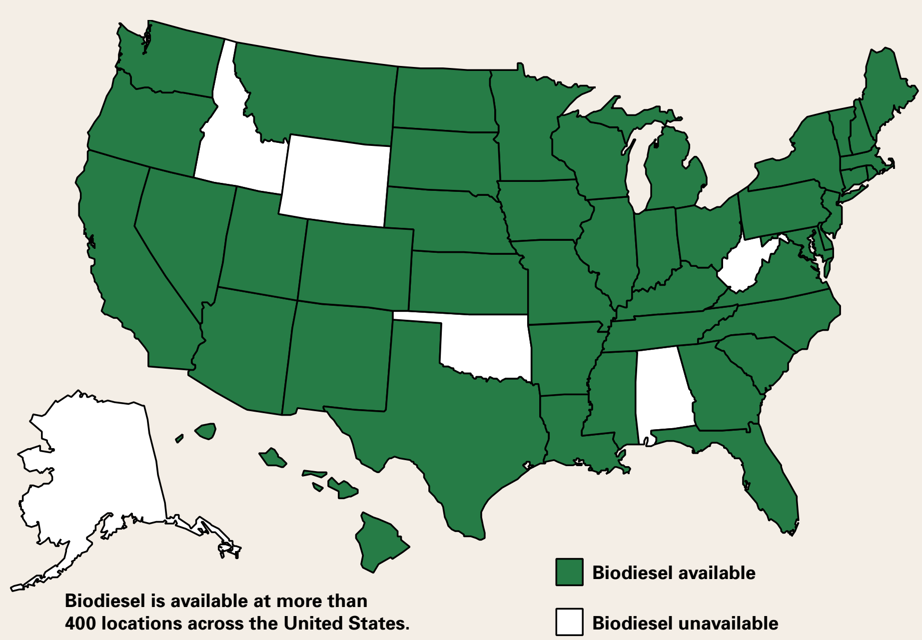
The cetane rating is a measure of how readily a fuel combusts under the high pressures in a diesel engine. A higher number means that the fuel combusts better, produces more power for a given volume of fuel, and is therefore more efficient. Biodiesel's oxygen content gives it a higher cetane rating, promoting better combustion. Biodiesel breaks down in the environment as fast as table sugar (about twice as fast as petroleum diesel) and it's less toxic than table salt, making it a desirable marine fuel. It has a higher cloud point, which means that it gels more easily in cold temperatures. This can be lowered by mixing it with a greater percentage of petro-diesel, adding anti-gel additives, or by slightly heating the fuel.

Biodiesel should be used within six months of manufacture, due to quicker oxidation rates and increased rates of microbe growth in the fuel. It's a good solvent, so it has a tendency to clean out fuel tanks and fuel lines. Vehicles that have used diesel for an extended period of time will usually require a fuel filter change after a couple of tanks of biodiesel.

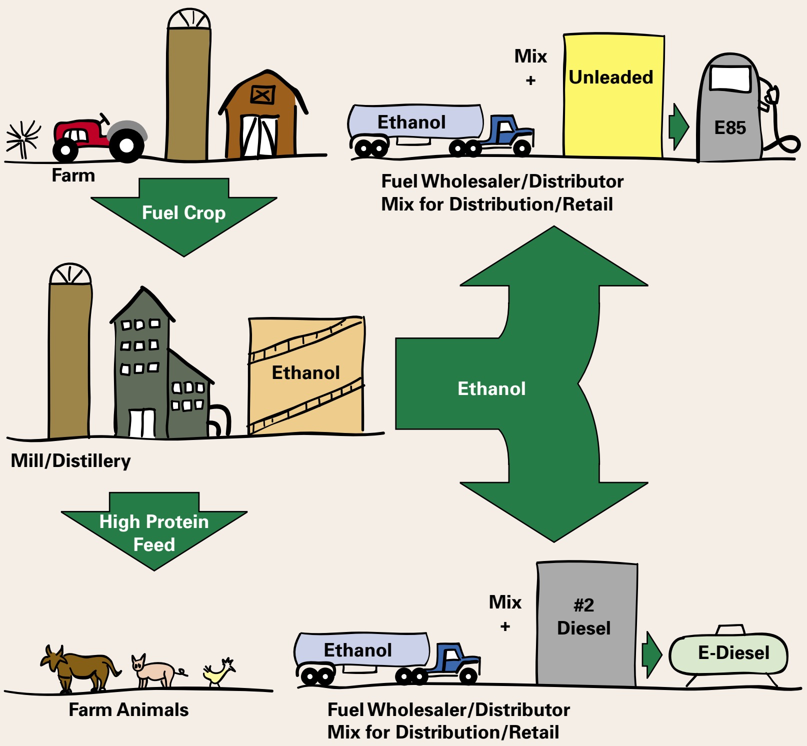
Use of pure biodiesel (100 percent biodiesel; B100) for an extended time may compromise some engine seals and fuel system components in some makes and models. Use of blends such as B2 through B20 are generally regarded as safe for indefinite use. Many engine manufacturers have stated that use of B5 is within the specifications for their engines. Biodiesel is also used as heating oil. It has similar fuel value to petroleum heating oil, and smells better when burned.

Since biodiesel is made from vegetable oils, it can be produced close to the point of use in most cases. This reduces

Biodiesel Availability



E85 Production



the total energy cost of the fuel. For instance, soybeans grown in Missouri can be grown, pressed for oil, and converted into biodiesel all within a couple of hundred miles of the retail pump. The Midwest is a friendly, politically stable oil field with great potential, just waiting to go to work.

The energy balance of biodiesel is impressive. Government and university studies show that biodiesel has a 320 percent return on invested energy. So for every Btu (British thermal unit) used to produce biodiesel, you get 3.2 Btu in return. That's a net gain of 2.2 Btu. By comparison, petroleum diesel has a net energy *loss* of 15.7 percent. So for every Btu used to produce diesel, you lose 0.157 Btu.

The main by-product of soybean oil production is a high-protein meal that is a great cattle feed supplement. Other plants can be used as well. Rapeseed (canola), milo, corn, cotton, and peanuts all produce high quality oil and yield high quality feed supplements as by-products. Industrial hemp and cotton also render valuable fibers as a by-product. Soybean oil is favored because of the large quantity of soybeans grown in the United States.

One drawback of note is that the most popular method of production uses methanol (methyl alcohol), which is toxic. Commercial production recovers the unreacted methanol from the biodiesel for reuse. Most commercial methanol is created by reacting natural gas with steam, meaning that there is a fossil fuel component in current production methods.

An alternative production method for making biodiesel uses anhydrous ethanol (water-free or 200-proof ethanol). Since anhydrous ethanol is used in both E85 and ethanol-blended diesel, it's possible that the fossil fuel component could be eliminated. Sustainable methanol production methods are also being developed that may eliminate fossil-based methanol.

Biodiesel performance is very similar to diesel, both in power and range. While it has a slightly lower fuel value, this is somewhat offset by the enhanced lubricity. In my short experience with my diesel vehicle, I have seen that diesel yields about 23 mpg in mixed highway and city driving, while B10 gives about 22 mpg under the same conditions. And wherever I go, 10 percent of the trip is soybean powered.

Currently more than 400 retail stations in 44 states sell biodiesel in blends from B2 to B100. By far, B2 is the most popular blend sold, especially in the Midwest, but it's encouraging to see how many places sell B20 or B100 as well.

Ethanol

E85 is a blend of 85 percent anhydrous ethanol and 15 percent unleaded gasoline. As a biofuel, it's second only to biodiesel for availability. It has a lot of promise as a cleaner alternative to gasoline.

Oxygen in the alcohol promotes complete combustion and reduces harmful emissions, such as carbon monoxide and nitrous oxides, although some studies show an increase in unburned hydrocarbons in the emissions when compared to gasoline. The 15 percent unleaded improves ignition during

An 85 percent ethanol-blend fuel can be bought straight from the pump, just like unleaded gasoline.

Author Nick Janes uses biofuels to help protect places like the Coronado National Forest.

Emissions Comparisons

Biodiesel Compared to Petro-Diesel	%
Particulate matter	-47%
Carbon monoxide	-47%
Hydrocarbons	-67%
Ozone production	-50%
Sulfates	-100%
Nitrous oxides	10%

E85 Compared to Unleaded Gasoline	%
Carbon monoxide	-4%
Carbon dioxide	-4%
Hydrocarbons	-43%
Nitrous oxides	-59%

starting, especially in cold weather. As with biodiesel, the bulk of the fuel is carbon neutral.

The use of ethanol as an oxygen provider eliminates the need for MTBE (methyl tertiary-butyl ether), a very toxic octane enhancer that is used in gasoline. MTBE used as an oxygenator improves efficiency, yields more power, and reduces pre-detonation in the cylinder. Since ethanol has twice the available oxygen of MTBE, a higher octane rating, and is nontoxic, it makes a great replacement for MTBE.

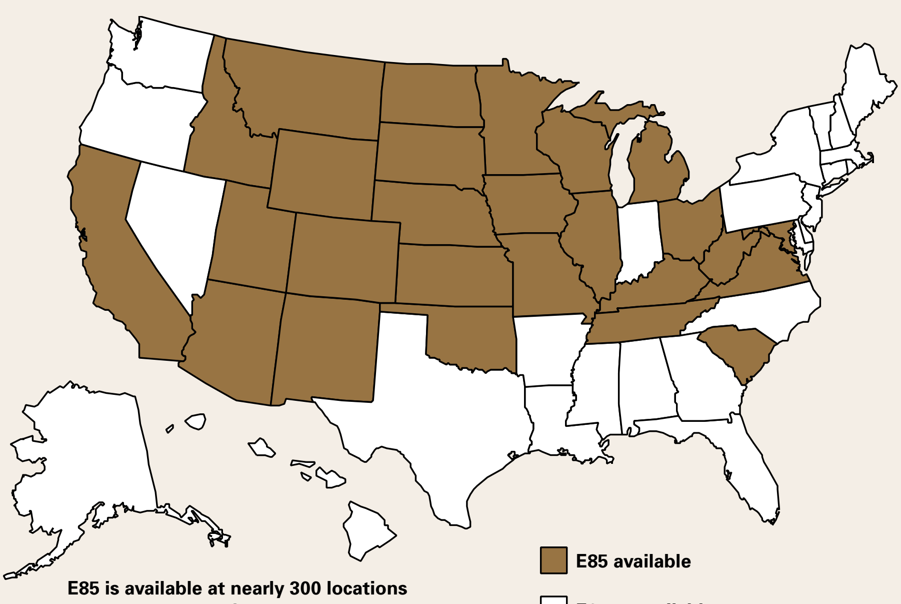
Most ethanol produced in the United States comes from corn. It's popular for the same reason as soybeans. As with soybeans, the corn is grown in the United States, close to the point of use. Other plants with high sugar content (such as beets and sugar cane) can be used as well. As with biodiesel, the by-product from ethanol manufacturing is a high protein meal that can be used as supplemental animal feed. Other by-products include gluten meal and corn oil. The fermentation process also yields carbon-neutral CO_2.

After the corn is harvested, it is put into fermentation tanks with water and yeast. When fermentation is finished, the mixture is heated to distill the ethanol off from the mash to yield 180- to 190-proof ethanol. Special steps are taken after this to remove the last of the water so that the alcohol is completely water free.

New processes are being tested that allow the woody material in the stalk to be broken down into sugars, which can be fermented by conventional methods. This would increase the energy balance of ethanol, since the stalk makes up a large part of the corn plant. The process may also be applied to other woody plant materials that are normally unsuitable for fermentation, which could greatly increase the availability of ethanol-producing feedstock.

Several university studies have placed the energy balance of ethanol at 124 to 167 percent. So for every Btu of energy expended to create ethanol, we get 1.67 Btu in return. This is a net gain of 0.67 Btu. A Cornell study from 2001 that depicted the ethanol energy balance as negative has been widely

E85 Availability



E85 is available at nearly 300 locations across the United States.

discredited since the study relied on obsolete figures based on 1970s production methods. Current methods in farming and ethanol manufacture are significantly more efficient than they were 30 years ago.

Other characteristics of E85 are:

- Lower flammability above 32°F (0°C)
- Higher octane than regular unleaded
- Similar power performance to unleaded
- Better smell
- Lower fuel value than unleaded, reducing mileage by 25 percent
- New tax incentives reduce the cost, offsetting the mileage difference
- Corrosive to the fuel systems in standard gas engines

Since E85 is mostly ethanol, it tends to degrade the rubber and plastics used in gasoline fuel systems, eventually causing them to fail. To combat this, flexible fuel vehicles (FFVs) are made by most of the automotive manufacturers. These are vehicles that have been built to run on either normal gasoline or E85. They have fuel systems with rubber and plastic parts that are alcohol tolerant. The vehicle's computer can sense the difference between unleaded and E85, and control the ignition timing or fuel–air mix to provide optimal combustion for either fuel. It's not easy to convert a vehicle to run on E85. It requires replacing all the rubber and plastic parts that are not alcohol tolerant, as well as changing the air–fuel mix and the ignition timing.

Even though 4 million FFVs are on the road in the United States, they can be difficult for average consumers to purchase. Many of them are fleet vehicles only; most car salespeople have no idea what E85 or an FFV is; and most FFVs are sold in the Midwest, where E85 is made.

Currently, nearly 300 retail locations in the United States sell E85. Most of them are in the Midwest, where the corn is grown. A few stations are out West—you just have to look harder for them.

Ethanol-Blended Diesel

Ethanol-blended diesel (E-diesel) is typically a mixture of 91.5 percent diesel with 7.5 percent anhydrous ethanol, and 1 percent of a solvent to keep the ethanol dissolved in the diesel.

E-diesel is currently in trial in many locations across the United States with diesel fleet vehicles. Results are favorable so far. While it uses fossil-based diesel for the bulk of the fuel, the ethanol is renewable and generally nontoxic. The low ethanol content will likely not cause problems with fuel systems, as E85 can. It also has some of the lubricity of biodiesel, since the added solvent is soybean based. Performance is similar to that of conventional diesel. I have not been able to find any retail sites for E-diesel. My fuel supplier told me that they had it for fleet use, and if I asked for it, I could buy it.

Alternatives Fuel the Future

Biodiesel and E85 are good alternative fuels that can help reduce our dependence on fossil fuels. They have track records proven for performance and sustainability. They reduce harmful emissions, which benefits the environment. Many of the raw materials are produced by North American farmers, strengthening our economy and reducing dependence on foreign oil. These fuels are compatible with current automotive technologies, and they lay the foundation for future fossil-fuel-free cars and trucks. As the availability of ethanol-blended diesel increases, it will become another good alternative to conventional fossil-based fuels.

Current tax incentives have helped to reduce the prices of these fuels to the point where they are within a few cents of their fossil fuel counterparts. More biodiesel and ethanol plants are being built, which is increasing availability. We need to encourage the government and manufacturers to continue to make them affordable and available. By purchasing these fuels whenever possible, we can continue to drive down costs, increase availability, and let the government and manufacturers know that we want alternatives to traditional fossil fuels.

The Midwest is a friendly, politically stable oil field with great potential, just waiting to go to work.

We also need to make sure that vehicles are up to the task, by increasing the number of FFVs, making hybrids into FFVs, and making hybrid diesels as well. We need manufacturers to certify that their vehicles are ready for these biofuels, in addition to the fossil fuels. We are in a transition period, and our cars and trucks need to be ready for bio-based fuels.

We aren't talking about flying atomic cars. This isn't some pie-in-the-sky dream. This is current technology. We know what needs to be done. If we want to change things, here's our chance.

Access

Nick Janes, 8216 North Equator Lp., Tucson, AZ 85741 • 520-579-3620 • nkjanes@yahoo.com

Alternative Fuel Information:

www.biodiesel.org • Biodiesel and retail station locations

www.e85fuel.com • E85 retail stations or flex-fuel vehicles

www.journeytoforever.org • Biofuels

www.e-diesel.com • E-diesel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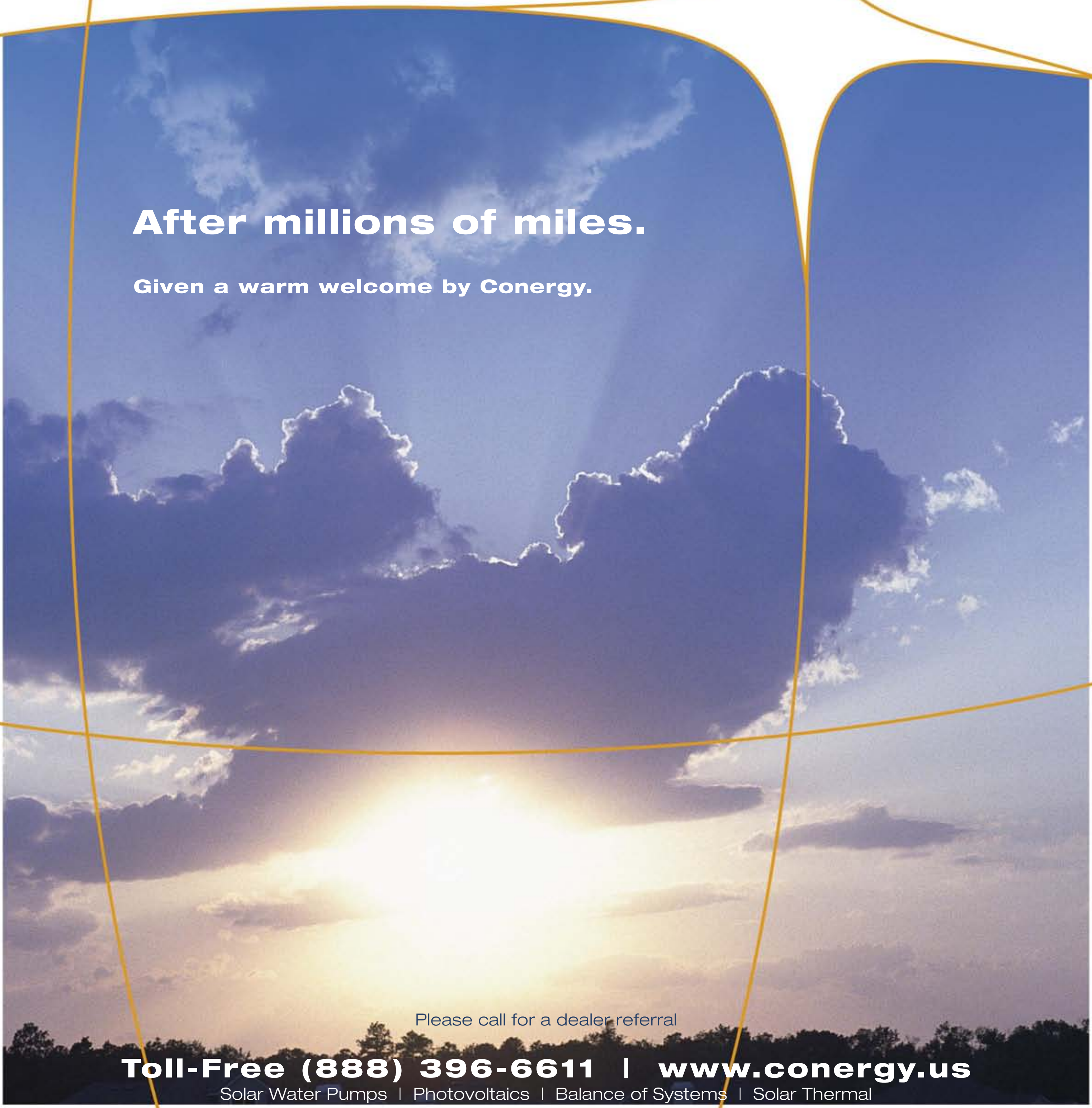
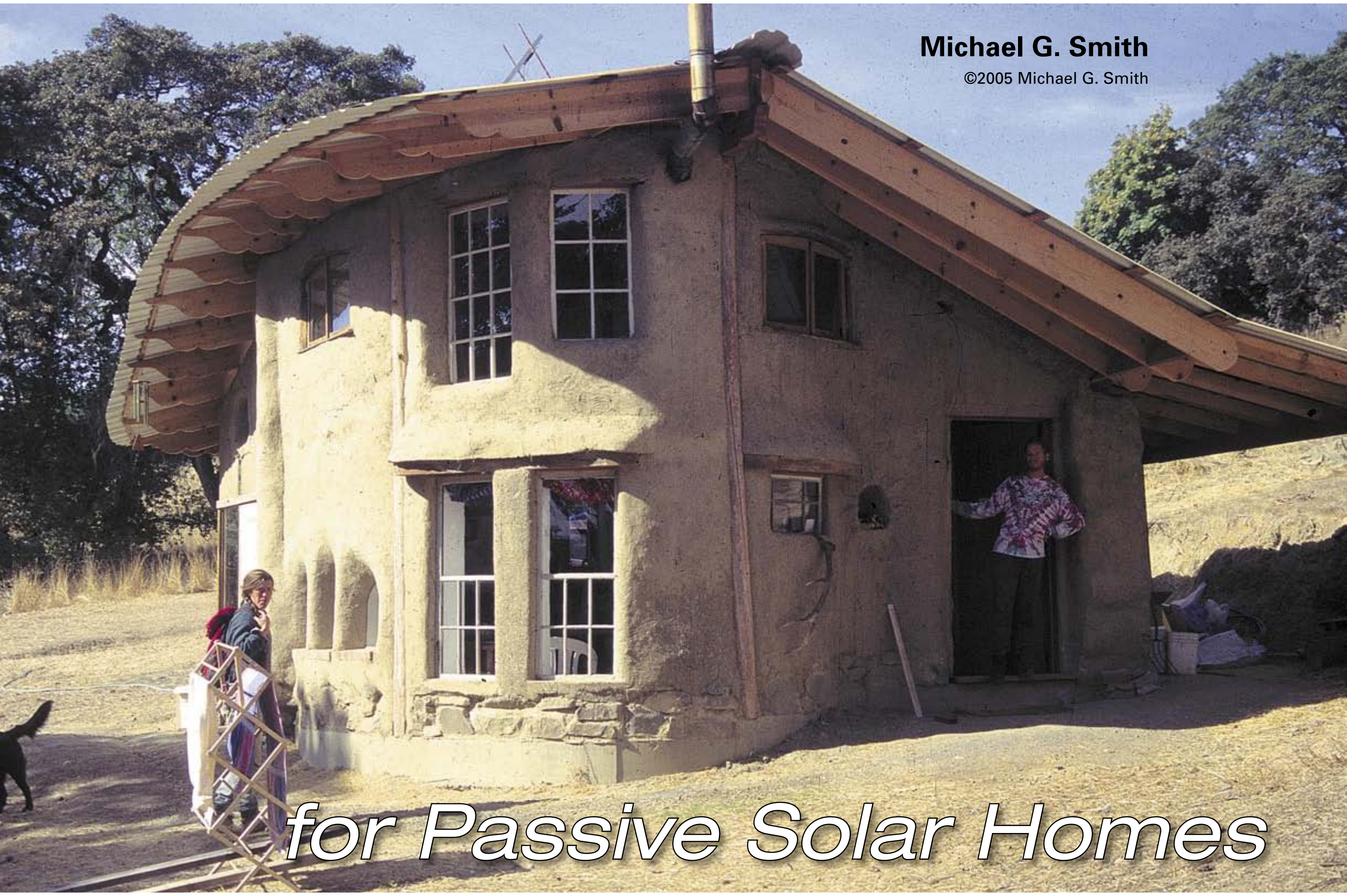


NATURAL MATERIALS for Passive Solar Homes

Michael G. Smith



This cottage in northern California uses sculptural cob for thermal mass on its south side, and straw bales for improved insulation on the north side.

Passive solar strategies are a great way to reduce the energy used for heating, cooling, and lighting in a house after it is built, but what about the energy that goes into a home's construction? Many passive solar homes are constructed with materials like steel, concrete, and fiberglass insulation, which all have high embodied energy. And besides using a lot of energy in their manufacture and transport, many of these products have detrimental environmental and health effects.

If you want to build a home that saves energy at every stage (and is more healthy to boot), natural materials such as earth and straw, with their lower embodied energy, offer an alternative to conventional, manufactured materials.

Natural Insulation

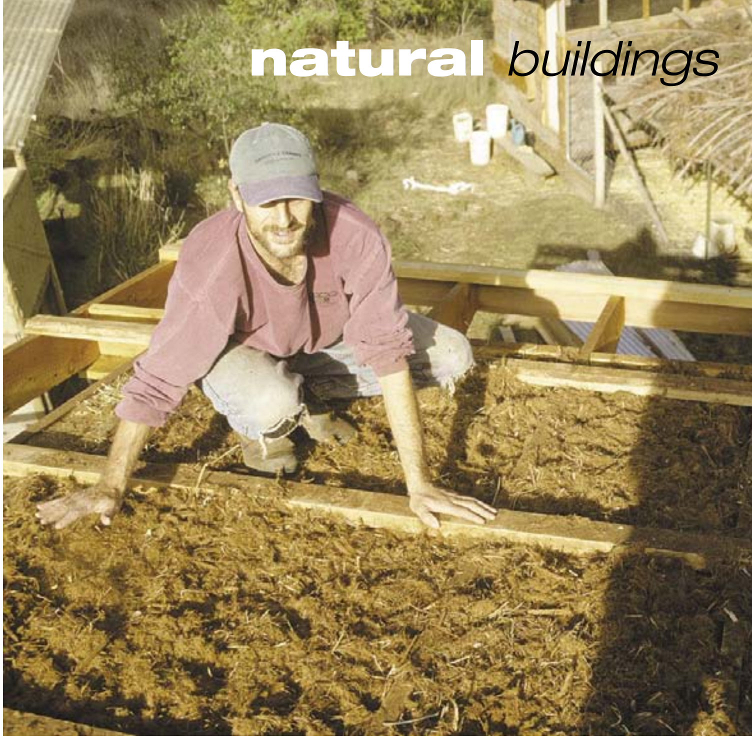
"Insulation" refers to a material's resistance to the passage of heat. Small pockets of trapped air or gas, or even a vacuum in a material provide this resistance. In general, the lighter a material is, the better its insulation value. Natural insulating materials include sawdust, wood shavings, feathers, leaves, bark, straw, and moss. Any natural insulation material can be used to fill a cavity, such as between your ceiling and roof. However, some materials settle over time, which reduces their insulation effectiveness. When you're choosing insulation, consider this, as well as a material's fire safety.

Commercially available natural insulation products include cellulose, rock wool, cotton batts, and sheep's wool. Cellulose insulation is made from shredded newspapers, treated with a fire retardant, and is blown into wall and ceiling cavities either wet or dry. Rock wool is made of spun fibers from basalt or limestone. It is available in both batt and board form, and is extremely fire resistant. Cotton batt insulation, fabricated from denim mill scraps, has an insulation value (also known as R-value) per inch similar to fiberglass, but is safer to handle and much more pleasant to install. Sheep's wool is naturally flame-resistant and insulates even when it's wet. Woolen batts have been manufactured and used in New Zealand for more than a decade, and are now available in Canada and through some U.S. distributors.

Lightweight volcanic rock, filled with little bubbles, is called pumice or scoria. Although it has a lower R-value per inch than the other natural insulations, pumice is one of the only ones that can be used in damp conditions or in direct contact with the earth, because it will not rot. It also can be mixed into concrete, lime, or earthen walls to improve their insulation values, and is often used to insulate underneath earthen floors.

Because high levels of attic and roof insulation are crucial to a home's energy efficiency, and because insulation usually needs to be as lightweight as possible for structural and safety reasons, buying a commercial nontoxic insulation for your roof may be the most sensible option.

This sample of "light clay" blocks showcases the various materials that can be used, such as straw, sawdust, wood chips, paper fiber, and perlite.



The fibrous bark of redwood and cedar trees can be shredded to make excellent, fire-resistant insulation.

Integrating Insulation & Structure

Natural materials offer more creative alternatives where walls are concerned. One of the most versatile is straw bale. Bales can be stacked up like bricks, may be load bearing or serve as infill within a post-and-beam structure, and offer R-values of 27 or more.

"Straw light-clay," also called "light straw-clay" or "slipstraw," is made by coating loose straw in clay slip (clay dissolved in water) and then tamping the mixture into a form, which is later removed. It is a nonstructural infill that can be used in combination with post-and-beam building or even conventional stud-frame construction. The lightest mixes contain so little clay that their densities are similar to straw bale, which gives them a similar R-value per inch of thickness (see the sidebar on the next page). You can also make light-clay mixtures with wood chips, hemp hurds (from the plant's woody core), or pumice.

If the framing for a light-clay wall is constructed like a standard stud frame, it will suffer some of the same thermal disadvantages. At about R-1 per inch of thickness, wood is only a moderate insulator, and studs act as "thermal bridges," transferring heat through the home's wall, and reducing the wall's overall insulation value. Staggering small framing members, such as 2 by 4s or even 2 by 2s, so that the light-clay infill makes up most of the wall thickness at any point (except around windows and doors) minimizes thermal bridging. Likewise, in post-and-beam applications of straw bale, better insulation results if a continuous bale wall is "wrapped" around the posts—rather than stacking the bales in sections between the posts.

Natural Thermal Mass

Thermal mass is a solar home's heat "battery" that stores the radiant energy it absorbs from direct sunlight. At night or in

Insulative Values of Natural Materials

The building industry uses "R-value" to refer to a material's insulation value. In theory, the higher the R-value, the better the material is at resisting heat flow.

Finding consistent, reliable R-value data for natural materials can be difficult. This is partly because little money can be made by testing and promoting inexpensive, abundant, and readily available materials like earth and straw. Also, natural materials are much more variable than industrial materials. And even variations in building techniques can affect the properties of a natural material.

An extreme example of this is straw light-clay. The density of the resulting material varies enormously, depending on the amount of slip used, the thickness of the slip, and the force used when tamping. Reported densities for straw light-clay range from 1,200 to 300 kilograms per cubic meter, which corresponds to a range of R-values between 0.1 to 1.4 per inch.

Several reputable tests have been performed to determine the R-value of a straw bale wall, and all report various results—from a low of R-1.13 per inch to a high of R-2.38 per inch. Some of the lowest values were probably the result of improper construction detailing. For example, if the spaces between bales are not carefully stuffed, and if plaster is not bonded to both sides of the wall, a lot of heat can be lost through the gaps.

Recycled cotton insulation is nontoxic and easy to work with.

A conservative R-value estimate for plastered straw bale walls is R-1.5 per inch of thickness. Using this value gives a wall made of three-string bales stacked flat (22 inches; 56 cm of straw, plus 2 inches; 5 cm of plaster) an R-value of 36. A comparable wall of two-string bales would have an R-value of 27.

A similar range exists in the published R-values for earthen materials, such as adobe. In a series of tests conducted by ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers), the R-values of adobe block walls ranged from R-0.38 per inch of thickness to R-0.62 per inch. The tested R-values varied considerably according to the color of the material and the temperature at which the test was performed.

Although there is no published R-value data specifically for cob, the values should be quite similar to those for adobe, about R-0.5. Adding straw or substituting a lightweight aggregate, such as pumice or perlite, for sand can improve cob's insulative value. Published R-values for rammed earth walls (the densest earth-building technique) range from R-0.25 per inch to R-0.4 per inch.

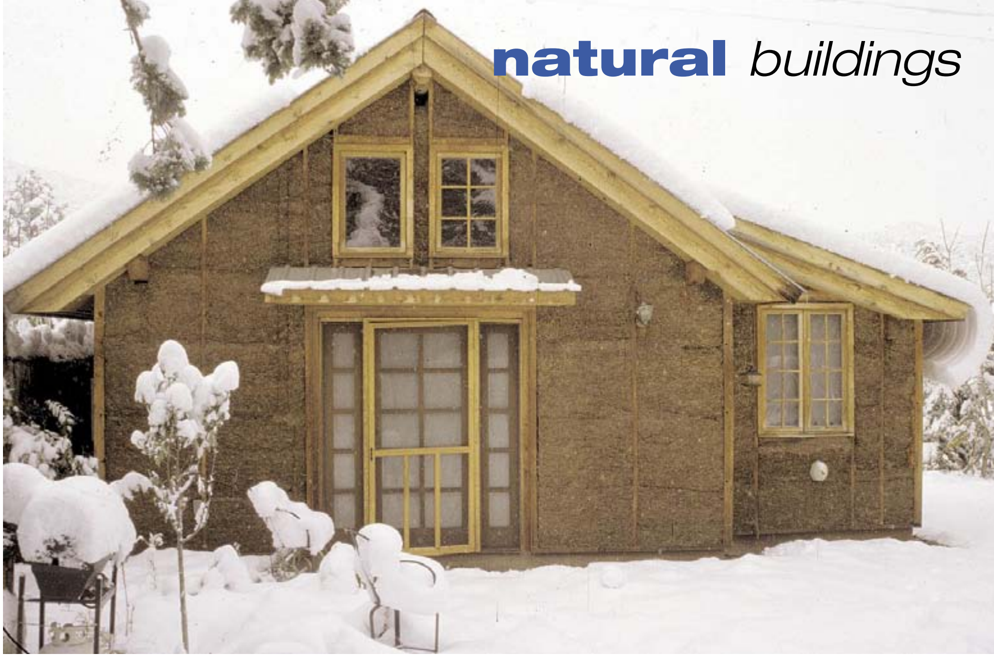
But R-value doesn't have the final word on thermal performance. Some engineers consider R-value to be a limited and often misleading number that was created specifically to favor fiberglass. Walls made of earth and/or straw combine some insulation with considerable thermal mass. The insulative value of a 2-foot-thick (61 cm) cob wall may be similar to a 2 by 4 stud wall with fiberglass insulation, a drywall interior, and plywood sheathing. But given the earthen material's tendency to hold onto both warmth and "coolth" over long periods of time, the actual performance of the two walls will be worlds apart. Even a relatively light, natural wall system of plastered straw bales has many times the thermal mass of a conventional wall, and this translates directly into improved thermal efficiency.

cloudy weather, as indoor air temperatures drop, the mass releases stored heat to warm the interior spaces. Materials with high thermal mass can also be used as a heat sink to pull heat out of the air when temperatures are high. No matter where it is located in a building, thermal mass helps moderate interior temperatures and improves your thermal comfort throughout the year.

In many conventional solar houses, concrete is used as the thermal mass. Lower embodied energy alternatives include stone (with a density similar to that of concrete), rammed earth, adobe, and cob. Although cob and adobe are only about 70 percent as dense as concrete, the savings in materials cost and environmental impact balance the need to provide more volume to get the same thermal performance as concrete.

For heat transfer, the surface area of thermal mass in a solar house is more important than its volume. The more surface area of thermal mass exposed to the sun, the more that heat is absorbed and stored. Within a 24-hour period, heat moves through most mass materials only to a depth of a few inches. For short-term heating and cooling, the best application of thermal mass is a fairly even, 4-inch-thick (10 cm) distribution over as many surfaces of the house as possible. Earthen plasters can easily be built up to a thickness of several inches over straw bale or light-clay walls.

Thermal mass walls that are more than a few inches thick will store heat (or coolness) longer. This strategy can be helpful in regions where the winter sun is not dependable, or where summer days are hot but nights are cool. In areas with mild winters, exterior earthen walls can be effective, especially on the south side of the house, where they absorb heat from the winter sun. But in most climates, thermal mass performs better if it's located *inside* a home, where it's protected from outside temperature swings.



Straw light-clay provides about the same insulation value per inch of thickness as straw bale, and is compatible with conventional stud framing. This straw-clay house was built by Robert Laporte of EcoNest, and is awaiting exterior plaster.

Adobe floors are inexpensive, beautiful, durable, and well suited for passive solar houses. Here, a final layer of mud is being troweled on to finish the floor in a cob home in Willits, California.

For maximum heating efficiency, place thermal mass where it will be struck by winter sunlight shining into the building. A sculptural cob hearth, a masonry heater, or a rocket stove within a cob bench can all serve to "collect" heat. Or you could use earthen walls for interior partitions, or build a Trombe wall, a thick masonry wall that's placed inside a bank of south-facing glass. Although Trombe walls are typically made of concrete or brick, they can easily be made of rammed earth, adobe, cob, or stone.

Another highly effective location for thermal mass is in the floor. Earthen floors, whether tamped earth or "poured adobe," are typically a minimum of 4 inches thick. Several coats of linseed oil harden the floor, provide water resistance, and also turn it a dark chocolate color, which absorbs solar heat well. From an embodied energy standpoint, earthen floors are ideal if suitable materials can be found on or near the building site. Where winters are cold, be sure to provide a thermal break to prevent the ground below from pulling heat from the floor. In arid climates, using straw-clay insulation under an earthen floor may work well. In humid regions, the only viable natural insulation is pumice.

Regional Variations

In general, the colder the climate, the more that insulation should be emphasized. Where winters are frigid (for example, in the north-central United States, the Northeast, and most of Canada), straw bale is probably the best choice for most or all exterior walls. And don't forget to heavily insulate the roof! Keep thermal mass inside—in the floor, thick plasters, interior walls, and hearths.

Less insulation is needed where winters are mild, such as along the Pacific Coast. In these regions, as well as using straw bale construction, a thinner light-clay wall might be appropriate. Mass materials like cob can be used for some exterior walls, especially on the south side of the building. Avoid building mass walls on the north side—they'll tend to leak heat out of the building in the winter. Lots of interior mass, warmed by the sun or a woodstove, can help keep the building comfortable through spells of cloudy weather.

In the arid Southwest, summer days are hot, but nights are usually cool. A traditional solution is to make exterior walls from a material with high thermal mass, like adobe. Using wide roof overhangs to shade the walls and keeping windows closed during the day also limits heat gain. At night, opening windows admits the cool outside air and helps flush heat from the thermal mass. During the winter when the sun is lower in the sky, the mass walls take advantage of the sun by direct gain, soaking up the heat. Some of this heat reaches the interior, where it adds to the solar energy coming in through the windows.

Another way to take advantage of thermal mass is to use the earth itself as a heat sink and temperature moderator, either by nestling your home into the earth or by piling up earth around a home's east, west, and north sides.

An additional strategy for the Southwest is to use a very insulating wall, like straw bale, which slows heat gain on hot summer days and retards heat loss on cold winter nights. Lots of interior mass, such as thick plasters and earthen floors, help minimize interior temperature swings and keep the building comfortable.

Perhaps the most challenging climate for a natural solar house is the hot, humid Southeast. Where summer nights stay warm, the cooling value of thermal mass is much reduced. Mass will heat up during the day, not cool down much at night, and then heat up even more the next day.

The traditional solution is to build lightweight houses, raised off the ground, with lots of ventilation. Natural materials suited for this strategy include light-clay and wattle-and-daub, made from a lattice of woven sticks with a clay-and-fiber plaster smeared over it. Where air conditioning is available, insulate a home's walls and roof well, and use interior thermal mass to absorb heat during the day. Use your air conditioner at night, instead of during the hottest part of the day, to cool the mass and reduce your energy use.

Choose Your Site Carefully

Not all sites are suitable for building a natural solar home. Walls of earth and straw are vulnerable to water damage and should not be built where flooding is likely. And heating with the sun can be difficult or impossible on steep, north-facing sites and sites heavily shaded by trees or tall buildings.

However, in most locations, passive solar strategies can be combined with local, natural materials to create some of the most sustainable, energy efficient, and beautiful housing you can imagine. With the prices of energy and manufactured materials on the rise, and environmental health and indoor air quality on the decline, does it make sense to build any other way?

Access

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The Art of Natural Building: Design, Construction, Resources, edited by Joseph F. Kennedy, Michael G. Smith & Catherine Wanek, 2001, Paperback, 304 pages, ISBN 0-86571-433-9, US$26.95 from New Society Publishers, PO Box 189, Gabriola Island, BC, Canada V0R 1X0 • 800-283-3572 or 250-247-9737 • Fax: 250-247-7471 • info@newsociety.com • www.newsociety.com

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Engineers Without Borders:

Pumping Water in the Sahara

Zeke Yewdall, Hildie Henderson & William Sisk

Mike Carlson, Valery Strassberg, Beth (Peace Corps), William Sisk, Hildie Henderson, Zeke Yewdall, Caroline (Peace Corps), Ed Church, Hope Corsair, and John Brogan (squatting) in the village of Lemraiveg.

Inset: A villager drinks from the system's new distribution box.

In June 2003, eight college students and a geotechnical engineer from Colorado took a different kind of summer vacation. Under the direction of Engineers Without Borders (EWB), they traveled to the small village of Lemraiveg, Mauritania. While there, they designed and installed a concrete well cap and protective gabion wall around a well, a solar-powered submersible pump system, and an underground PVC pipeline from the well to a new water distribution box in the village. They did all this while enjoying the blowing sand, 120°F (49°C) heat, and an attempted military coup!

Mauritania

Mauritania (or the Republique Islamique de Mauritanie) is a large but sparsely populated country on the west coast in Africa. It is a moderate Islamic republic. Out in the countryside, the people are mostly subsistence farmers, with only a few advances from when their ancestors were nomads in colonial eras. Sleeping out on the sand and having a propane camping stove, an old flashlight, and one radio as the only household appliances may seem like primitive living conditions for Americans. But many of us found the pace of life there to be a welcome change from the stress and materialism constantly bombarding us in the United States.

Mauritania doesn't get many American visitors aside from the Peace Corps. Our crew of nine people probably increased the total number of Americans in the country by about 10 percent. Mauritania has been remarkably stable for an African and Islamic country. Intermittent droughts and encroachment of the Sahara are forcing Mauritania's rural population to abandon their traditional nomadic way of life and move to the larger towns and cities. Sanitation is poor, though disease is lower than most African countries, especially in northern Mauritania, partly because the extremely hot, dry conditions help sterilize or dry out everything.

Project History

The village of Lemraiveg relied on a propane-fired pump to draw water from a shallow, hand-dug well in a seasonal waterway, and send it 300 meters (1,000 ft.) to cisterns in the village via a fire hose. Drawbacks of this system were fuel and maintenance costs; seasonal floods, which would fill the well with sand; and replacement of the fire hose every year due to deterioration in the sun, as well as moving the fire hose from cistern to cistern.

This project was first envisioned about five years ago by Brandy Eisenbart, who was a Peace Corps volunteer at the time. She helped Lemraiveg begin the application process to the U.S. Embassy in Nouakchott, Mauritania, through the Ambassador's Special Self-Help Program. At the time of the project, she worked at the U.S. Embassy in Nouakchott and her continued help was instrumental in the success of this project.

The village has between 50 and 200 people (depending on the season (that's the kind of accuracy you can get in a nomadic village). It is not as poor as other sections of Africa. They had water systems, and farmed dates to sell for cash. They do still rely on U.S. food aid, and have no family links to the rich urban traders that we saw driving through to other villages. (Some of these traders drove new Mercedes SUVs that would put the ones in the United States to shame.)

Funding Sources

The U.S. Embassy provided US$9,000 for the materials for our project. (Final project expenses came in at a little under US$7,000.) Funds are used to purchase materials that go directly to villages that apply for projects in which they agree to provide certain contributions, typically labor. The

Map: Courtesy of the General Libraries, University of Texas at Austin

Embassy not only provided financial support; in this case it also solicited technical expertise in the form of collaboration with EWB.

The University of Colorado, Boulder, came through with a few thousand dollars for some travel expenses, but most of the students expected to have to purchase their own plane tickets. At the last minute, donations from private individuals, and a large contribution by Colorado School of Mines came through for a sizeable portion of these expenses, courtesy of a grant from the William and Flora Hewlett Foundation for the purposes of humanitarian engineering projects.

Hurdles

In early June, five of us arrived in Nouakchott, the capital of Mauritania. We were planning to travel to Lemraiveg the next day to perform an on-site assessment before the arrival of the remainder of the team later that week. We woke up at about 2 AM to the sound of antiaircraft fire, small arms fire, and tank shelling. It seemed that some disgruntled, recently fired military commanders were staging a military coup. We hid out in Brandy's house for a few days, and were certain that the project would be called off. Then amazingly, the coup was put down, the airport reopened, and everything seemed to return to normal with only three days of interruption. The project went on.

We brought the pump and 100 meters (30 ft.) of submersible pump cable from the United States, but were

The villagers look at the completed PV array on the roof of the chief's house. The rack was later weighted down with rocks and sandbags to keep it secured.

The supplier was apparently waiting on photovoltaic (PV) modules from Europe, though we had seen several boxes of Siemens modules in a shop in Nouakchott. We threatened to buy the modules we had seen there. In less than an hour, the supplier was down at that shop, loading the PV modules into our truck. We drove back, happy.

The rest of the supplies were supposed to leave that afternoon on another truck. Two days later, they finally made it to Lemraiveg, with drain pipe accidentally substituted for the PVC pressure piping. Lesson learned: in Mauritania, you better watch your supplier and your supplies until they are in your hands. Also, there is a tendency to view white people as walking cash machines—shopkeepers would try to charge much higher prices if they knew that Americans were involved than if just Haier (the village chief) went in. Even project coordinator John, who spoke fluent Hassaniya (the local Arabic dialect), got this treatment on occasion.

planning to obtain everything else locally. The Embassy contracted with a supplier, and all the materials were supposed to be on their way the day after we drove up to the village. After almost a week of calling (driving an hour into Atar to get to a phone) and never getting the same story twice, we finally drove back down to Nouakchott to apply some pressure.

While not unexpected, the weather was not exactly conducive to working. Days were 115°F to 120°F (46–49°C), with nighttime temperatures in the high 80s (30–32°C). By noon, the rocks and sand were too hot to touch, and stayed that way till after dark. Then there was the persistent

Wind or Sun?

We chose solar electricity for our pumping project, though the wind resource in Mauritania is also excellent. Some of the best wind resources in Africa are on the northern coast, and there were two large (5 KW) French wind-electric water pumping turbines in the village about 2 km (1.2 mi.) from Lemraiveg.

The previous year, EWB members Hope and John had traveled all over Mauritania to assess wind systems, and found many broken ones, but very few working ones. The two near Lemraiveg were the only two working wind-electric turbines found outside of the university in Nouakchott. The constant blowing sand takes its toll on moving parts. Electricity supply is not a strong enough desire for people to maintain wind-electric systems. Water might be.

A French wind-electric water pumping system in a neighboring village. The wind resource was strong enough that we never saw this turbine stopped while we were there. The water is pumped to the storage cistern on the pole, and then used to fill up tanker trucks that deliver it.

Setting the rebar for the poured concrete well cap.

John and Hope discuss the wiring of the pump with Ahmed and Haier, the village chief (left to right).

blowing sand. There was a fairly constant 15 to 25 mph (7–11 m/s) wind, occasionally getting up to 30 or 40 mph (13–18 m/s). When it came from certain directions, the air filled with sand. We got used to sleeping at night with turbans or sarongs wrapped around our heads, to keep the wind from packing sand into our ears, hair, eyes, and noses. Even during the day sometimes, we would keep turbans wrapped over our faces. Ever wonder why Arabs dress the way they do? Sand.

Local Expertise

One of our biggest concerns was finding a local person who we could train to properly maintain the system. That was handily solved when Ahmed, the chief's brother-in-law, turned out to be a master electrician, trained in Italy to work on giant mining equipment. He had never worked with PV-powered pumps before, but knew all about wiring in series and parallel, and making proper connections.

Ahmed was very impressed that the solar-electric pump system "only" cost $1,000,000 ouguiyas. While US$3,700 may seem like a lot to us, to him it represented a major improvement in the level of living, and he thought that it would be well worth selling part of his date palmery to buy a solar pump system to irrigate the rest of the palmery. He was also excited about the possibility of importing solar pumps and installing them, after we had taught him the principles of this one.

We also had the good fortune to find Sidahmed, a skilled local mason who had been hired to build concrete wells in the neighboring village. He and his concrete forms were invaluable, all for the very reasonable price of 2,000 ouguiya per day (about US$7.14). In local terms, this skilled craftsman is pretty rich compared to a typical soldier in Mauritania's national guard, whose salary is equivalent to roughly US$35 per month.

In addition to bringing his experience in practical engineering, our mentor, Colorado geotech engineer Ed Church brought an unexpected benefit to the project. In the age-based hierarchical social structure of the village, Ed, grey bearded and in his 60s, gave credibility to the group that we would have lacked without him. Although the design team had a strong educational background, the Mauritanian culture is still one that relies heavily on wisdom acquired with age as a measure of social importance and credibility. Ideas voiced by Ed were given far more consideration than those suggested by younger parties.

Choosing the Pump

The pump chosen is a product from Grundfos. It uses a helical rotor pump—a positive displacement design that has been used for years for industrial applications, such as pumping peanut butter or toothpaste. It has only recently been adapted for use in solar water pumping. Etapump (now Lorentz) and Monoflo also produce helical rotor pumps for use in solar water pumping systems.

The second part is an extremely advanced motor. The 900 watt peak (7 amp max), brushless permanent magnet motor can accept DC voltages between 30 and 300 volts, and AC voltages between 90 and 250 volts, of any frequency. A sophisticated controller, built into the motor, handles this, as well as performs maximum power point tracking for connection to solar-electric arrays or wind turbines.

The whole pump–motor assembly is also submersible. Initially we wanted a surface-mounted pump, for ease of repair, but the suction lift needed, if we had mounted the pump higher than the seasonal floods, was too great. The wide voltage range of this pump also came in handy when we had to add another 200 meters (660 ft.) of wire, incurring a 25 percent voltage loss! Adding a fifth PV module was cheaper than upgrading the wire size.

Lowering the submersible pump and sand trap assembly into the well.

Success—the first water flows.

Project Partners

There are two focuses of Engineers Without Borders (EWB). One is to provide engineering expertise to the developing world. The other is to provide engineering students with hands-on projects. This project was very good for giving students a feel for engineering on the fly. Many of the components had to be largely, if not completely, redesigned after we made it to the village and saw what we were actually dealing with. Some of this was because of differences in materials compared to what we expected. Some was differences in what the villagers wanted, after more in-depth discussions with them.

The collaboration with the Peace Corps on this project was invaluable. Brandy and John are ex-Peace Corps volunteers who have since worked with the U.S. Embassy in Mauritania. Beth and Caroline helped translate for the engineering team to French and Hassaniya. Another volunteer let us use her apartment in Nouakchott as a base of operations, saving us several hundred dollars over renting a hotel. While the attempted coup d'etat resulted in delaying our plans for discussion with the Peace Corps about EWB offering a solar-electric system design and installation training seminar, we did talk to individual Peace Corps volunteers, and will be pursuing this further. Caroline also took note of suppliers of solar equipment in Mauritania, which should help a lot for future projects.

Installation

Aside from waiting for materials and having to substitute some materials for others, the installation went fairly smoothly. There were of course, many discussions with the chief and Ahmed about the details of everything. They were particularly interested in why we were doing everything we did, and how to properly take care of the new system. There was much discussion on how to lay out the gabions (wire cages filled with rocks) around the upstream side of the well cap, to prevent it from being washed away during the floods.

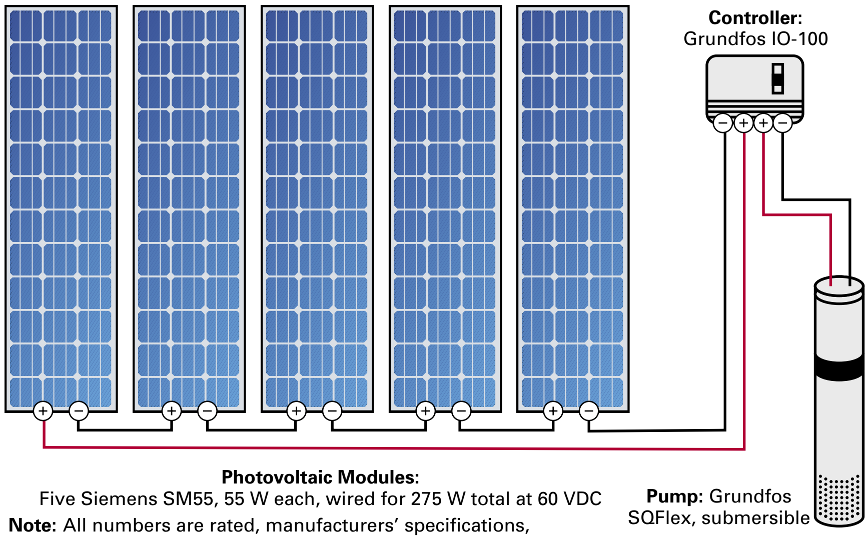
The biggest change in design after we arrived was finding that they wanted the solar-electric panels mounted on the chief's house in the village, instead of by the well in the wadi (a seasonal desert waterway). The wadi was used as a road most of the year, and the local people were concerned that the modules might be stolen there. Luckily, we had enough room in the budget to purchase an additional PV module to account for the voltage drop in the much longer wire. Another change was when we found round, steel, concrete forms used for making wells, which we easily adapted to make the well cap, without having to laboriously build forms with wood from old shipping pallets.

The majority of our design calculations made in the United States were not aimed at specifying a certain product or material to use, but for determining what range of products or materials would work. For example, in the pipe sizing, we calculated the minimum size and pressure rating that we could accept, and decided to buy whatever met these criteria, rather than specifying 50 mm (2 in.), schedule 40 PVC pipe in 6 m (20 ft.) segments, which is what we finally ended up with.

Work was performed in the early morning, and then again during the late afternoon around sunset. During at least one day, work had to be curtailed due to blowing sand that was burying our tools. Staying hydrated was important, as was staying sane despite the large amounts of time we were lying around inside doing essentially nothing. The pace of work was much less urgent than we are used to in the United States during project implementation.

We assembled the PV array onto a homemade rack of angle-aluminum, which the villagers hoisted onto the roof of the chief's house. The wire was first laid on the ground next to the trench, and the system was tested with only the pump in its final position. The first flowing water was greeted with much excitement, both by our team and the villagers. But we still had to get the water to the distribution box in the village some 300 meters (1,000 ft.) away.

To dig the trench for the pipeline, the old propane-fired pump and the fire hose were used to soak the sand dunes. This made them stable enough for a trench to hold its form for the hour or so required to get the pipe laid, before



U.S. foreign policy—reaching out to the world and using the positions of entitlement that we have by virtue of being U.S. citizens to help those who are less fortunate.

Access

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Engineers for a Better World–CSM • www.mines.edu/stu_life/organ/ewb

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Statistics on Mauritania • www.cia.gov/cia/publications/factbook/geos/mr.html

Peace Corps, The Paul D. Coverdell Peace Corps Headquarters, 1111 20th St. NW, Washington, DC 20526 • 800-424-8580 • www.peacecorps.gov

Grundfos Pumps, 17100 W. 118th Terrace, Olathe, KS 66061 • 913-227-3400 • Fax: 913-227-3500 • www.grundfos.com

Renewable Energy for Water Pumping Applications in Rural Villages, NREL/SR-500-30361 by Neway Argaw et al. & *Opportunities for Renewable Energy Technologies in Water Supply in Developing Country Villages*, NREL/SR-430-22359 by John Niewoehner et al. • www.nrel.gov

Water Pumping: The Solar Alternative, by M. B. Thomas, Sandia National Laboratories. April 1987. Document No. SAND 87-0804 • www.sandia.gov

Water pumping system information on Sandia National Laboratory Web site • www.sandia.gov/pv/docs/WPdescription.html • www.sandia.gov/pv/docs/WPSize.html

moving on to the next section. The villagers also began collecting rocks for the gabion diversion structure around the well, which was finished after we left.

When we left the village, we had installed the drain pipe from the well to the cistern and the pump was working, albeit with a leaky pipe system. Earlier fears that the pump would not be strong enough to pump water to the cistern had been allayed when the cistern filled up. The chief was used to a centrifugal pump (which pumped very fast), instead of the positive displacement pump, which pumps the same amount whether to a small or high lift. So he was initially very disappointed in the low flow of the solar pump.

In November, we got the good news from the village that the Embassy had used the leftover money in the budget to purchase pressure piping to replace the leaky drain pipe. Best of all, the seasonal rains had come for the first time in three years, and the wall of rocks and the concrete well cap in the wadi had withstood the floodwaters. The solar pump resumed normal operation when the water subsided. After the initial period of getting used to the operation of the solar pump, the villagers report that they are very happy with the system.

Why EWB?

Why would students pay half of their summer earnings to go to the desert and do more school work? Why would engineering professionals take their precious two weeks of vacation time to mentor these projects? It is because we feel that we are making a difference in the world. EWB was founded by an engineering professor who decided that he had worked long enough for the well-off people in the United States. While many engineers work on projects that make it faster and easier to flip among 500 high-resolution digital TV channels, people in other countries are dying because of a lack of clean drinking water.

At least one village in Mauritania can see that the United States, like every country, is not a homogenous society in which the rhetoric of their leaders always describes the sentiment of the population. EWB is doing our small part towards demonstrating to the world what we believe is a more suitable

Intermediate Technology Development Group (ITDG), The Schumacher Centre for Technology & Development, Bourton Hall, Bourton-on-Dunsmore, RUGBY, CV23 9QZ, UK • 44-19-26-634-400 • Fax: 44-19-26-634-401 • itdg@itdg.org.uk • http://itdg.org • Technical briefs on rural water pumping technology & issues

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Walking the Talk

Energy Group Gets Solarized

Michael Welch

Redwood Alliance (RA) is a community-based social and environmental organization whose main focus is advocacy and education to promote safe and efficient energy use and development.

Twenty-four Shell Solar, 130-watt solar-electric modules provide energy for several businesses in this building in Arcata, California.

Integrating the panels into the building design offered the perfect opportunity to showcase the system to the public.

Founded in 1978 in Arcata, California, RA's original goal was to stop the reopening of the Humboldt Bay Nuclear Power Plant near Eureka. After that success, RA's focus shifted to working on the safe storage of the old, irradiated nuclear fuel that is still on site there, and the eventual decommissioning of the plant.

But RA, where I work as a volunteer, found that being anti-nuclear was not enough—we needed to show that safe, effective, sustainable alternatives to nuclear energy existed. On that front, RA began advocating for and educating about renewable energy (RE). Dozens of workshops, energy fairs, public meetings, and other forms of community publicity have helped put Arcata on the RE map.

Since the early '90s, one of the goals of RA has been to generate our own electricity using solar energy and to demonstrate the technology to the community. This is a very difficult accomplishment for a grassroots nonprofit on a tight budget, and in the situation of being a renter. But in the last couple of years, several circumstances came together to finally achieve this goal.

System Starts

Several times over the last fifteen years, we had attempted the task, and each time were foiled either by lack of equipment or by an unfavorable landlord. Getting donations was very tough because lots of deserving nonprofits and projects are out there, and after awhile we became pretty discouraged.

This state-of-the-art installation provides clean, renewable energy and serves as a fantastic demonstration system for the public to see firsthand.

PV System Tenants

Besides generating electricity for RA, two other offices housed on the second floor of the building also benefit from the solar-electric system installation.

Like RA, Center for Environmental Economic Development (CEED) is a nonprofit organization. For more than ten years, CEED has worked as a catalyst for environmentally sustainable community development. CEED's work in sustainability is divided into seven project areas, including RE and Climate Change, Green Building and Sustainable Tourism, and Sustainable Materials and Zero Waste.

Visual Tattoo (VT) is the first known solar-powered tattoo parlor in the world. In February 2005, VT artists Dean Shubert and Brian Kaneko designed a special tattoo to commemorate the solarization of the business. The solar-electric system supplies energy for area lighting and task lighting, and the electricity for needles, which each draw about 100 watts. (What's a tattoo customer's least favorite word? "Whoops!")

Then we moved to a building with a landlord who loved the idea of solar energy. We decided to try anew and began putting out feelers about getting equipment donations, or obtaining equipment at a substantially reduced price.

After spending more than a year working with various PV manufacturers with no luck, we were again on the verge of giving up. Then we heard that Shell Solar, which had recently purchased Siemens Solar, had some modules with the former company's name on them—and they were willing to give them to our organization. We received a wonderful donation of forty-eight, 130-watt modules.

Designing a Showcase System

With the all-important module donation in hand, we knew we were most of the way home. We could now figure out what kind of system we wanted and start designing it. First, though, we worked on improving our energy efficiency, adding task lighting for each desk in the office, replacing standard fluorescent fixtures with energy efficient T-8 fluorescent lighting throughout the building, and swapping out a CRT computer monitor with a low-power ViewSonic LCD display.

We wanted to showcase both batteryless and battery-based grid-intertie systems in this demonstration system. An off-grid system uses nearly identical components to

Tech Specs

System Overview

Type: Battery-based, grid-tie PV

Location: Arcata, CA

Solar resource: 4.4 average daily peak sun-hours

Production: 320 AC KWH per month

Utility electricity offset: 100 percent

Photovoltaics

Modules: 24 Shell Solar SP130-PC, 130 W STC, 33 Vmp, 24 VDC nominal

Array: Eight, three-module series strings, 3,120 W STC total, 99 Vmp, 72 VDC nominal

Array combiner box: OutBack PSPV, 15 A breakers

Array disconnect: OutBack PSDC, 60 A breaker

Array installation: Direct Power & Water LPRGM mounts installed on SSW-facing balcony, 50-degree tilt

Energy Storage

Batteries: Twelve Concorde PVX-1080T, 12 VDC nominal, 108 AH at 24-hour rate, sealed AGM

Battery bank: 48 VDC nominal, 324 AH total

Battery/inverter disconnect: 175 A breaker

Balance of System

Charge controller: OutBack MX60, 60 A, MPPT, 72 VDC nominal input voltage, 48 nominal output voltage

Inverter: OutBack GVFX3648, 3,600 W, 48 VDC nominal input, 120 VAC output

System performance metering: GE CL200 KWH meter, WinVerter PC software, OutBack Mate

a battery-based grid-tied setup, so for demonstration purposes, our battery-based system covers both applications. Even though Arcata does not experience frequent or prolonged utility outages, we are surrounded by areas that do, and surrounded by areas with no utility service at all. Demonstrating a system for the off-grid community was important to us. And as we eventually found out during a recent outage, it is very nice to be able to keep working right through a blackout. We would be able demonstrate either type of system—on grid or off grid—with a flip of the switch that controls the utility connection.

Two utility services with separate KWH meters, one for each floor, serve the building we rent space in. We wanted to install two separate systems—one for each meter—so that we would not be overpowered and give away too much excess energy to the utility. California's net billing law allows us to annualize PV production versus energy consumed. So summertime's higher production can make up for fewer watt-hours produced during the winter season. The effect of this is that the customer is paid at retail price for all power produced, up to the amount consumed over a year, and any excess energy produced is "donated" to the utility. For our 6,240 watts of solar panels, having two meters on this building created a perfect situation in matching our electricity production with our electricity consumption.

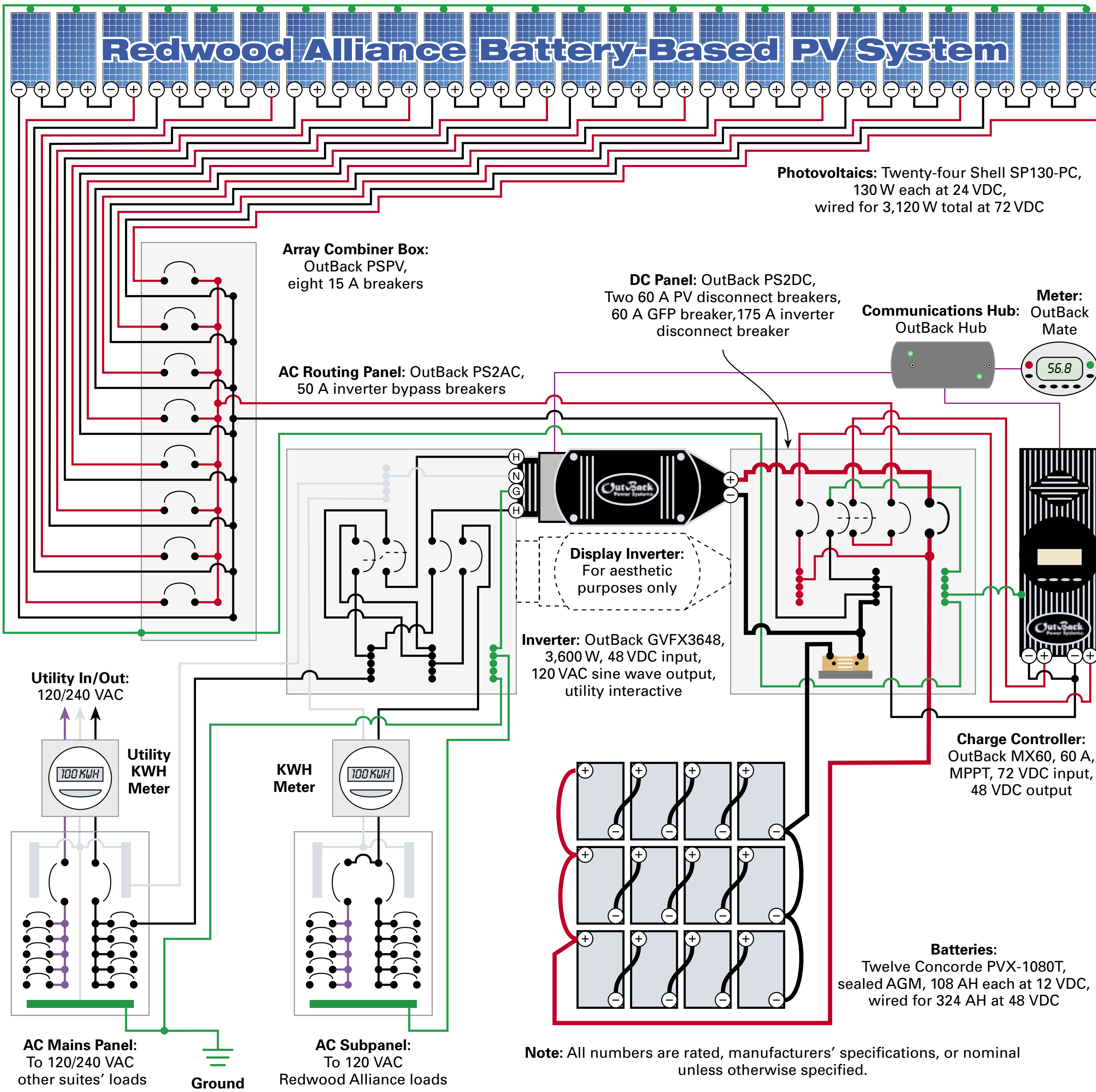
The installation crew mounts photovoltaic panels on the second floor balcony.

The Process

We decided to start with the battery-based system, to be attached to the meter for the upper floor, which houses RA and two other businesses.

But before we could start, we needed to begin the application process to reserve our state rebate, which would cover costs for equipment and labor that would not be donated. Although we were working with OutBack Power Systems to source equipment, their inverters were not yet approved under the rebate program. Instead, we substituted a different, approved inverter for application purposes. Once a rebate application is approved, it is permissible to switch to other approved equipment, and we kept crossing our fingers that the inverters we selected would qualify before we needed to start the installation.

It took almost a year to line up the rest of what we needed and design the system around that equipment, giving OutBack plenty of time to complete their certification



and ETL-listing processes. Batteries are not covered under the rebate program, and just as we were about to purchase some at a huge expense, Concorde Battery Corp. donated twelve Sun Xtender sealed batteries perfect for our indoor installation. OutBack donated an MX60 charge controller, a Mate remote monitor and control, and a PSR battery rack, and gave us the normal discounts they give all nonprofits on the rest of the equipment we needed.

Since this was a demonstration system, we really wanted to show off the modules. A south-facing balcony runs the entire length of our building on the second floor. It was the perfect place to show off PV panels since it is visible to a major street and a well-used sidewalk. We approached the City of Arcata's design review committee with our proposal, but they really didn't like the idea of PV modules just hanging off the building. They wanted the array to look more like a conventional awning, and even asked for triangular side covers, ornamental mount legs, and cute awning skirts. We talked them out of the custom legs by assuring them that the support system would be hidden entirely behind the modules, but agreed to their other ministrations to keep the project moving forward. After the array was installed, they agreed that it looked great without the previously required embellishments.

From poring over the building's blueprints, we could not be certain that our balcony would handle the extra

Battery-Based System Costs

Item	List or Street Price (US$)
24 Shell Solar SP130-PC modules	$14,229
OutBack GVFX3648 inverter	2,345
Miscellaneous wire, conduit, electrical	2,265
12 Concorde PVX-1080T sealed batteries	2,100
Labor, PV system installation	1,763
DP&W LPRGM6-SQ roof mounts	1,568
Labor, AC electrical site preparation	1,145
Engineering for balcony installation	875
OutBack MX60 charge controller	649
OutBack PSR battery rack	649
Lumber, steel & carpentry for balcony reinforcement	512
OutBack PS2DC with 175 A breaker	385
OutBack PS2AC with 50 A bypass breakers	385
OutBack display inverter, no innards, with covers	329
Permits & documentation	306
OutBack Mate system display & controller	295
Cables for batteries & inverter, 2/0	198
OutBack HUB4 communications manager	195
Miscellaneous hardware	161
OutBack PSPV array combiner box	139
Scaffold & tool rental	131
OutBack OBDC-GFP/2 ground fault protection	129
OutBack PS2MP power system mounting plate	129
8 OutBack OBPV-15 breakers for combiner, 15 A	96
OutBack PSR-SK battery rack shelf kit	89
OutBack PSR-SZ4 battery rack seismic kit	89
3 OutBack PSR-SCT battery rack trays	87
OutBack PSR-HDT battery rack HD top	79
2 OutBack OBDC-60 breakers for controller, 60 A	58
Square D DU221RB utility disconnect	48
Cutler-Hammer 2-100 breaker	46
Cutler-Hammer 8-16 load center, 125 A	41
Total	$31,515

weight of the PV system cantilevered from it, and we were not sure what kind of extra wind loads the system might create. The blueprints showed that the balcony wall was attached to the walkway merely with Simpson Strong-Tie clips, though none of that could be seen through the stucco. Visual inspection showed the 4 by 6 posts were strictly ornamental, and not able to support anything.

Our engineer calculated that the potential for wind loads would be minimal compared to the weight problems. The 24 modules and their rack would add about 1,300 pounds (590 kg) to the balcony structure, some of which would be levering downward from several feet out and applying lots of outward torque to the balcony wall. We made some suggestions to the engineer, who calculated them out and approved our solution of adding thick, steel reinforcement plates to both sides of the balcony posts, attaching them to the heavy glue-lams top and bottom, and then adding 2 by 10 Douglas fir top plates to the balcony wall, running 24 feet in unbroken lengths between the posts. The new top plates would keep the array mounts in line, the posts would keep the top plates from moving outward, and the steel plates would tie it all to the building. With a system design, stamped engineering, and an OK from the City's design reviewers, we finally got our permits.

Construction Ready

We ordered the steel plates and specialty lumber, and started construction. The local Blue Lake Rancheria tribal authority's head of construction, Bruce Ryan, oversaw the crucial balcony reinforcement. Next, our installer Roger and his crew, along with our volunteers, went to work mounting the PV subarrays. It turned out that eight subarrays of three modules (72 V nominal) in series would be a great match for a single MX60 controller (converting to 48 V nominal for the battery bank) with the 3,600-watt OutBack GVFX3648 inverter, and perfect for the length of our balcony. The balcony has just enough room left at one end for the future sign touting the system, and a little empty space on the other end where, ironically, a utility pole would have shaded the end of the array each midafternoon.

After some deliberation, we decided that looks were as important as performance for this demonstration system and set the module tilt at 50 degrees instead of at 40 degrees, which is optimal for our latitude. Hopefully, this will help folks with concerns about the aesthetics of a PV system accept this technology.

Next, we needed to figure out how to best show off the electrical equipment and the bank of batteries. We wanted a very clean-looking installation, so we decided to go with the OutBack PS2 power system rack. For a simple and neat installation, this system combines all the inverter-related components onto a backing board, including the charge controller, the inverter, both AC and DC disconnect enclosures with breakers, the OutBack Mate communications–display module, and the OutBack Hub (which allows the Mate, inverter, and controller to interact). The PS2 system is capable of handling two inverters and charge controllers, for double the size of our system.

To best display the system, we decided to put the power system in our office space. Our biggest concern was that noise from the variable-speed fans in the inverter and charge controller would disturb our work. The fans go on and off individually, and vary in speed as the amount of heat to be dissipated fluctuates. Clearly, these components do not belong in living or work spaces where noise is a concern, but for our demonstration purposes, having the equipment front and center was critical. Now that the system has been up and running for several months, it is a hair louder than we expected, but still within acceptable limits. Our office mate hasn't complained at all.

A floor-to-ceiling stub wall, built next to our windows and viewable from the balcony, houses the OutBack PSR battery rack below the PS2 system. Conduit was run through an open space behind the wall and into holes punched in the backside of the electrical equipment—not one piece of conduit is visible from the wall front. Finally, to polish the look of the system, we purchased an OutBack FX display inverter, sans guts, to fill the empty spot in the PS2MP mounting plate.

We wired and installed the power panel components using the color-coded wiring diagrams that accompanied the PS2DC and PS2AC boxes, though I don't recommend this for most end-users. Even the internal wires were provided, the right size and cut to length. Normally, all the wiring for these units is done at the wholesale level by trained system integrators. Our components came directly from OutBack, so we did not have that advantage.

I had insisted on hiding all of the wire and conduit for the PS2 installation, and I wanted the battery racking and cabling to also be as neat as possible. I ordered precise cable lengths for the twelve Concorde batteries. I made all the cable ends and battery terminals perfectly flat to increase contact area. Instead of covering the batteries with the opaque front that comes with the battery rack, we used clear Plexiglas.

Brant Electric installed our utility disconnects and put in an AC subpanel so that the battery backup would provide power only to our office out of the three businesses on the utility service. Finally, Roger and his crew put in a performance KWH meter on the backside of the stub wall, completed the wiring between the PV combiner box and the DC disconnects, and then hooked up our new AC subpanel to the inverter panel's AC disconnects.

With everything in place, Roger set up the inverter and controller. Later, he complained to me, "Why do inverter manufacturers make this so hard? Why can't the menus be more descriptive, and not so deeply nested?"

Really, all he needed to do was set the nominal battery voltage, set the system to "sell," and have the system give the batteries an initial charge. It wasn't so difficult, but the settings also allow for the finest of tuning, which can involve using a deep and complex system of setup menus.

Working with OutBack tech support, I decided that the only fine-tuning our system needed was to turn off the inverter's charger so that the grid would never be called upon to charge the batteries. Our relatively large solar-charging source enables us to quickly make up for any outages that cause us to dip into our battery backup.

Up & Running

With the system installed and paperwork filed, our utility, Pacific Gas and Electric Co. (PG&E), came out and installed a new, digital KWH meter, which reads in both directions.

Installer Ben Scurfield assembles the OutBack PS2 power panel. The second inverter case is for display only.

The utility representative inspected the system, and then we went upstairs to turn it on. With the system operating, we went downstairs again to see the utility meter running backwards. Success!

Long before, we knew it would work just fine, as PG&E allows pre-approval operation of the system for testing purposes. We were careful not to "test" it too much, as we did not want the meter reading to show a surplus from the last time it was read. We had heard horror stories from folks who had run their systems too much before PG&E's inspection, and got caught in some kind of corporate, bureaucratic maze. We quit "testing" just in time to show only a small, positive amount of KWH used for that month.

PG&E's interconnection approval came the day before the National Solar Tour—on September 30, 2004. RA participated in the tour, which is coordinated in communities nationwide. We had quite a few folks come through our office that day, and I have kept in touch with some of them. At least two of them have ordered systems of their own. One is almost identical to our battery-based intertie system because they live in a rural area that is last on the list for repair when there are extensive storm-related outages. The other system will be a batteryless system in the heart of Arcata, proving that the Redwood Alliance demonstration center is already doing its job. Once RA's second system is up and running, we plan on scheduling a dedication ceremony and solar-electric celebration for the community.

Number-Crunching

After a year in operation, we know that the system is making much more energy than our suite consumes, even in the winter. And it looks like we can count on the system averaging as much as *all* the suites are using, making the annual net usage equal zero.

RightHand Engineering donated their WinVerter software to us, which monitors both the inverter and the charge controller, and gives us a ballpark view of how the system is running. This software gives me the ability to monitor the system from my computer.

Compared to older battery-based, grid-tie inverter designs, the OutBack GVFX3648 inverter has a very high conversion efficiency. For example, WinVerter was showing an array output of 2,730 watts. The only loads are 132 W for a computer and a monitor, so the available output is 2,598 W. Yet the output to the grid has been showing 2,268 W, which indicates an efficiency of about 87 percent. We are quite pleased with these results.

Some modern batteryless inverters achieve peak efficiencies of about 95 percent. This difference in efficiency, the additional cost of the equipment for handling batteries, and the cost of the batteries and their eventual replacement are strong arguments in favor of batteryless systems—unless the security of backup power is necessary. Our second PV system is now demonstrating a batteryless system, with a Xantrex GT3.0 inverter attached to the other 24 Shell Solar modules we have. Stay tuned for this story.

Eventually, RA hopes to have an extensive data collection system that will monitor individual offices' consumption, as well as graphically display a full range of data for both PV systems.

Keeping the Good Energy Going

Part of our process included applying for California's rebate program for both of our PV systems. The rebates will cover all of our system expenses. When our rebate arrives, we will offer a portion of it as matching grants to the other businesses in the building, so that they can have funds for installing energy efficiency measures too. PG&E also has awarded us a generous grant to our general fund, some of which will go to energy efficiency measures, and some of which we may use to remove the power pole that shades the east end of the balcony.

Finally, after nearly 30 years of energy activism, Redwood Alliance can take pride in where its energy comes from. Instead of sucking up Diablo Canyon's nuclear-created electricity, or damming rivers, or burning fossil fuels, we've taken our energy matters into our own hands, and we will be cranking out a few extra watt-hours onto the grid for other folks to use.

Access

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

Bruce Ryan, Blue Lake Rancheria, PO Box 428, Blue Lake, CA 95525 • 707-668-5615 • www.allianceofcatribes.org/bluelake.htm • Balcony reinforcement

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

Center for Environmental Economic Development, PO Box 4167, Arcata, CA 95518 • 707-822-8347 • Fax: 707-822-4457 • ceed@humboldt1.com • www.ceedweb.org

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

Direct Power & Water Corp., 4000-B Vassar Dr. NE, Albuquerque, NM 87107 • 800-260-3792 or 505-889-3585 • Fax: 505-889-3548 • jrandall@directpower.com • www.directpower.com • PV mounts

OutBack Power Systems, 19009 62nd Ave. NE, Arlington, WA 98223 • 360-435-6030 • Fax: 360-435-6019 • sales@outbackpower.com • www.outbackpower.com • PS2 power system components, battery rack & PV combiner box

RightHand Engineering LLC, 19310 226th Ave. NE, Woodinville, WA 98077 • Phone/Fax: 425-844-1291 • info@righthandeng.com • www.righthandeng.com • WinVerter software

Roger, The Little House, 1527 Buttermilk Ln., Arcata, CA 95521 • Message only: 707-826-9901 • Solar contractor

Ben Scurfield, Scurfield Solar • PO Box 41, Arcata, CA 95518 • 707-825-0759 • bscurfield@yahoo.com • Solar contractor

Shell Solar Industries, 4650 Adohr Ln., Camarillo, CA 93011 • 800-272-6765 or 805-482-6800 • Fax: 805-388-6395 • solarsales@shellsolar.com • www.shellsolar.com • PVs

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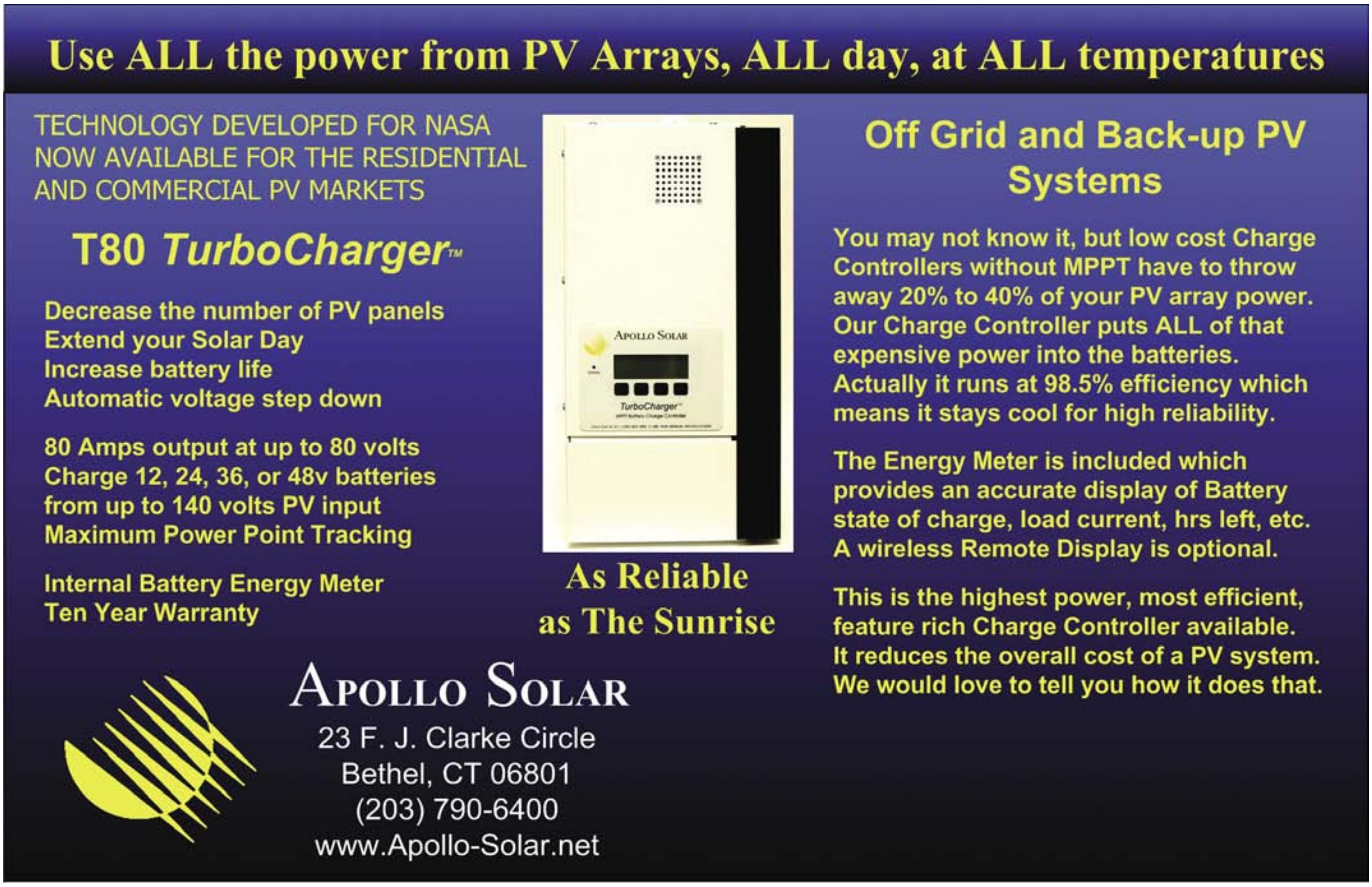
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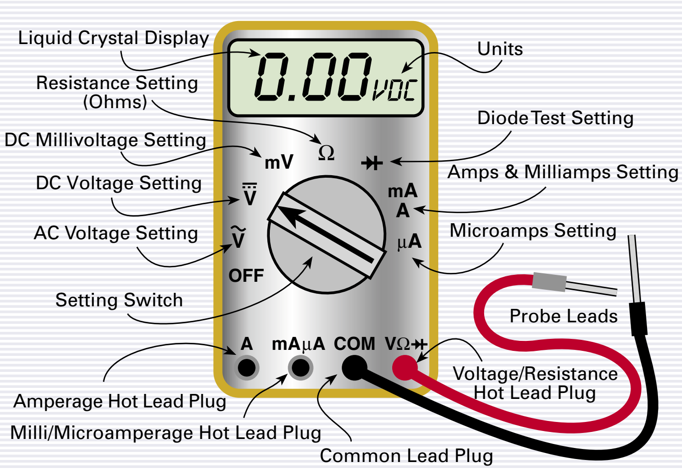
Must-Have Tools for Solar-Electric Installations

Richard Perez

If you're planning to install a solar-electric (photovoltaic; PV) system, a digital multimeter (DMM) is a must-have tool to get the job done. A DMM is your eyes into the invisible world of electricity, and without a meter, you're flying blind when installing, maintaining, and troubleshooting your renewable energy (RE) system. Using a DMM can save thousands of dollars in misconnected, ruined equipment.

A digital multimeter is a hand-held instrument for measuring basic electrical properties such as voltage, current, and resistance. DMMs have a variety of functions. Some are necessary for all systems; others are only used for more advanced electronic design and troubleshooting. If you're installing a solar-electric system, here's a shopping list of what your DMM should measure if it is to be an effective tool for you. For electrical novices, refer to the Quick Definitions sidebar (on opposite page) to learn about essential DMM measurements.

Elements of a Multimeter

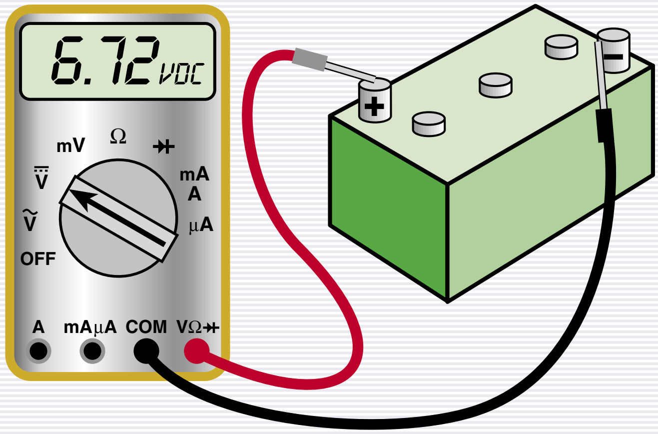


AC Volts

In the United States, the standard AC electricity used in households is 117 volts rms (root mean square). This figure is a mathematical abstraction describing a sort of average of a voltage waveform that alternates 60 times per second between +164 volts and -164 volts.

Any DMM worth having should be able to read the rms voltage and the peak voltage of an AC waveform. Many inexpensive DMMs will only read the rms voltage of sinusoidal waveforms. If the DMM is to be used on modified square wave inverters, it must be of the "true

Measuring Voltage



rms" type or it will give wildly erroneous readings. Many inexpensive DMMs do not have the ability to read the peaks of the AC waveform. Reading the peak of the AC waveform is essential for use with engine-powered AC generators.

DC Volts

All DMMs will measure DC volts, and do so accurately. The meter will identify polarity—which wire is positive and which is negative. If the meter is connected backwards (positive to negative and negative to positive), it will indicate this by showing a minus symbol before the number. The polarity feature allows verification that PV modules, inverters, charge controllers, and batteries are properly installed and not reversed in polarity, which often will damage expensive equipment. Checking for correct polarity is an important step when installing systems.

AC Amps

AC amperage is usually measured in two ranges on most DMMs. One range is in the 200 milliamp (mA) scale, and the other usually can measure up to 10 amps. Both ranges are fuse protected, and if you exceed their capability, you will blow the fuse.

> ## Quick Definitions
>
> **Voltage** is electrical pressure, called EMF (electromotive force) by electronics nerds; the unit used is the volt (V).
>
> **Current (or amperage)** is the rate of electron flow in a circuit; the unit is the amp (A).
>
> **Resistance** is the quality of all materials to impede the flow of electrons; the unit is the ohm (Ω).
>
> **Frequency** is the regular reversal in the direction of flow of electrons; the unit is the hertz (Hz).

Using a digital multimeter to measure array voltage.

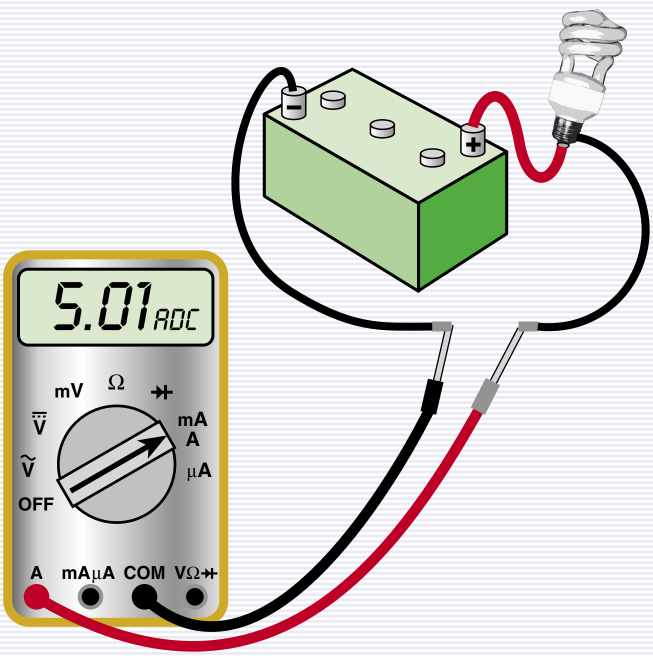
AC electricity can be measured by using the meter's normal probes, with the meter in series in the circuit, or by using an external probe that clamps around the wire. This probe uses the induced magnetic field generated by alternating current to measure the amperage. While not quite as accurate as running the circuit through the meter, AC clamp-on meters allow the measurement of amperage above the standard 10 amps that most DMMs can measure directly. The AC clamp-on current probes are usually inexpensive. Once again, "true rms" DMMs must be used on modified square wave inverters to get an accurate measurement.

DC Amps

Measuring DC amperage is much the same as measuring AC amperage. Two ranges are available with the DMM and both are fused. The polarity of the current is indicated by the DMM—it tells you which direction the electrons are flowing.

DC clamp-on probes are available to measure DC amperage by clipping around the wire. The situation is similar to the AC clamp-on current probes—they are less accurate, but more convenient since you don't have to open up the circuit and run the circuit through the meter, and they allow you to measure higher amperages. DC clamp-on probes are relatively expensive—an accurate one will probably cost more than the DMM itself.

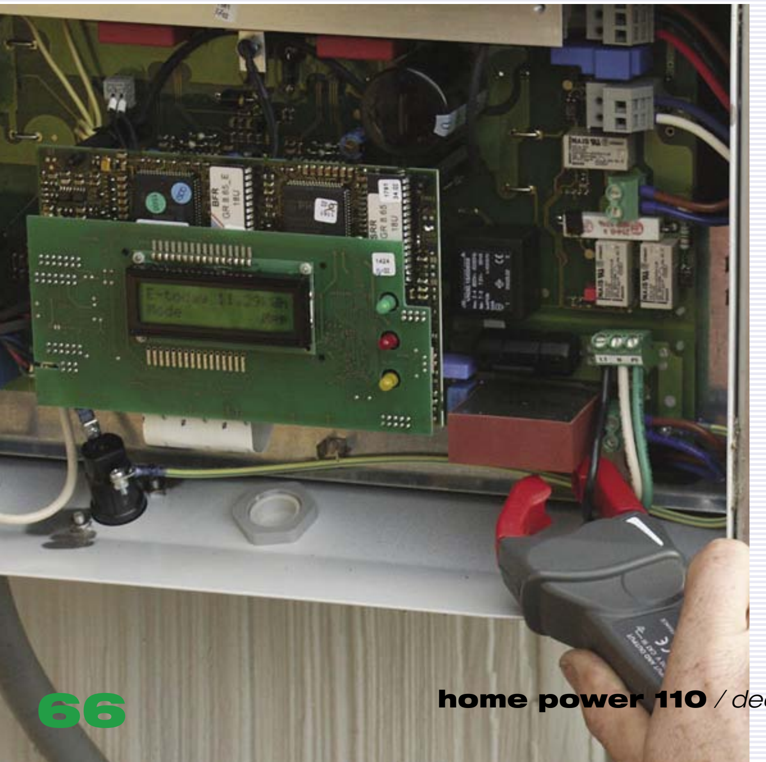
Measuring Amperage



Resistance/Continuity

You will probably only need to measure resistance if you get into electronics design or troubleshooting. But the continuity function of a DMM is frequently used in troubleshooting electrical systems. It can tell you that the circuit is complete, and that all wiring and connectors are continuous. Many meters have an audible continuity function that sounds a tone when there is continuity between whatever points the two probes are touching.

AC and DC clamp meters allow you to measure system amperage without modifying any wiring.



Frequency

Many of the more expensive DMMs will also measure frequency. This function is great to fine-tune your 120/240 VAC generator and make sure that it is running at exactly 60 cycles (Hz). It can also be used to do esoteric things, like calculate the rpm of your wind generator.

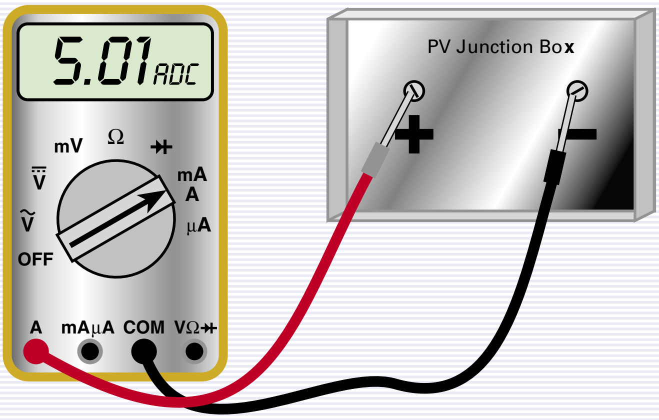
DMM Purchasing Tips

Many, many makes of DMMs are available. Prices start at under US$50 and go to well over US$300. In general, the more you pay, the higher the accuracy and the greater the number of functions the DMM will have. I usually recommend that novices start with an inexpensive meter, and once they have learned to use it, upgrade to a more expensive instrument.

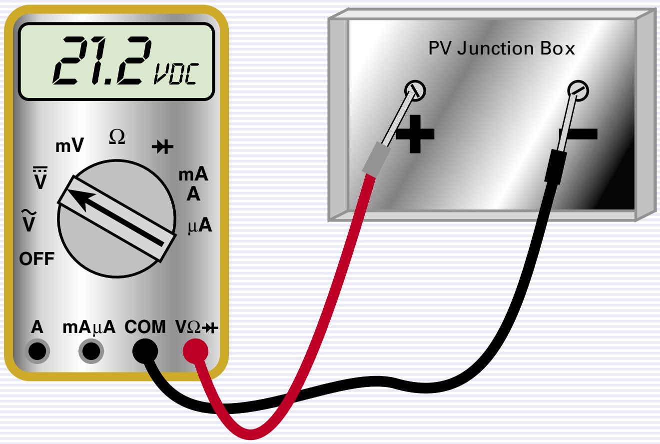
Here are some ideas to help you find a good DMM. Look at the mechanicals on the DMM—the switches, jacks, and plugs. These mechanical items most often fail first. (This is from experience—I've owned dozens of DMMs over the years.) Check out the ruggedness of the case—is it light and flimsy, or heavy and durable? Investigate the fuses used for current protection in the meter—are they easy to replace and are the fuse types common? What type of battery does the DMM use? Most use a 9-volt transistor radio battery, but some use AA cells. An unusual battery can be a pain over the years.

In terms of brands, the inexpensive meters marketed by Radio Shack are adequate for beginners. If you are willing to spend more than US$200, consider those made by Fluke. The Flukes are my all-time favorite, and I currently own three of them. The better Flukes have all the features described above, and a few more besides. I particularly like their "average" function, which allows taking measurements for up to 42 hours, and then gives a true arithmetic average of the data—very useful. Flukes are ruggedly built and should last for many years with careful handling and storage.

Measuring Short Circuit Current



Measuring Open Circuit Voltage



Using a DMM with PV Systems

DMMs are particularly useful when installing solar-electric systems. They can make quick checks for polarity, which is of prime importance. If controllers and inverters are installed with the polarity reversed, they can be instantly damaged.

When wiring a PV array, I check each and every module before adding it to the array. With the module facing the sun in full light conditions, I check the module's open circuit voltage (V_{OC}) by attaching the DMM's positive probe to the module's positive terminal or lead, and the negative probe to the PV's negative terminal or lead. The voltage reading on the meter should match the Voc specification listed on the back of the module if the measurement is taken in full sunlight. I also make sure of polarity at this stage, since some PVs are not marked clearly as to which terminal is positive and which is negative.

Next, I check the short circuit current by changing the meter's setup. I put the DMM into high current DC mode (usually this is 10 amps for most meters) and attach the probes to the positive and negative terminals or leads of the PV, and to the meter as shown in the illustration. This short circuits the PV through the meter and allows a measurement of its short circuit current (I_{SC}). This specification is also printed on the back of the module.

While I've never discovered a new PV that didn't meet the Voc and Isc specs, I've often used this procedure to test older modules and to troubleshoot arrays. When installing large arrays, remember that a clamp-on DC current probe will be necessary to measure the full current of the array. Performing these tests on a new array makes sure that all the elements are functioning properly and that all the polarities are correct.

Checking Battery Polarity

I perform a voltage measurement on each battery before I wire it into the battery pack. I have seen batteries, brand new and fresh from the factory, that are reverse polarized. (The terminal marked positive is really negative and the terminal marked negative is really positive.) Such batteries should be immediately returned and not wired into the battery bank.

As I assemble the series strings of batteries that make up the pack, I measure the voltage of each resulting string. I want to see if the numbers add up and if everything is properly polarized. For example, in a 24-volt nominal battery bank made up of individual 6-volt batteries, four batteries will be connected in series (6 x 4 = 24). I test to make sure that each string is at 24 volts nominal, and that the positive and negative poles of the resulting battery string are correct. Finally, when all the series strings are wired into parallel, I check the resulting voltage and polarity of the completed battery bank before wiring it into the system.

Checking Inverter Polarity, AC Output Voltage & Frequency

The first check to make before installing an inverter is to make sure that the battery input polarity is correct. While the main battery/inverter breaker is still in the off position, check the polarity on the inverter input cables by measuring the DC voltage between the battery side of the breaker, and the negative bus bar. Connecting an inverter in reverse polarity will kill it dead, immediately. Double-check this—inverters are expensive, and connecting them reverse polarity is not covered in any inverter warranty I've ever encountered. (The same goes for charge controllers.)

Once the inverter is connected and operating, use the DMM to measure its AC voltage and frequency. Do this immediately to make sure it is functioning properly. Voltage should read 117 VAC plus or minus 5 VAC. Frequency should read 60 Hz, plus or minus 0.2 Hz.

Checking Engine Generator Voltage & Frequency

Use the DMM to check both generator voltage (rms and peak), and generator frequency. RMS voltage should be between 110 VAC and 120 VAC. This depends on generator loading, so make sure that the generator is at least at half load before making this measurement. Peak AC voltage should be around 164 VAC, but no lower than 150 VAC. Low peak voltage will make your battery chargers work poorly. Frequency should read 60 Hz, plus or minus 0.2 Hz. While the generator is under its typical load, adjust the generator's throttle control to bring the frequency as close to 60 Hz as possible.

DMMs Are Your Eyes...

Using a DMM at all stages of system installation ensures a working system, and no catastrophes or surprises. Where the DMM really shines is doing diagnostics and troubleshooting, but that's another, far deeper subject than this beginning article can cover. If you want to know more about DMMs and how to use them for troubleshooting, please see my article in *HP60.*

Buying an expensive DMM will not make you an experienced electrician any more than buying a Gibson Les Paul guitar will make you play like Jerry Garcia. What counts is practice and experience. While the DMM is your eyes into the invisible world of electricity, it takes understanding and knowledge to determine what the meter is telling you. So learn all you can about electrical theory, and use the DMM to apply this knowledge.

Access

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Selected DMM manufacturers:

Advanced Test Products Inc. • www.amprobe.com

AEMC Instruments • www.aemc.com

B&K Precision Corp. • www.bkprecision.com

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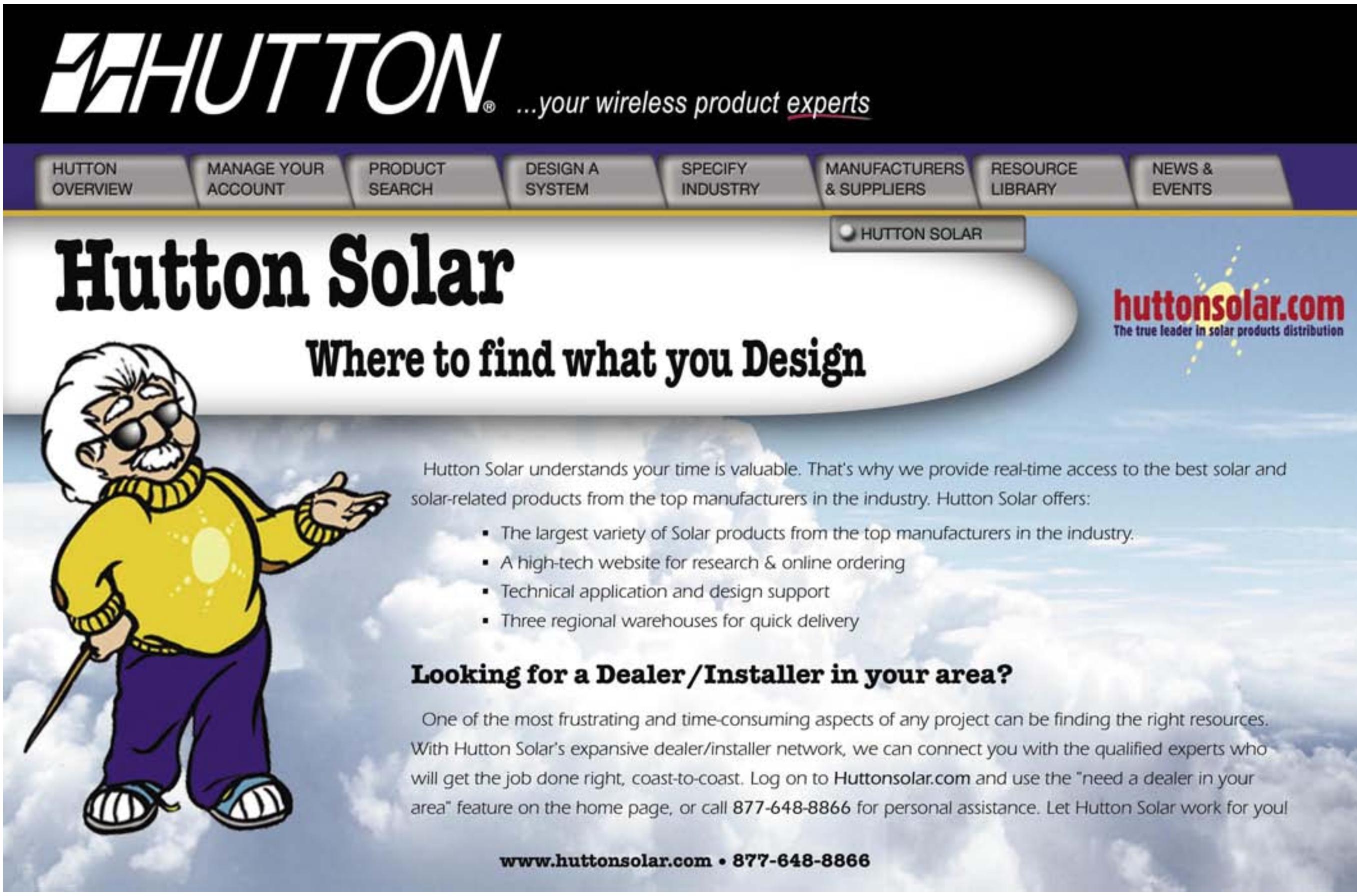
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Efficiency Pays

Small Changes Equal Big Savings

Bernd Geisler

Caulking and weather-stripping the gaps in your home probably offer the best use of your bucks in terms of home energy improvements.

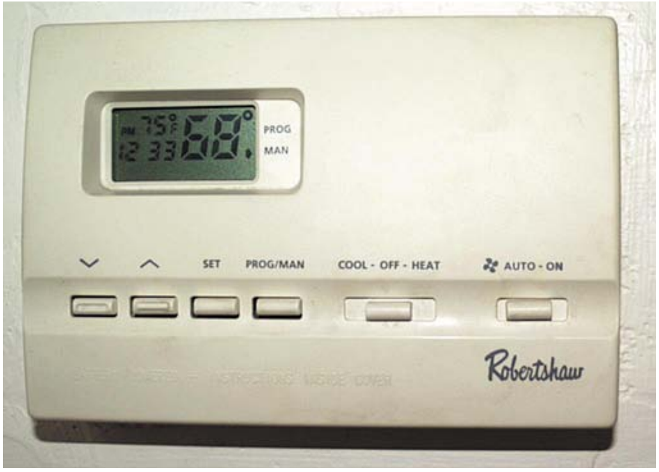
Even if you live in an ordinary suburban home like my family does, you can still take advantage of many opportunities to save energy and money. Over the last four years, I have monitored my family's energy consumption and the effectiveness of several measures we took to make our home more energy efficient. The energy efficiency measures complement our renewable energy (RE) systems—wind, photovoltaics, and solar hot water. (See *HP100*.)

Find Your Starting Point

Even though our house is only ten years old, it needed some efficiency improvements. I started with an inventory of small, energy-wise changes I could make that would reap the most benefits. No matter the age or condition of your house, starting with a list gives you a place to begin. From there, it's just a matter of fitting it into your budget. For about US$30, you can buy a kilowatt-hour meter to help you analyze your appliances' energy use. For larger electric loads, you can refer to the EnergyGuide labels that come with most large appliances.

Good Setbacks. Although you shouldn't have to sweat or freeze in your own home, you probably have a comfort zone. Keeping indoor temperatures near the borders of that zone can save lots of energy. The U.S. Department of Energy (DOE) estimates that setting your thermostat back 10°F to 15°F (5.5–8.3°C) for 8 hours can provide an annual savings of 5 to 15 percent on your heating bill. Each degree Fahrenheit (0.5°C) of setback over 8 hours can shave about 1 percent off your utility bill. A similar relationship holds for cooling loads.

A programmable thermostat (US$50 and up) allows you to adjust indoor temperatures to the lowest comfortable



Programmable thermostats offer hassle-free comfort.

Using a removable whole-house fan eliminated one month of air conditioning use in this Texas home.

level in winter and the highest comfortable level in summer without constantly fussing with the dial. Common models let you set several different programs to activate during different times of the day. This turns the furnace or air conditioner off automatically when the house is unoccupied, or dials the heat down or air conditioner up when you need it least, such as while you're sleeping.

Bundle Up. Sealing the leaks in your house is one of the cheapest and quickest energy upgrades. Professionals use blower door tests to diagnose a leaky house. These specially equipped units fit into a home's doorway. Powerful fans pressurize or depressurize the house slightly, and measure the airflow and the fan-induced pressure. The more airflow that is required to induce a pressure difference, the leakier your home is.

You can make a less accurate but quick assessment of leakage by lighting a candle and then watching the flame flicker as you move it next to door and window frames, or by burning incense and observing how the smoke moves. These methods work best in the wintertime when leaks expand as building materials contract. If you can see the flame flicker near the leak or feel a cold air stream, take action.

Caulking and weather-stripping the gaps in your home probably offer the best use of your bucks in terms of home energy improvements. It will also make your home feel warmer and eliminate or at least reduce drafts. Before you batten down the hatches, assess the air quality in your house and make sure your home's ventilation is adequate. Sealing up a house too tightly can trap indoor air pollutants, such as carbon dioxide, mold, and dust. A house should replace its air volume two or three times every hour.

Also consider adding insulation to your home's attic, walls, and floors, which will keep your home cooler in the summer and warmer in the winter, and reduce the run time of your cooling and heating equipment. The DOE recommends in most regions that, at a minimum, attics be insulated to R-49, walls to R-18, and floors to R-25.

Get a Cheaper Cool. Using fans can be exceptionally helpful in keeping your house cool during transitional seasons, since running a fan draws just a tiny fraction of the power required to run an air conditioner.

I found an ideal position for a fan in my house in the ceiling of the second floor, right under a circular attic air vent. Since the fan is positioned close to the highest point of the living space, it exhausts the hottest air straight through the attic, and draws cooler air from the rooms below. Before I installed the fan, on warm days that upper room was uncomfortable and pretty much useless because all the hot air in the house would accumulate there.

I bought an industrial-grade fan for US$40 (available at most home improvement stores) and fitted it with a little flap I made from Styrofoam insulation board. The flap opens by air pressure when the fan is switched on and closes when it is switched off. The whole setup cost less than US$50 and can be installed in about five minutes.

One of the two inefficient electric attic fans that were removed and replaced with ridge and soffit vents.

Our whole-house fan draws between 67 and 123 watts, depending on the chosen setting. Our 4-ton air conditioner pulls 4,000 watts—for that amount you could run about 33 small fans!

This small upgrade saves us from at least one month of air conditioning in our hot, humid climate, and easily paid for itself within one year. When we finally turn on the air conditioner, we keep the fan off to prevent blowing out the cool indoor air. In the winter, I remove the fan and fit the hole with an insulated piece of drywall.

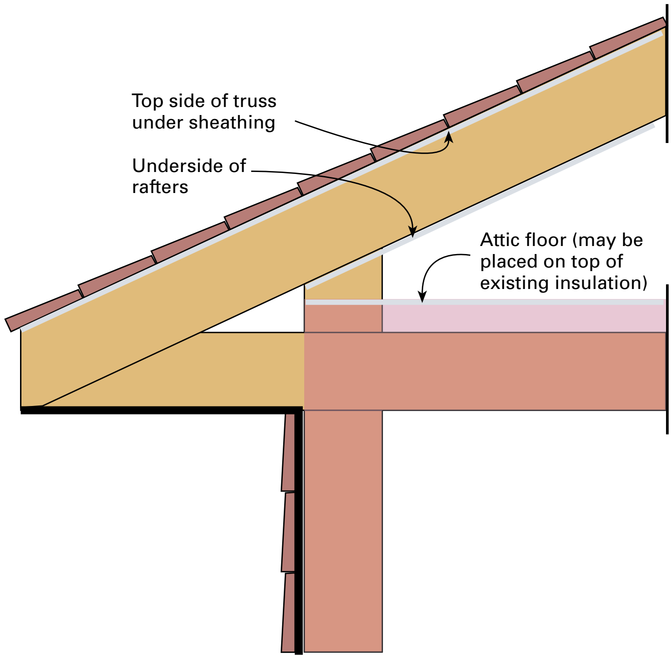
Ventilation. In warm months, an uninsulated attic transfers heat to the living space below. Our thermostat-controlled electric attic fans consumed about 6 KWH on a typical, hot summer day, without cooling the attic noticeably. A better way to ventilate an attic is with ridge and soffit vents that run along the whole length of the roof. The air circulation works naturally—the hottest air escapes at the ridge, while cooler air is drawn in through the soffit vents.

A 4-foot-long (1.2 m) section of ridge vent costs about US$10, and a 1-foot-long (0.3 m) piece of soffit vent costs less than US$2. Installing ridge and soffit vents for my entire house cost less than US$100. This passive attic ventilation works better than the active one did, and saves us several hundred KWH per year. At our current rate of US$0.135 per KWH, that translates into annual savings between US$40 and US$80.

Block the Heat. Up to one-third of a home's heat gain comes through the attic. Radiant barriers (foil-faced insulation, films, or sheathing) work by blocking radiant heat transfer. In certain climates, they can save between 8 and 12 percent on air conditioning costs.

Installing a radiant barrier under attic rafters can considerably reduce heat gain through the roof.

Attic Radiant Barrier Placement



For retrofits, the recommended way to install radiant barrier in an attic is to staple it to the bottom side of the roof rafters, which leaves an air space between the barrier and the roof sheathing. Install the barrier with the foil side facing downward.

The hot air, within the space enclosed by the rafters and the radiant barrier, rises toward the roof's ridge, and cooler air is drawn in from the bottom. Provided there are enough ventilation openings, the hot air will rise out of the attic naturally. For that reason, the radiant barrier should end 1 foot (0.3 m) above the attic floor and 4 inches (10 cm) below the roof ridge, so that the hot air can escape through the ridge vent and the cooler air can enter at the bottom.

Even a well-insulated and ventilated attic will still get slightly warmer than the outside air temperature. But reducing summer attic temperatures by just 10°F (5.5°C) goes a long way towards reducing your cooling bill. It cut our cooling bills in half.

A Bright Idea. Compact fluorescent lightbulbs (CFLs), which use 75 percent less energy than typical incandescent bulbs, offer an easy energy saving opportunity. Just unscrew your old incandescent bulbs and screw in

Renewable Efficiency

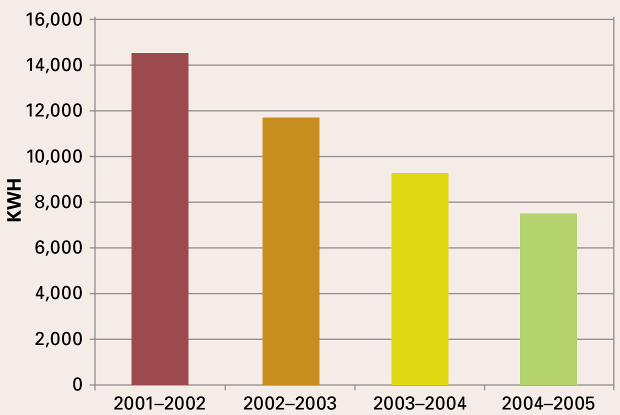
We have cut our yearly energy consumption by almost half—from 14,619 KWH per year to 7,341 KWH. Without accounting for subsidies or changes in energy prices (which are bound to keep increasing), the worst-case scenario payback time of all our efforts should be about twenty years.

My first improvement was to install a whole-house attic fan and add insulation to the attic in June 2002. These changes cut our energy use by about 46 percent. The energy-saving benefits of improved insulation, caulking, and weather-stripping that following winter decreased our December 2002 energy use by more than 30 percent.

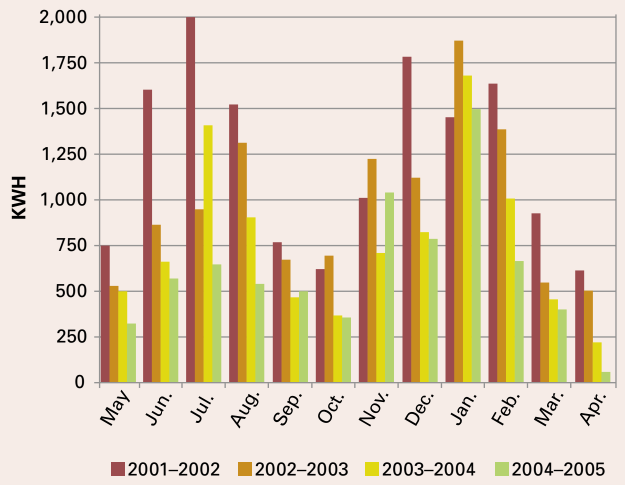
The other changes are more difficult to pinpoint on the graph at right. For example, if the solar water heater saves 1,500 KWH annually, that represents a 150 KWH change over 10 months of operation—an amount too small to show dramatic results on the graph. That's where examining the complete picture, by comparing overall annual reductions in consumption, comes into play.

Our average energy use per month is 611 KWH. Our African Wind Power 3.6 wind turbine, which generates 104 KWH per month on average, and our 880-watt solar-electric system, which produces an average of 92 KWH per month, meet about one-third of our energy needs. The solar hot water system and the backup electric tankless water heater are an efficient combination, and the 40-gallon, solar-heated water capacity is more than sufficient for our family of four. Replacing our ten-year-old heat pump with a state-of-the-art unit could shave between 25 percent and 50 percent off the remaining heating and cooling bills. This would be an excellent improvement.

Annual Household Energy Consumption



Household Energy Consumption



A 10-day vacation in July 2002, compared to July 2003, accounted for the lower energy consumption.

Hotter than normal fall weather accounted for the small increase in energy consumption from September 2003 compared to September 2004, and from October 2002 compared to October 2003.

In November 2004, guests increased the household from four to six people, increasing the household's energy use.

A weeklong vacation in January 2002 reduced energy consumption compared to January 2003.

new CFLs. Many CFLs offer a light spectrum similar to their incandescent counterparts, and come in shapes, styles, and sizes to fit a range of fixtures and lighting needs. Most come with a seven-year manufacturer's warranty, start quickly without flicker, and cast a warm light.

With a design life of 10,000 operating hours, one CFL will outlast at least ten incandescent lightbulbs. Although their upfront cost is more than the cost of incandescent bulbs, the lower energy use multiplied with their longevity results in impressive lifetime cost savings. Another benefit is that CF floodlights and bulbs generate much less heat in recessed ceiling fixtures.

We identified 24 fixtures that we use most often and over extended periods, and then replaced those incandescent bulbs with CFLs, at a total cost of about US$100.

Appliance Upgrades. Horizontal-axis clothes washers consume at least one-third less hot water than traditional top loaders, easily saving 500 KWH per year, depending

A front-loading (horizontal-axis) washing machine reduced hot water consumption from 40 to 24 gallons per load.

on the number of loads and wash-water temperature. Three years ago, we traded in our old top loader for a front-loading washer. This upgrade played a big role in saving energy.

Besides clothes washers, other wise appliance investments include refrigerators, water heaters, room air conditioners, and dishwashers. Our 21.6-cubic-foot Kenmore refrigerator is still a guzzler, using 767 KWH per year. We will save another 300 KWH per year once we replace it with a modern Energy Star model.

According to the American Council for an Energy-Efficient Economy, replacing a 20-year-old refrigerator with a new, energy-efficient model will save about 800 KWH per year, and, if you're reliant on the utility for your energy, it will reduce your home's greenhouse gas emissions by about one ton per year.

Bigger Changes. After our other efficiency upgrades, we decided that we were ready to invest in a solar hot water system. Using the sun to heat water is one of the most cost-effective applications of solar energy. Generally, you can recoup your investment in three to five years.

For us, the most important criteria for our solar hot water system were simplicity and low maintenance effort. I decided on a passive, open-loop system with an electric tankless water heater for backup. The ProgressivTube 40 (US$1,650) batch water heater fit the bill. (For more on solar hot water systems, see "Solar Hot Water—Simplified," in *HP107* and "Simple Hot Water," in *HP108*.)

A batch water heater mounted on the garage roof (alongside the solar-electric array) meets a large portion of the Geisler family's hot water needs. The 880-watt, utility-intertied array offsets electrical use by about 15 percent.

Author Bernd Geisler maintains his African Wind Power 3.6 turbine—another component in achieving his family's goal of energy independence.

I chose a Seisco RA-28 (US$490), electric, on-demand backup water heater. Because the unit uses polymer heating chambers, it is impervious to scale. The heater monitors the temperature of the incoming water and, using five temperature sensors, adds just the right amount of heat, raising the outgoing water to the desired temperature. The sensors' resistances all have to be within 10 percent of each other, or the device will not work and will give an error message identifying the sensors that are out of spec. Replacing a temperature sensor turned out to be necessary more often than I liked. Although the procedure is quite simple and well documented, there's probably some room for improvement.

That said, our system is very reliable; if one heater fails, we can still use the other one most of the time. The ProgressivTube's design is robust; apart from possible freeze damage, virtually no other components are vulnerable to breakage. For precaution, I drain the solar heater and bypass it in January and February, when there is a chance of hard freezes. For the remaining ten months, we get our hot water almost for free!

The Bottom Line

Many small changes like these can add up to make a big difference in your household's energy efficiency, and help you on your way to lower utility bills and greater energy independence. While you're enjoying the benefits at home, saving energy and using RE resources wisely also can benefit local, regional, and national economies by employing local solar installers and supporting the solar industry, as well as others striving to make useful, energy-smart products. Besides demanding that our political leaders support renewable energy, we can all do our share. So instead of propping up the United States' dependence on oil and coal, start a renewable energy revolution at home, beginning with your own.

An energy saving, on-demand, tankless water heater serves as a good backup to a solar domestic hot water system.

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The Most Energy Efficient Appliances, 2004, Paperback, 46 pages, US$5 from American Council for an Energy-Efficient Economy, 1001 Connecticut Ave. NW, Ste. 801, Washington, DC 20036 • 202-429-0063 • Fax: 202-429-0193 • info@aceee.org • www.aceee.org

Laurent Koechlin

Racing by the Sun

and Moon

Sunracers (from front to back) Solelhada, Kamm, and Helios, at the race finale in Toulouse, France.

Rallye Phebus is an annual solar-powered race that links the Pyrenean mountain crests at the Spanish border to the French city of Toulouse, 200 kilometers (124 miles) to the north. Our previous solar rallies only had daytime stages, but last year we decided to make a demonstration, among other things, that solar energy can be used on the road by day—and even by night!

This was the first night stage we organized, and to my knowledge, the first time ever that a solar race took place at night. As a prologue to the rest of the race, we tested the concept on a short, 4-kilometer (2.5-mile) nighttime trip from the village of Age to Puigcerdà and back. At 10 PM, the bright stars in the mountain sky only shed some 10^{-7} watts (one ten-millionth of a watt) per square meter. However, nobody was stalled by the lack of energy. It had been stored the day before.

Racing by the Grid

For solar vehicles to operate completely independently, a large area of highly efficient photovoltaic (PV) panels is required—for example, 8 square meters (26 ft^2) of 20 percent efficiency solar-electric panels. This is an expensive application that can cost at least US$40,000 per vehicle. Even with all that PV, at best the system only peaks at 2 or 3 kilowatts, and achieving high speeds with so little power requires a specially designed vehicle, like a sunracer.

Sunracers rely entirely on their onboard solar-electric panels for electricity, which allow them to ride at sustained speeds of 60 to 90 kilometers per hour (37–56 mph) on a flat road. A battery serves as a buffer, absorbing the surplus electricity when driving downhill or at low speeds under the sun, or boosting the motor up to 130 kph (81 mph) as needed. Sunracers are definitely not for everyday transportation, however. With their fragile carbon-fiber bodies, these three-wheeled vehicles only weigh from 200 to 300 kilograms (441–661 pounds) and can cost more than a Ferrari.

Last year, out of the twelve electric vehicles entered in the race, only three were sunracers. The other nine were electric scooters and bicycles, some homebrew vehicles, and even some conventional cars that had been converted to electric vehicles. These vehicles use electricity to recharge their batteries—it cannot be provided by onboard solar-electric panels, since they don't carry any. A car's rooftop lacks the space to accommodate the large number of PV panels that would be required to power the vehicle. This isn't surprising—not even nature has found a way to power fast-moving beings directly from the sun. (After all, have you ever seen animals with leaves?) However, all of the energy used during the four days of this rally is derived from renewable, solar sources (except for a few internal combustion-engine vehicles that transport the prototypes before and after the rally).

So how can a vehicle without any solar-electric panels work on solar energy alone, and even race through the night? The answer can be found not on the road, but on some rooftops. Take mine, for example. It's covered with 16 square meters (52 ft^2) of PV panels. These 36 panels have been tied to the grid since 1996, and provide up to 1,450 watts.

In the eight years since my system started operation, it has produced more than 2,000 KWH per year on average. If one day I save enough money to convert the 1983 Volkswagen Rabbit I use for commuting, I will be able to drive almost 12,000 kilometers (7,500 miles) per year using the energy my PV system produces, without fossil fuels and without contributing any greenhouse gases to the environment.

About 250 households in France are grid-tied PV producers. This number increased rapidly until a few years ago, when the side effects of a French bill slowed the process by requiring excessive paperwork and causing administrative delays. Although we have more sun than our neighbor Germany, we have far fewer grid-tied systems. Despite this, enough grid-tied PV arrays exist along the race route to feed our vehicles' needs. The secret to our daytime and nighttime solar race success is that we use the French utility grid to carry and store our solar-electric energy. We simply measure the KWHs that come out of the home meters and, from that, subtract the KWH readings on the meters that monitor the vehicles' battery chargers.

Moon Power—Sheer Lunacy?

As for "lunar energy," don't dream of powering or charging anything with it. The moon, even at its fullest, yields 10^{-3} watts per square meter—much more than the stars, but still 1 million times less than the sun. This means that a photovoltaic (PV) array rated for 1 kilowatt of peak power under the sun yields at most 1 milliwatt in moonshine. This is barely enough to light an LED. In most cases, the output voltage from the whole PV array under moonlight will not even reach the 2 or 3 volts necessary to overcome the LED voltage barrier.

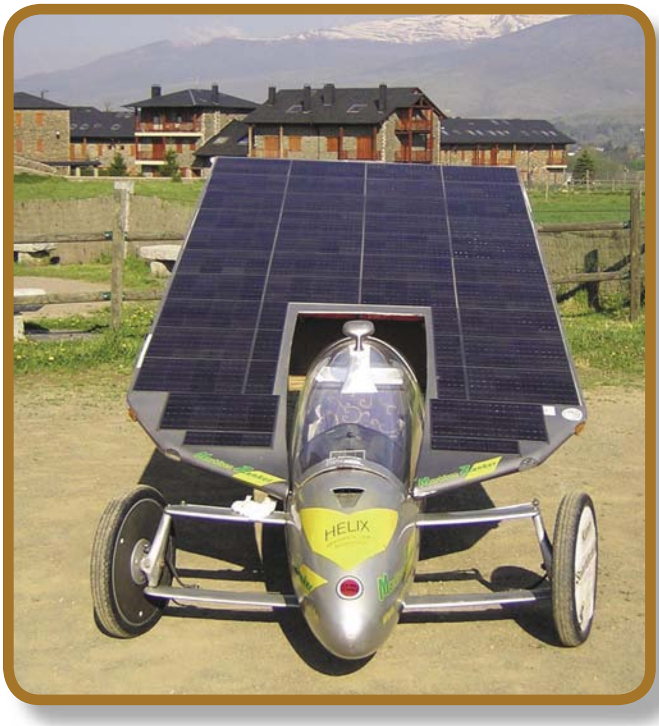
And the Winners Are...

The scope of this rally is to show that using solar energy for transportation is feasible and becoming more affordable. As with other events of this type, many other facets are involved, such as having fun together, comparing experiences, cross-fertilizing ideas, and creating vocations for young engineers in renewable energy technologies. So what makes it a rally? Is there a competition? Yes, there is! However, it's not based on speed. Instead, vehicles are evaluated on their reliability, energy management, and fitness to different road conditions.

A point system scores the rally, and the winner is the one who receives the most points. Each kilometer traveled successfully earns the participant 10 or 15 points, depending on the slope. Each minute spent repairing or pushing a vehicle during a stage costs racers 10 points. And each KWH "taken" from the grid to recharge a vehicle costs 50 to 150 points, depending on the vehicle type. Every vehicle starts with a full battery, and every KWH is accounted for. In the 2004 Rallye Phebus, solar-charged vehicles consumed a total of 20.9 KWH over the race route. During the same four-day period, the grid-tied solar arrays along the rally route produced a total of 51.8 KWH, more than twice the KWHs required by the vehicles.

The rally has witnessed increased public interest over its short history. Last year's race drew the largest crowds ever, and an estimated 100,000 people tuned in to a radio program dedicated to the rally. In Europe, where the diesel engine rules the road and produces prodigious amounts of pollution, it's heartening to see people interested and curious about tapping into solar energy for transportation.

While parked, the Kamm sunracer can tilt its PV panels for maximum solar exposure.



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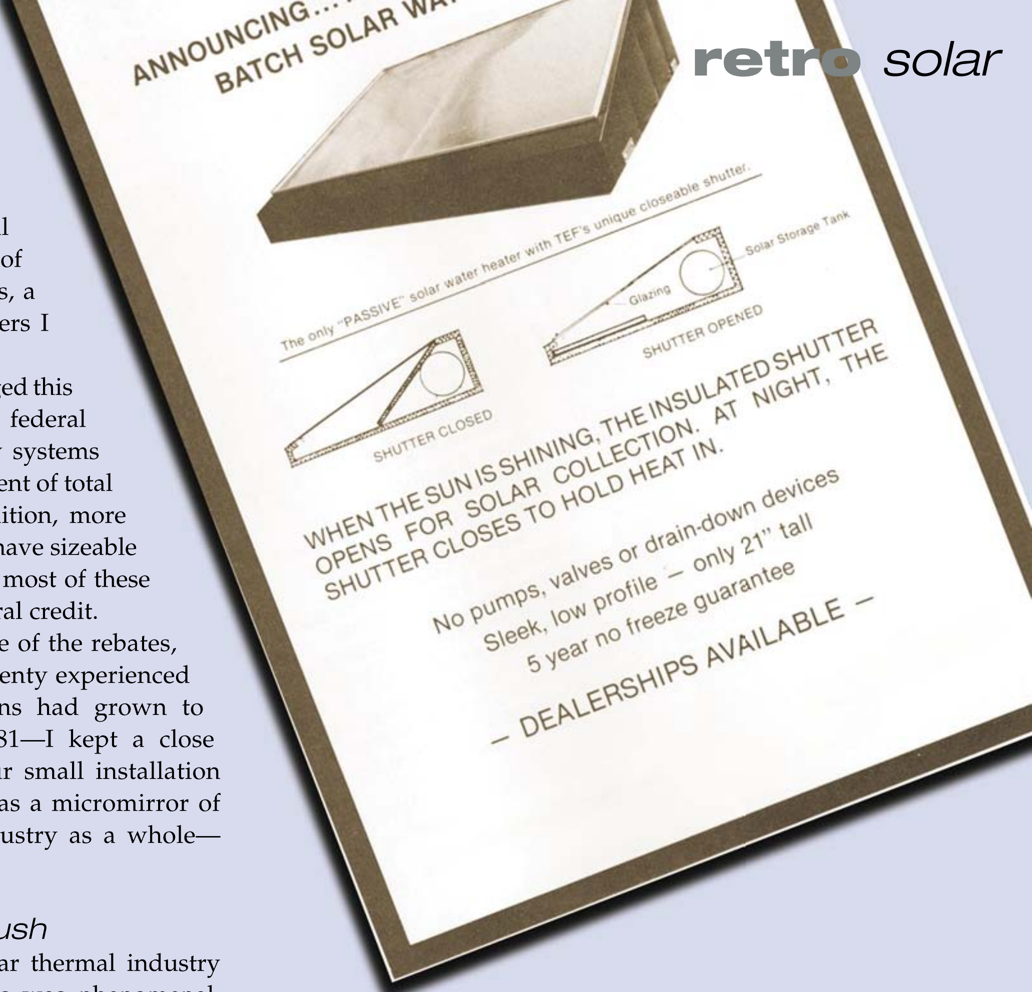
Runaway Solar

Lessons Learned from the ’80s

Chuck Marken



The year 1980 was a tough one for a solar thermal installer. I almost threw in the towel and went back to conventional electrical and heating jobs. I was working out of my house with one truck, a set of tools, a trailer, and a couple of part-time helpers I could call on.

Federal tax credits and rebates changed this almost overnight. In 1981, the existing federal tax credit for all types of solar energy systems was simplified and increased to 40 percent of total expenditures up to US$10,000. In addition, more than half the states had or soon would have sizeable tax credits, rebates, or deductions, and most of these state incentives supplemented the federal credit.

By the end of 1981, under influence of the rebates, my company had seven trucks and twenty experienced hands. Our solar thermal installations had grown to almost a thousand systems (981—I kept a close count back then). Our small installation company's success was a micromirror of the solar thermal industry as a whole—things were *booming!*

The New Gold Rush

The growth of the solar thermal industry in the next three years was phenomenal, but not necessarily positive. It attracted lots of people who saw easy pickings and quick returns on their investments. Many were sales-types with backgrounds in home siding, vacuum cleaners, and other high-pressure sales jobs. They set up sales companies to capitalize on the tax credits. Find a manufacturer, recruit an installation contractor, set up financing, hire a sales crew, and crank up a phone room. Voilà—you're in the solar business.

Many of these sales companies were so successful and got fat bank accounts so rapidly that they started manufacturing and installing what they sold. This led to most of the abuses that you may have heard about. Overzealous sales pitches promised products and performance that couldn't be delivered, unqualified manufacturers produced substandard products, and poorly trained installers did lousy work. Not all companies and not all the time, but way too much to ensure the continuation of a healthy industry.

A couple of seasoned sales guys told me that this was a three-year deal—make the money today, because tomorrow the opportunity would be gone. I thought they were shortsighted and flat wrong. But I was the wrong one, and here are some details of why this tax credit era was so disastrous for the solar industry.

Super Sales, Shoddy Products

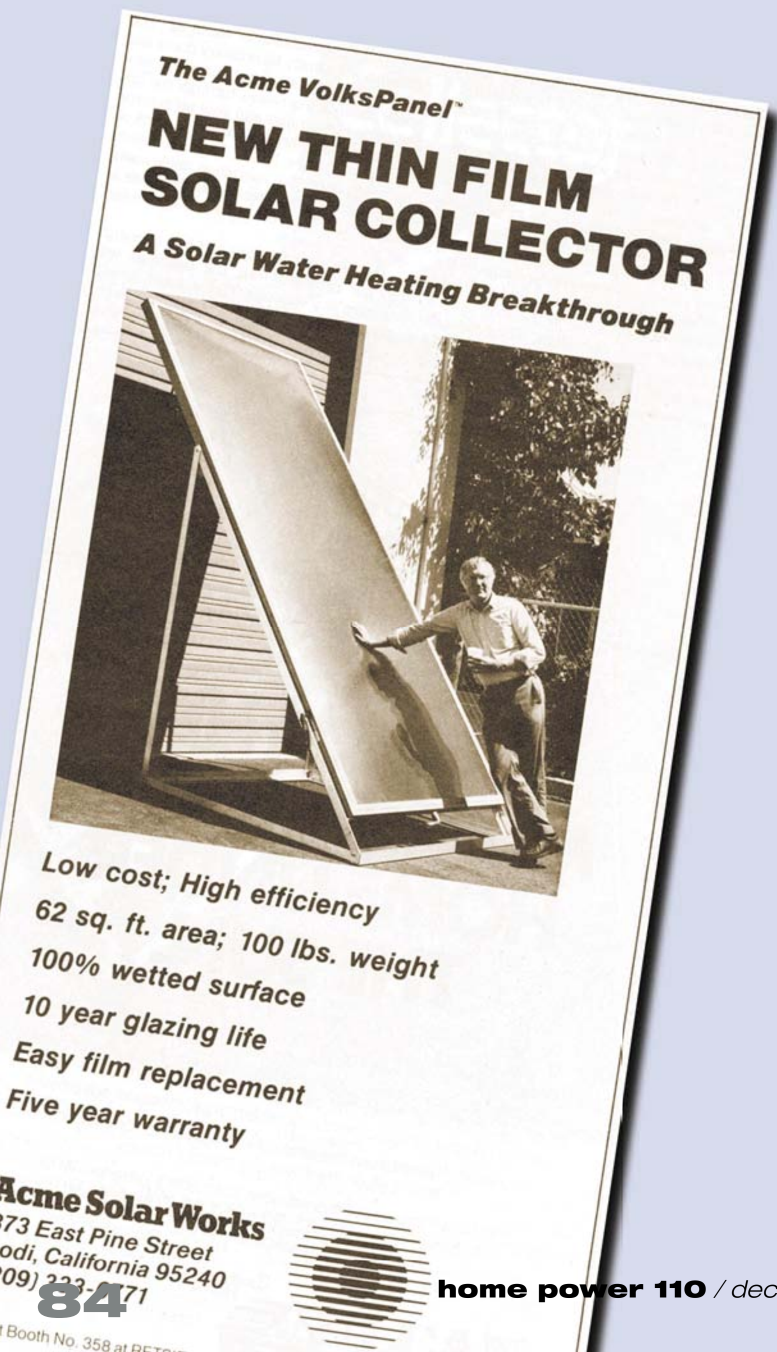
Take the normal marketplace and inject it with a temporary, artificial boom, and you invite untold, unintended consequences. Manufacturers who look down the road only a few years may decide to make a much different product than they would with a twenty- or thirty-year outlook. Couple this with the fact that many product defects may not show up for five years or so—this seems to have been particularly true in the budding solar industry—and an artificial boom with a known lifespan often results in inferior products from the get-go.

Here are a few examples of poorly performing products that were floated in tax credit times.

- High-temperature concentrating solar collectors that tracked the sun were installed on homes to heat domestic water. Thousands were installed across the United States, but I doubt any are still in operation. (If any readers have one of these still tracking the sun daily and producing hot water, please let us know.)
- Poorly designed, Freon-filled thermal collectors for water heating that leaked Freon within a few years and became useless, since there was no provision for refilling them.
- "Solar Magic." These tiny solar hot air collectors (only 8 to 10 square feet) were supposed to heat a whole house, but would barely heat a bathroom.
- Solar thermal hot water collectors with heat-vulnerable rubber tubing inside; a plastic transparent front; and flimsy aluminum foil—yes, foil—on the back.

- Draindown water heating systems that relied on a valve to drain the collector in freezing weather and used tap water to fill the collector. These valves were notorious for clogging after a few years. Here's a hint: A clogged draindown valve and freezing temperatures equals frozen and burst tubes in the collector.
- SolarCones were maybe the worst-performing liquid solar collectors ever certified. The SolarCone was a cone-shaped collector with plastic glazing all the way around it. This poor design resulted in the cone losing up to half of its heat gain through the glazing, but the cone still found its way to hundreds of rooftops.

Virtually none of these products were truly viable then, and none or very few are still in service today. In a normal marketplace, they would never have seen the light of day.



Rubber-Stamping

In response to this inferior product mess, the government told the industry to clean up their act, so the industry formed an organization—the Solar Rating and Certification Corporation (SRCC). They collected fees from manufacturers based on how many square feet of collectors the manufacturer produced.

The SRCC certified the collectors based on independent test-lab results. The tests required setting the collector in the sun for 30 days, after which the collector was performance-tested. Essentially, if the collector didn't fall apart during the test, it was certified.

The SRCC eventually changed their protocol to certify collectors by performance numbers, but they still certified plastic-glazed collectors with rubber tubing on the inside. Results varied widely from these independent labs and the standards weren't very strict. For example, the SolarCone is listed in the Fall 1985 SRCC Directory of Certified Collectors as being able to produce 494 Btu per day per square foot of collector area in a category of heating domestic hot water on a bright sunny day. In that same category, a well-respected liquid collector manufacturer (Novan) is listed as producing 1,082 Btu per day per square foot.

SRCC ratings were only meaningful for the performance tests; their rating was worthless for durability. Because of this, some poorly manufactured products dogged the industry until well after the federal tax credit expired in late 1985.

The Solar Sell

My first experience in competing with the real sales pros came shortly after my company started manufacturing. We were selling a 66-gallon (250 l) solar water heater,

Solar Thermal, Today

The solar hot water and heating industry has matured a great deal in the past twenty years since the previous federal tax credits expired. The people who survived—manufacturers, dealers, and installers—did so because they offered superior products, workmanship, and business ethics. Most of the survivors of the tax credit era stayed in business for reasons other than making a buck—and for years after the credits expired, there were little or no bucks to be made.

With very few exceptions, all of the solar thermal products built in the United States today are designed to last for many decades. You can count on years of excellent performance from a collector built out of aluminum or steel, glass, and copper. And also with very few exceptions, you can count on the installers, dealers, and service people—old hands and newbies alike—for their top-notch professionalism and service.

Tax Credit Lingo

"Spike the job." Installers initiate work on a job immediately after a high-pressure sale is closed, delivering the equipment, and maybe installing something small, like a collector mount or control. Consumers have a 72-hour right of rescission, but "spiking the job" helps to stave off any buyer's remorse.

Round-table seminar sales. High-pressure sales outfits used round tables in their so-called seminars, which allowed the salesperson to slide around the table and align themselves with the customer when "negotiating a better deal" with the company "manager." Don't laugh—it works when pros use it; so well that some companies used this technique exclusively.

Sales rebates. Manufacturers and sales companies offered these rebates to spice up the federal tax credits. The company marked up their product, giving customers an increased tax break, and then refunded them the markup difference in cash. Although there was no increase in their per-product profits, the company got increased sales volumes (compared to other companies who weren't offering rebates); plus, they got free advertising, because the rebates required customers to post the company's signage in their yards.

Backdating. January sales were terrible during the tax credit era. The reason? It would be at least thirteen or fourteen months before a homeowner would see the tax benefits. If they hadn't filed their April tax return yet, a little paperwork shuffle could make it appear that they had installed the system in December, during the previous tax year. The tax benefits were then just around the corner.

"No payment till tax refund time." This high-interest financing program gave a customer the option to put nothing down on a solar installation (or something nominal, like US$50), with the first payment due when they received their tax refund.

installed, for US$1,800. A company across town was selling the same size water heater for US$6,000. I was perplexed. My company was a vertically integrated, local company (manufacturing, sales, and installation—all in-house). How could an out-of-state company possibly stay in business selling essentially the same product for more than three times as much? I made it my business to find out.

Round-table seminars, creative financing, and having the installers "spike the job" were part of the reason (see "Tax Credit Lingo" sidebar). These companies also had great sales commissions, regular conventions with sales awards, and trips to Hawaii to reward the top salespeople—everything to keep the morale of the sales crew pumped to the max.

Take this highly charged sales atmosphere, add a poorly informed public, and you have the makings for sales based on performance hype that would never be reality. In a normal marketplace, false claims eventually come back to bite you. But in this short-term, get-rich-quick business model, they had few consequences.

Solar Shortcuts

Installation fieldwork is where the rubber meets the road in the solar industry. It's where good products can be made to look bad and bad products can be made acceptable—at least for a while. With home products like solar energy equipment, installers depend on manufacturers for much of their training. When manufacturers' specific requirements are well understood and an installer incorporates the materials and techniques of the respective trade, good workmanship usually results in a good installation.

The artificial boom of solar tax credits broke down this whole infrastructure. With almost an overnight growth in the industry, there weren't enough trained installers in the field, not to mention qualified installers who wanted to be inspectors. And current inspectors needed training on solar energy systems, but they didn't get any. Manufacturers who were new to the industry had their hands full just producing a decent product to fit their three-year business plan. Training installers was last on their list.

With the lure of quick cash, even some installers with good manufacturers' training and instructions took shortcuts that sacrificed performance and safety, and got away with it because inspectors didn't know what to look for.

Going for Broke

The consequences of tax credits that were clocked to expire in a relatively short time caused much more harm in the long term than the four-year boost in sales the incentives provided. The 40 percent federal credit expired as the original legislation provided—on December 31, 1985—and the solar industry went down hard.

Estimates are that more than 95 percent of solar businesses went broke or closed their doors. By 1987, the solar thermal industry was a complete bust—leaving a mountain of solar collectors and balance-of-system parts behind.

Maybe the worst thing about the industry's crash was the so-called "orphan" systems, in which the distribution chain had disappeared—no manufacturer, no dealer, no service. My company survived on servicing orphan systems, and buying and selling the mountain of inventory. In five short years, we had gone from a handful of people with a few trucks, to more than a hundred people, with warehouses in three states and dealers in thirty, then back to a handful of people and a couple of trucks. And once more, we micromirrored the solar industry.

Moving Forward

Instead of tax credits for consumers, perhaps the solar industry would benefit most from significant government subsidies to U.S. manufacturers of solar equipment. In reality, nothing would change in the industry except that the price to the consumer would come down. The manufacturers wouldn't pocket the money in a competitive environment—they would drop their prices to gain market share. The industry would stay essentially the same, except for more sales because of reduced prices. And the scammers wouldn't have the tools to scam.

Significant subsidies for solar manufacturers would simply lower consumer costs, at a proportion equal to the manufacturers' savings. This could make U.S. manufacturers more competitive in world markets and keep jobs in the States. After all, it's U.S. tax dollars that pay for the subsidies—why finance Chinese- or German-made solar equipment when we can support jobs here?

A 30 percent federal tax credit for solar water heaters is slated to start in January 2006. I think the incentives will bring another temporary boom to the industry—and the credits will also spawn some of the solar scams of the past. You can help prevent the abuse. Spend some time researching the systems you're interested in. Surf the Internet and publications like this one. Use your common sense for product evaluations and make sure to buy from dealers, contractors, and installers who have a solid track record in the solar industry. The best solar financing package from Johnny-Come-Lately Solar ("no interest or payments till hell freezes over") isn't worth a dime if you're buying junk. Fast-buck dealers are usually hard-closing sales outfits with slick sales pitches. Avoid them and spend more time shopping. If it looks too good to be true—it probably is. Forewarned is forearmed, I hope.

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Code Questions and Answers

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

Understanding the *National Electrical Code* is not a simple task. If you are ever uncertain about what the code means, you should be safe and find out through one of the many resources available to you. As the *Code Corner* columnist for *Home Power* and through my work with Sandia National Laboratories, I receive many questions on code-related topics. I'm always happy to answer your questions. On a regular basis, I plan to share some of those questions and their answers in this column. Here are some recent questions I've received.

Are "Double-Taps" a Code Violation?

Q Is it a code violation to make "double-taps" (more than one wire) on circuit breakers or panel lugs in any application, but specifically in residential applications? If it is a violation, where is it located in the *NEC*?

I have purchased a house, and the electrical inspector stated that there could be no double-taps. I have been a construction electrician for 40-plus years and have made numerous double-taps when needed. Perhaps I have been wrong in doing so. My criteria in doing so were:

- Each wire size had to be correct for the breaker rating.
- The breaker had to have a termination that would handle more than one wire and not just be under the head of a screw.

There is a section in the code just for downsized wiretap rules. How are they to be accomplished if there are to be no double-taps?

In checking out Cutler-Hammer's Web site, they list the BR breaker that can only have one wire and the CH breaker that can have two wires. If both breaker terminations are setscrew types and have adequate room, why can't both breakers be rated for two wires? It seems to me the only concern is for a tight connection so that no heat is generated. Maybe I am wrong, so I would appreciate your input.

A *Double-tapping or double-lugging is a very common code violation, mainly because many people do not read all the markings and instructions that come on or with the product. Inspectors red-flag double-tapped or double-lugged connections nearly every day.*

Section 110.3(B) requires that all equipment be installed and used in the same manner in which it was listed and tested, following all instructions that accompany or are available for the product. Section 110.14(A) requires that terminals suitable for more than one conductor be so identified.

While you list good practices, these rules are not sufficient to ensure a long-lasting termination. A terminal listed for #14 to #2/0 (AWG) conductors has room for about ten or more #14 conductors. However, tests at UL and practical experiences throughout the country indicate that the terminal may not remain tight when more than one conductor of any size is used, unless that terminal is specifically tested and listed for use with more than one conductor. That information is found marked on the product (molded into or printed on circuit breakers), on the disconnect labels, in the instruction manuals for load centers, in the catalogs for some of the products, and on the cut sheets for other products.

A number of splicing devices are available that can connect two or more wires together. They include twist-on wire connectors, split bolts, insulated splicing blocks, bus bars, and others. All are available in any electrical supply house. These devices allow many conductors to be connected to a single breaker legally and in a code-compliant manner.

Physical space is not the criteria. Each conductor must stay connected through rigorous thermal cycling and mechanical pull tests. I have not seen the breakers that you mention, but I suspect that they have a square plate under the setscrew or some other clamping device that clamps both conductors equally to the breaker. The smaller Square D QO breakers have a similar feature.

For PV systems, which will be generating electricity for the next 50-plus years, the goal is that all connections meet code and do not come loose for those 50-plus years. Following the guidance and instructions supplied by the manufacturer and the code is the best way to ensure a safe and long-lasting connection.

Why Did I Fail My Inspection?

Q I recently installed a grid-tied 4,950-watt PV system. I failed the inspection allegedly because I ran the wires in the wall using a 1/2-inch EMT conduit. I read in your magazine that such type of conduit not only is allowed, but requested by the 2005 *National Electrical Code (NEC).* The inspector claims that it is not allowed by the 1999 *NEC* and that's the code New York State still uses. That was why he failed the installation and said that I must rerun the wire on the roof (rather than the attic and wall) in a PVC conduit. It seems to me he is really shooting from the hip. Can you help? Do you have any suggestions?

A *The 2005* NEC, *in Section 690.31(E), requires the use of a metallic raceway when PV source and output conductors are run inside a building prior to reaching the main PV disconnect. The code does not require that this routing be used since it is also possible to run the conductors in* *conduit down the outside of the building to the readily accessible disconnect required by 690.14.*

Editions of the NEC *prior to the 2005* NEC *did not have this provision for the use of metallic raceways inside the building, and all installations were required to keep the PV circuits outside the building until reaching the readily accessible disconnect described in 690.14. Section 690.14 was specifically written into the code by the NFPA in the 2002* NEC *because this language was not in previous editions of the code, which referred the installer back to Article 230. Essentially, until the 2005* NEC, *the DC PV circuits from the array had to be handled in a manner similar to AC service entrance circuits.*

Various states adopt the NEC *as the local state law when they get around to it. Some states adopt it automatically on January 1st of the year the new edition is issued. Others are way behind, like California, which just started using the 2002* NEC. *Others are even further behind, such as New York.*

The inspector is fully justified in using the code that is legally required in his jurisdiction. However, as the authority having jurisdiction (AHJ), he may apply whatever rules and requirements he feels are proper. Be friendly, it can go a long way toward establishing a positive relationship with your local inspector.

Inverters in Parallel

Q My question is about paralleling the outputs of two inverters (Fronius IG 4.0 KW) into one for a grid-tied application. Must I always use a dedicated subpanel for paralleling inverters together? I would rather not because of cost and space constraints, and because I will be using a fused AC disconnect to meet our utility's requirements and *NEC* requirements for overcurrent protection between the inverter output circuit and the grid. I would prefer to use a Burndy terminal adapter/connector (see photo) to combine the two inverter outputs together. I could be wrong, but I believe the code describes the use of certain connectors, such as twist-on wire connectors, which can be used for combining inverters.

A *The* National Electrical Code *does not allow the outputs of two or more inverters to be directly paralleled. Section 690.64(B)(1) requires that the output of each utility-interactive inverter be connected to a dedicated circuit breaker or fusible disconnect. The "dedicated" nature of this circuit and connection is to ensure that nothing else is connected to the output of the utility-interactive inverter, including loads and other inverters. The use of a dedicated circuit allows each inverter to be turned off independently for servicing, and prevents the possibility of anything being connected directly to the inverter output that might, under unusual circumstances, cause it to continue running after it was disconnected from the grid.*

After connecting the two inverters through the two dedicated overcurrent or disconnect devices, you may parallel the circuits in several ways using listed components for the task, such as the splicing connectors that you have indicated. However, you must apply the requirements of 690.64(B)(2) to all of the conductors involved in the splice. These requirements involve the rating of each of the dedicated overcurrent devices, the overcurrent device that feeds the combined output to the grid, and the size of each of the conductors.

It is usually simpler to just backfeed a couple of circuit breakers in a standard load center than to go through all of the above exercise. A properly selected load center will meet both 690.64(B)(1) and 690.64(B)(2) requirements in a single device that may be smaller than the two separate overcurrent devices (in their enclosures) and a splicing device in its enclosure. Once the requirements for separate disconnects for each inverter are met, the utility should allow combining the two sources into one utility disconnect.

Integrated Overcurrent Devices

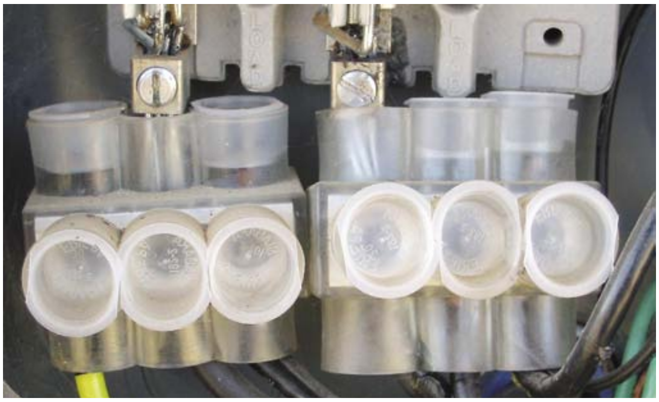
Q I have a question about paralleling inverters: It makes sense from a servicing perspective to have a dedicated overcurrent device for each inverter. However, many inverters nowadays come with these devices integrated into the inverter case (Fronius and Xantrex GT 3.0, for example). An overcurrent from the grid, backfeeding to the inverters, would be covered by the fused AC disconnect or breaker between the grid and the inverter, but a failure in one of the inverters could damage the other inverter (if they were parallel spliced—for lack of a better term—together). But with integrated overcurrent and disconnecting devices inside the inverters, it seems they should be self-protected…

I'm sure that I am missing something. And this probably gets into certification and testing agencies listing the internal devices and the equipment, and then this finding its way into the *NEC*, which I'm sure takes decades.

One more question—is it possible to use a terminal adapter (previously mentioned) to combine two combiner boxes and PV output circuits prior to landing them in an inverter DC disconnect?

A *An additional consideration is the requirement that the AC and DC disconnects for the inverter be available to service the inverters. Many inspectors will not accept the internal disconnects as meeting these disconnect requirements, since they may expose the unqualified person pulling the inverter for service to dangerous voltages. I am neutral on this subject, but many inspectors are not. Usually these disconnects must be in sight of the product being serviced. Also some inverters that do not have internal AC breakers, such as the Sunny Boy SB2500,*

The output of two inverters could be combined by using a splicing device such as this Burndy insulated power block—but only if you connect the inverter outputs to dedicated overcurrent devices or disconnects first.



require an external, dedicated overcurrent device to protect internal circuitry. If UL looked into this, many more inverters would probably require this external overcurrent device as part of the listing.

Yes, you can always parallel circuits, if each set of conductors is protected from faults from all sources or has ampacity greater than any possible fault currents. In the case of the outputs of two DC PV combiners, the cables should all be rated at 1.56 times the sum of the two short-circuit currents being fed to the inverter. This would be no different than the bus bar ratings in the output of a single, fused combiner, and some combiners are designed to facilitate such paralleling.

Questions or Comments?

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

Access

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2005 PV Power Systems and the NEC: Suggested Practices, a 143-page manual, can be downloaded from the SWTDI Web site • www.nmsu.edu/~tdi

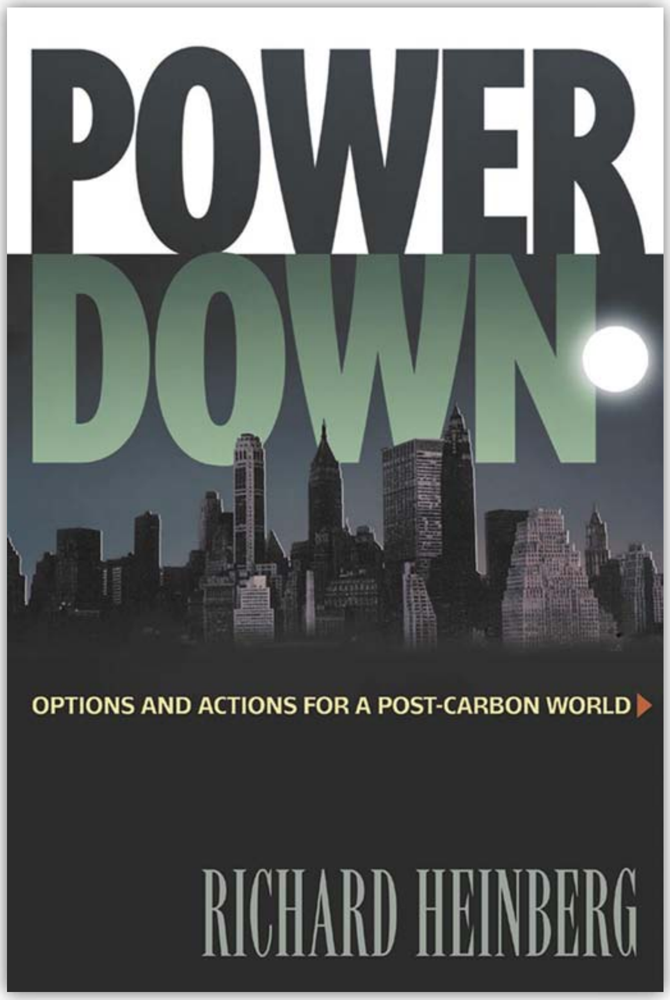
2008 *NEC* Proposals PDF • www.nmsu.edu/~tdi/pdf-resources/2008NECproposals2.pdf

Sponsor: Sandia National Laboratories, Ward Bower, Dept. 6218, MS 0753, Albuquerque, NM 87185 • 505-844-5206 • Fax: 505-844-6541 • wibower@sandia.gov • www.sandia.gov/pv

The 2005 *NEC* & the *NEC Handbook* are available from the NFPA, 11 Tracy Dr., Avon, MA 02322 • 800-344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301 • custserv@nfpa.org • www.nfpa.org

Powerdown: Options & Actions for a Post-Carbon World

by Richard Heinberg



Reviewed by Jennifer Barker

Although oil is only one of many available sources of energy, its importance rests in its dense energy-carrying capacity and portability. Everything we do and everything we consume is intertwined with oil. But two centuries of per capita growth in energy usage is about to come to an end, as the rate of oil extraction peaks and begins to slow.

According to New College of California Professor Richard Heinberg, author of *Powerdown: Options and Actions for a Post-Carbon World*, the imminence of "peak oil" is already affecting the economy we live in by causing increasingly uncontrollable energy price fluctuations. Since energy is embodied to some degree in everything we purchase, its price will ultimately affect all other prices of goods and services, as well as our ability to do work.

Resource peak theory has been well publicized in the past few years, both in books (*Twilight in the Desert* by Matthew Simmons and *Out of Gas: The End of the Age of Oil* by David Goodstein) and film (*The End of Suburbia*). Heinberg devotes the first chapter of *Powerdown* to providing evidence that we are perilously close to oil's peak, and that the implications are grave for the continuation of societies that rely on this resource too much.

He points out that modern societies depend heavily on supply-side solutions—when we need more energy under a supply-side scenario, we exploit existing resources more intensively or find new resources. But Heinberg notes that "supply-side solutions are always temporary, and sometimes counterproductive, resulting in spectacular population crashes in species that have momentarily benefited from them."

The remaining chapters of the book discuss four likely scenarios and our choices, as Heinberg sees them. Heinberg groups responses to the coming threat into four categories: "Last One Standing," warring over the world's remaining supply of oil; "Waiting for a Magic Elixir," hoping for the discovery and development of a new, inexpensive, unlimited source of energy; "Building Lifeboats," preserving knowledge and tools for producing your own energy, shelter, and food in a cohesive local community; and "Powerdown," Heinberg's term for cooperative political solutions, re-establishing local economies, reducing consumption, and re-using and repairing things.

Heinberg gives us compelling reasons to change our current course, and points the way. If you are not already thinking about how to deal with diminishing and increasingly expensive energy supplies, this book is a wake-up call to consider which thoughtful, well-directed actions might allow you to live a comfortable and fulfilling life in an uncertain world.

Access

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Powerdown: Options & Actions for a Post-Carbon World, by Richard Heinberg, 2004, Paperback, 288 pages, ISBN 0-86571-510-6, US$16.95 from New Society Publishers, PO Box 189, Gabriola Island, BC, Canada V0R 1X0 • 800-283-3572 or 250-247-9737 • Fax: 250-247-7471 • info@newsociety.com • www.newsociety.com

The Party's Over: Oil, War & the Fate of Industrial Societies, by Richard Heinberg, 2002, Paperback, 288 pages, ISBN 0-8657-482-7, US$17.95 from New Society Publishers (see above)

Killing & Saving

Solar Initiatives

Don Loweburg

California's Solar Initiative, Senate Bill 1 (SB1), which would have provided a ten-year funding commitment for solar-electric (photovoltaic; PV) systems and a transition to performance-based incentives, died in the California Assembly on September 8, 2005. In a classic cliff-hanger, the bill became mired in committee by partisan bickering, and perished on the eve of the last legislative session without a vote being taken.

As solar advocates, as a solar industry, and as citizens, we must ask, "How could this happen?" How could this happen in a state where more than 80 percent of voters support solar technologies? How could this happen at a time when all carbon fuels are experiencing price increases, and electricity costs are climbing? How could this happen in the face of the effects of global warming, and the possible connection to the devastation that resulted from this year's exceptionally severe hurricane season?

Electrical Interference

More than two years of collective work by PV manufacturers, installers, environmental groups, and solar advocates went into the bill. SB1, as initially proposed, was nonpartisan and endorsed by California Governor Schwarzenegger after being introduced in the California Senate by Democratic Senator Kevin Murray and Republican Senator John Campbell.

However, the International Brotherhood of Electrical Workers (IBEW) and the utilities lobbied for amendments in committee, and these three amendments ultimately disintegrated the broad support for SB1.

The first stipulation required all solar-electric installers to be electrical contractors. California currently allows for several license classes to install solar-electric systems, and the restrictive amendment would have disenfranchised more than 50 percent of those already installing systems.

The second amendment by the IBEW inserted language that called for "prevailing wage"—union scale work done by union members. The prevailing wage amendment cost the support of one of the authors, Republican Senator Campbell, and of Governor Schwarzenegger.

Bernadette Del Chiaro, speaking for Environment California, an environmental advocacy group supporting SB1, said this about its failure: "The bill was derailed when it reached its second-to-last stop, the Assembly Appropriations Committee, where three amendments were added to the bill after intense lobbying of two labor unions, the International Brotherhood of Electrical Workers and the State Building Trades Council."

The third fatal amendment came from the investor-owned utilities. They cut themselves in for 10 percent of the available funding (approximately US$200 million), and at the same time, decreased the proposed grid-connected PV limits under the program from 5 percent to 2.5 percent of total capacity. These changes were contrary to the very intention of SB1, which called for the cost-effective use of PV as distributed generation, and substantial increases in the amount of grid-connected PV. Utilities are known to favor central station generation—the *least* cost-effective way to use PV in a grid-connected system.

Major solar groups, such as California Solar Energy Industries Association (CALSEIA) and Americans for Solar PV (a recently formed PV manufacturers group), opposed SB1 as amended. In addition, many environmental groups that had been in support could no longer support the amended changes to SB1. On August 25, 2005, Senator Campbell, a co-author, removed his name from the bill and opposed it. Finally, two days before the end of the legislative session, Governor Schwarzenegger retracted his support of the amended bill.

At one level, it's easy to simply conclude that SB1 failed due to politics. Behind the scenes is a looming battle between the Republican Governor and the Democratic Legislature. And yes, the Governor antagonized several powerful California unions. However, the destruction of SB1 falls squarely on the regulated utilities and their union, the IBEW.

All Is Not Lost

Though California failed to establish a long-range PV program, the immediate future for PV remains positive. The current rebate program has sufficient funding for perhaps several more months, though this funding is limited to small systems (up to 30 KW). Large commercial systems continue to be unfunded.

But California's regulatory agencies, the California Public Utilities Commission (CPUC) and the California Energy Commission, may be able to accomplish what the political process failed to deliver. During the drafting of SB1, a parallel track of action was developed within the CPUC. This consisted of formal hearings and testimony that established the cost effectiveness of distributed PV, and the benefits for individual customers and for the entire electricity distribution system. Getting this information "on record" enables the public utility commissioners, who are enfranchised to act for the public good, to incorporate the cost of PV programs into the rate base and start a solar rebate program of their own.

Another avenue suggested is a ballot initiative, where Californians could cast their votes to support a statewide solar-electric program. With the high level of support for solar electricity in California and the rest of the United States, successful solar legislation is bound to arise again. The question is, "How difficult will the opposition make it?"

The lessons of SB1 pertain not only to California but to the rest of the United States too. With vested interests managing to defeat important bills, citizens must strongly advocate and act on their own behalf to support a sane renewable energy future.

Access

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History & details of the amendments that destroyed SB1 • www.leginfo.ca.gov/billinfo.html

REbuilding Energy Policy

Michael Welch

While I am appreciative for the small boost that renewable energy (RE) and energy efficiency will get from the new U.S. energy bill, it is still hard for me to swallow that we ended up with such a bad bill overall.

Many fine people and great organizations worked hard to make this bill a good one. But aside from a poor political climate for environmental issues, one reason it was allowed to pass was because portions of the RE industry signed off on the entire bill after obtaining all the tax incentives and other concessions that they could. This gave a lot of politicians the excuse they needed to vote for the bill.

Two years' worth of tax credits are not long enough to instill sufficient market certainty so that the RE industry can invest significantly in new manufacturing facilities. What our industry really needed was more like the decade-long incentives that some competing industries received. Credits for nuclear energy run all the way to 2020, and to 2015 for "clean coal"—both mature industries that should not need any subsidies at all. For an example of what can happen with inappropriate or short-term tax credits, see Chuck Marken's article on page 82.

It is interesting to note that many RE manufacturers are also heavily invested in competing technologies like nuclear or fossil fuels, which benefited much more significantly from this energy bill than RE. Keep in mind that all publicly traded corporations, whether involved in competing technologies or not, are largely bound by law and circumstance to maximize short-term profits instead of taking the long-term view of considering the environment along with profit. Without placing any blame, realize that the energy bill's passage was likely helped by the support of very powerful interests.

Regardless, let us celebrate and put to good use the few benefits that the RE industry got from the energy bill. We have two years to take advantage of the tax credits for putting renewable energy on our homes and businesses, so go out there and do it.

New Legislation

Even before the president inked his signature on the bill, sustainable energy interests were trying to figure out how to move forward on the energy front. It is too late to change overall policy, but we can and must continue working toward a renewable, sustainable energy future. It is going to be a long, hard haul, but at least some progress might be made by subsequent legislation—if we and our politicians have the political will to do so.

You can count on the many independent energy-related organizations to begin pushing for new legislation on the federal level. It is not entirely clear what their agendas will be, but I expect to see efforts continue on many of the things we didn't get from the energy bill, including:

- Mandated higher fuel economy standards for vehicles
- Increased support for mass transportation, including railroads
- A renewable electricity standard to increase sales of renewable electricity by major utilities
- A national net metering policy
- Increased incentives for higher efficiency in appliances, lighting, and industrial motors and controls
- Longer-term RE tax credits
- Increased funding for RE and energy efficiency budgets
- A permanent ban on drilling in the Arctic National Wildlife Refuge (ANWR)

But sustainable energy interests are not the only ones that are looking to change things since the energy bill passed. Some members of Congress have announced their intention to introduce legislation that would open ANWR to oil drilling, open previously untouched coastal waters to oil and gas drilling, and waive liability for the producers of the fuel additive MTBE that is polluting groundwater across the United States.

Start Gearing Up for Change

Sustainable energy groups will be spending as much effort fighting new regressive legislation as they spend supporting new legislation that promotes a sustainable energy future. And this is where you can come in, and our country's weaknesses revealed by this year's hurricane season may help us.

In *HP108*, I talked about working from both the top down and the bottom up. More and more, I am thinking that positive political change is going to come from the bottom up. We can no longer rely on the feds to do the right thing, even under tremendous pressure to do so. There is so much political money from the business sector that it is difficult to overcome. Yes, we need to support groups working on the national and international levels, but maybe we should

Energy Policy Bummers

Unfortunately, the bill passed by the Legislature and signed into law does the following harm and much more, according to Public Citizen:

- Repeals the vital Public Utility Holding Company Act (PUHCA). PUHCA prevents the massive consolidation of unregulated utility ownership and prohibits nonutilities—such as oil companies, investment banks, and foreign companies—from owning public utilities.
- Promotes a nuclear power relapse, giving the industry billions of dollars in subsidies and other incentives that could cost taxpayers more than US$13 billion.
- Federalizes the siting of liquefied natural gas (LNG) importation terminals, stripping states of the right to oppose such projects.
- Provides US$4.5 billion in tax breaks and more than US$7 billion in authorized subsidies to the fossil fuel industry, and eases environmental regulations for oil and gas drilling and refining.

The bill will not reduce global warming, our dependence on foreign oil, or gasoline prices.

start spending a greater percentage of our money and time working locally and regionally.

Some states are working toward laws that will increase the use of RE and decrease their state's contribution to greenhouse gases that contribute to global warming. According to two reports released by MaryPIRG, the Maryland Public Interest Research Group (see Access), states are in a position and already starting a trend toward local clean energy policies. MaryPIRG's press release about the two reports lists twenty states and their recent progress on state energy policy.

Hurricane Alley

Local education is key to encouraging statewide and local implementation of a reasonable energy policy. With the recent effects of this season's Gulf Coast hurricanes heavy on our minds, now is a good time to gently point out how much the warming of the oceans may be contributing to the intensity of hurricanes and other storms. And the (in part) energy-related causes of the tragedies this year are opening eyes and increasing the will to improve national energy policy. According to a September Associated Press article:

Just over a month after President Bush signed into law a massive energy bill, lawmakers are talking about the need for a second one. If it emerges from Congress, it will carry the stamp of Katrina and the vulnerabilities the storm exposed to the nation's energy system.

"Hurricane Katrina exposed the harsh reality that we have been skating on thin ice when it comes to this country's energy concentrations on the Gulf Coast," said Sen. Pete Domenici, R-N.M., chairman of the Senate Energy Committee and an architect of the energy legislation passed this summer.

Domenici, in an interview and an appearance Sunday on cable TV's C-SPAN channel, also said that the Gulf disaster and the skyrocketing gasoline costs it unleashed has made it clear that more needs to be done to reduce energy use. That includes requiring automakers to significantly increase the fuel economy of their fleets, he said.

The hurricane was "a serious wake-up call that we have to do something both on the supply side and the conservation side" that before was politically impossible, Domenici said. He added that he is a convert to increasing auto fuel economy standards after first believing it should be left to the marketplace.

Future hurricanes are going to rival the intensity of Katrina, and are going to help us achieve our goals. Headlines such as "The Storm Next Time" (*New York Times*), "Katrina Fuels Global Warming Storm" (Reuters), and "Global Warming Called Insurance Peril" (*Sacramento Bee*) are going to help us out.

Make a Difference

There are plenty of other reasons to learn about and undertake improving national energy policy. Most have existed long before the 2005 hurricane disaster. For example, citizens need to find out how coal mining is stripping away entire mountains in the Southeast, and how coal burning is contributing to acid rain, global warming, and children's health problems. Citizens need to understand that there really is no good answer to our nuclear waste problem, which will likely be increased by the Energy Policy Act when implemented.

So once again, I ask you to start helping organizations working and educating toward a sustainable energy future, especially the local ones. Write letters to the editor, and organize and attend local meetings to talk about energy policy. And on the federal level, support the groups that are trying to keep the special interests from hijacking energy policy—including those interests that are involved in RE as a sideline.

Most of all, do not lose faith that you can make a difference. Let's get busy now to capitalize on this building momentum, in hopes of creating a sustainable energy future, and keeping the future effects of global warming at a level we can all live with.

Access

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Maryland Public Interest Research Group, 3121 St. Paul St., Ste. 26, Baltimore, MD 21218 • 410-467-0439 • info@marypirg.org • www.marypirg.org • Free download of two papers on states' sustainable energy trends: *Achieving a New Energy Future: How States Can Lead America to a Clean, Sustainable Economy*, and *Making Sense of America's Oil Needs: A Sustainable, State-Based Response to Dwindling Oil Supplies*

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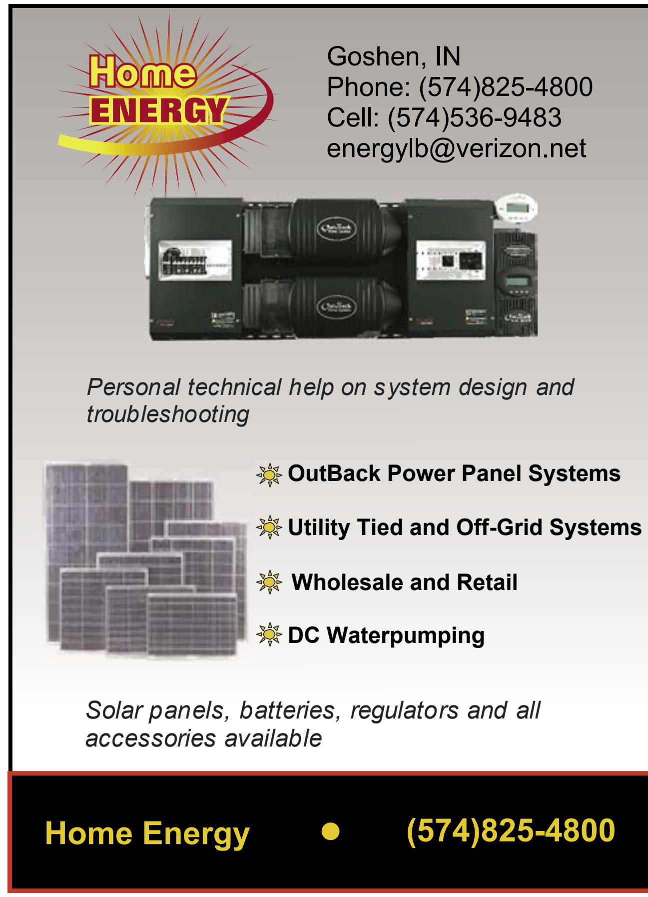
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AC Receptacle & Plug—
Safe Connectors

Ian Woofenden

Derivation: From Latin receptaculum, *place to receive and store things.*

We get electricity from a utility, an engine generator, a solar-electric array, a wind generator, or a hydro turbine. The energy is carried to a home's distribution panel, and to the individual appliances via commonplace wiring. At this point, we need a safe, convenient, and effective means to connect and disconnect our appliances to and from the circuit wiring. The same basic method has served this purpose for more than a century—the plug and socket.

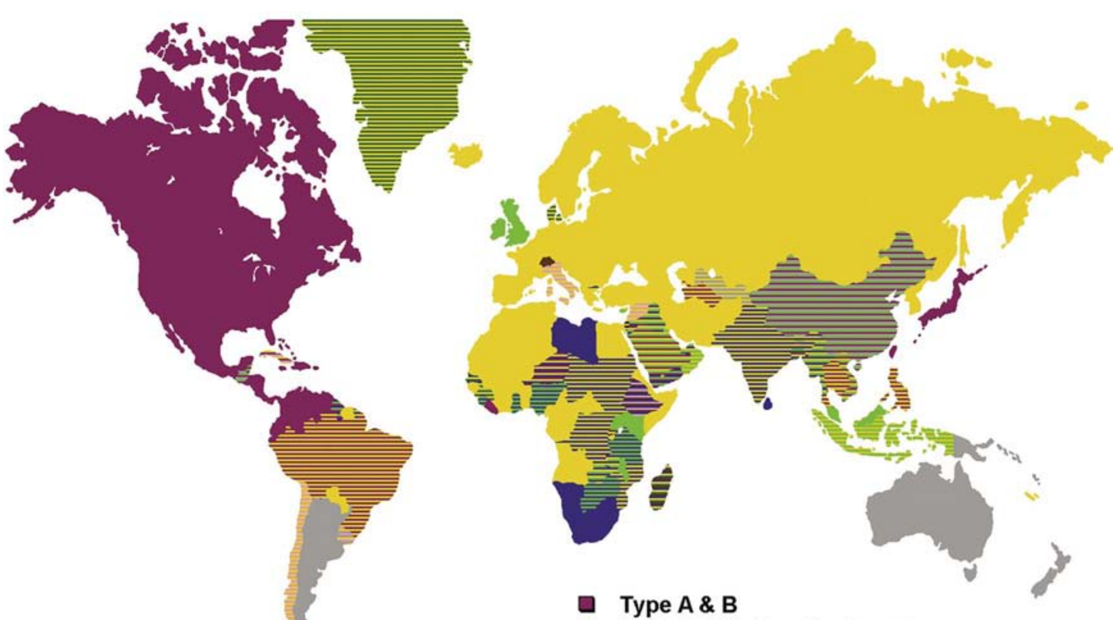
When electricity was first used in homes for operating lights, they were "hard-wired" (not easily disconnected). But as electrical appliances became available, a better connection arrangement was needed. In 1904, Harvey Hubbell (who also invented the pull-chain light socket) developed the first electrical plug and socket. The two-prong plug and socket that we still see on occasion in older homes came into use in the 1920s. Later, a third wire and terminal was added to circuits to allow the equipment to be grounded (or "earthed"), so it won't be "hot" in the case of a wiring fault.

Specific receptacles and plugs are used to prevent plugging into the wrong voltage source. Even high voltage electrical connections can be made with relative safety. The "hot" (electrified) terminals of the receptacle are encased in a plastic housing, with only small slots and holes exposed. By the time the plug contacts the live terminals, most of its metal is no longer exposed. So unless you actually try to get shocked or are careless, it is not likely to happen.

Here in the United States, we take our AC receptacle style for granted—it is "normal" to us. But a wide variety of AC electrical socket configurations are used around the world. See the map and socket diagrams for the variations, and the locations where they are used. The Web site listed below the map provides more information on specific receptacles.

No universal standard has been adopted for AC receptacles. This can be confusing when you travel to different countries, especially in regions that use more than one style of receptacle. But it also is fascinating to see the diversity of configurations that serve the same purpose. It's

AC Receptacles 'Round the World



Courtesy of Conrad McGregor • http://users.pandora.be/worldstandards/electricity.htm a demonstration of human inventiveness, and the different ways we solve problems.

Whatever the receptacle configuration, the goal is the same—allowing you to easily and safely plug in the appliances you want to use, where you want to use them.

Access

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The Wrench's Wife

Kathleen Jarschke-Schultze

Why is it that things always go wrong when my spouse Bob-O is gone? Could this be some sort of cosmic test? Must I prove that I am no longer "marginally mountain," as Bob-O claimed my first year here?

Home Alone

It has been a busy year for our renewable energy installation business, and Bob-O is rarely home during daylight hours. One particular job took him away for three days a week, for several weeks in a row.

One morning, just after Bob-O left for his three days away, I began to prepare myself for the day. Once I get Bob-O out the door, I can concentrate on myself. I finished my coffee, and went to the bathroom to brush and braid my hair.

Kathleen, Inverter Ace—Note the floral-handled multi-tool on the worktable. Bob-O never borrows this one.

As I stood at the mirror, I heard a funny noise. I listened to the faucet. I listened to the toilet and to the shower. The sound seemed to be coming from the floor. I went downstairs into our half basement and dragged a chair over to my Sun Frost F10 freezer. I climbed onto the chair, removed the crawl-space hatch door, and set it on top of the F10. Then I crawled on top of the freezer to check out the crawl space.

That's Not Funny

Water was spraying everywhere. It took me a second to find the source—a valve in the bathroom plumbing. Obviously, it had been leaking for a long time. The dirt under the house was an adobe mire. I found a piece of cardboard, threw it on the mud, and climbed in. I tried turning the valve handle, and the water spray lessened a little. I went upstairs and got an adjustable wrench. I crawled back under the house and tried to tighten the valve.

The water spray intensified, and I was instantly drenched. I felt like Lucille Ball (from TV's *I Love Lucy*). I crawled out and found the shut-off valve for the house, turning off the water as much as I could. I got a garden hose, and putting it on the lowest hose bib in the system, turned it on and let the water run downhill towards the creek.

Friend In Deed

This stopped the water from spraying under the house. I came upstairs and called Friend. You remember Friend; he put the roof on the Chicken House of Mystery (*HP101*). Friend arrived about 35 minutes later. Friend knows plumbing. He can solder and sweat pipes, and do all kinds of things I would not ever attempt.

We rummaged around in Bob-O's shop. Between what we found there and what he had thought to bring, we were able to repair the leak. Apparently the valve had frozen last winter, which weakened it. I don't know how long it had been quietly leaking, but we surmise it was a long time.

Now What?

While Bob-O was still gone on this big job, out of cell phone range, the next thing that happened was that the power shut off. I rushed down to the warehouse and grabbed an OutBack Mate control meter so I could check on the status of the inverters. Back at the house, I went to the basement and plugged the Mate into our OutBack system. Then I called

OutBack on the portable phone. (Not before I automatically flipped on the light switch so I could see to dial. No lights, of course.) I got engineer boB Gudgel on the phone. He ran me through the program to start the inverter again. He asked me to call if it happened again so we could find the error message.

A couple of weeks later (yes, Bob-O was gone), it happened again. I called OutBack again and boB gave me directions to run a diagnostic test, during which we found an "overtemp" error on the slave. With our two stacked FX2024s, one is designated as the master and the other one is the slave.

The upshot is we discovered that our inverters were older beta models that Bob-O had field-tested (I found the very early serial number of FX00018 on one), and our firmware revisions were also old. I was given the choice of sending the slave in for a board change or doing it myself.

Kathleen, Inverter Ace

"Send me instructions to follow and I will do it," I said confidently. Didn't I change out a dented MX60 controller cover with complete success? This, I felt, was well within my purview.

Bob-O came home. "Great," he said, "But I'll have to take it off the wall for you." I began to lose my feeling of autonomy. Then as I explained the diagnostic procedures and findings, Bob-O revealed to me that the master was really the slave and the slave was really the master.

Bob-O reprogrammed the FXs so that the master was on top. We figured out that the power went off whenever the slave inverter had to come on—like when I was using the dishwasher, the washing machine, or the dryer, and also microwaving some leftovers for lunch. That shut everything down, all right. By then, I had been schooled on how to turn the inverters back on, so I wasn't without power for long that time.

We decided I would change out the boards on the FX that had the oldest firmware. OutBack sent the boards, but it took several weekends before Bob-O and I were both free to work on this project. I set up a worktable in the basement. Bob-O took the slave off the wall and put it on my worktable. I got out the printed instructions and the boards. I am grateful there were pictures. It was all very straightforward.

No Static, Please

The directions contained dire warnings about the possibility of a static charge buildup in your clothes destroying the boards. That gave me pause. Apparently the safest way to work on the unit was to stand naked in a mud puddle. This is straight from the instructions. The other method, and the one I chose, was to wear all-cotton clothes and touch a water pipe to drain my static buildup. As I worked on the unit, I would occasionally walk over to the sink by the washer and touch the faucet.

Bob-O came to see how I was doing. He had on a fleece shirt. "Don't touch that," I said, "You're all static-ee." He said not to worry; he had touched a ground. I told him what I had been doing. Apparently this was wrong because I could build up static on my walk back from touching the faucet. So I stayed where I was after that.

Up Against the Walls

Everything went very smoothly until we tried to heave the revamped inverter up onto the wall mount. It is very heavy. Being the slave, it was a close fit underneath the master FX.

We had tested the unit before reattaching it to the wall. When it was back on the wall, the error light would not go off, and we couldn't find an error code using the Mate. Back off the wall it came. I took it apart, a lot quicker this time, and checked to make sure I hadn't pinched a wire, left the fan unplugged, or some other obvious thing. I had not. We bench-tested again. The error light came on, but then went off.

We wrangled it back onto the wall again. Bob-O programmed it to be the slave of the duo. We watched and waited—no red error light. I was victorious!

Techno Kathleen

What I have realized out of this experience is that I can't be nontechnical any longer. Sure, I know how to live with renewable energy, but I need to get past my less than rudimentary knowledge of electricity. I've been threatening to take Solar Energy International's Women's PV class this spring. Now that would be high adventure! But, what will happen to Bob-O while I'm gone?

Access

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letters *to HP*

Not There Yet?

Hello, The following quote from President Bush prompted me to write this letter while listening to my stereo hooked to the "unit of the future" he describes. I am not a time traveler but a citizen who wishes our domestic RE industry could garner even a fraction of the support oil and nuclear industries receive.

I had an interesting opportunity to go see some research and development being done on solar energy. I'm convinced, someday in the relative near future we'll be able to have units on our houses that will be able to power electronics within our houses, and hopefully, with excess energy, be able to feed them back in the system. That's possible. We're not there yet, but it's coming.

—President George W. Bush,
October 4, 2005, Rose Garden Press Conference

I really enjoy the magazine as it continues to improve issue to issue. Despite my battles here in Boulder, Colorado, with the building department over electrical systems, tower heights, and other nonsense, I'm very proud to run my house and editing studio "electronics" off of twelve domestically produced PV panels (my wind turbine should be installed next spring)!

I have to recommend a *Home Power* subscription to the White House so they can keep up on what's happening, because I really wonder where their RE information comes from (the 1960s?). Obviously, nobody around the President reads your fine publication.

Keep up the important work! Regards, Eric A.

Thanks for the encouraging words, Eric. Needless to say, Home Power *hasn't reached everyone quite yet. In fact, the White House grounds were outfitted with a 9 KW solar-electric array in September 2002. With that in mind, however, the President's misunderstanding reminds me of one of the more satisfying aspects of the renewable energy movement—it's growing from the grass roots on up, rather than the other way. On behalf of* Home Power, *a huge thanks to you and all of the countless, happy end users of solar electricity who've chosen to make one person's "relative near future" their present. We're sending a complimentary subscription to the White House. Scott Russell • scott.russell@homepower.com*

Grounding Perspective

After reviewing the pole mount installation article in HP109, Code Corner *columnist John Wiles had the following suggestions related to system grounding:*

- *Many ground terminals are not listed for the termination of multiple ground wires. If this is the case, multiple ground wires should be bonded together with connectors approved for that purpose, and a single conductor should be terminated at the ground lug.*

- *UL has in the past concluded that star washers are generally not suitable for breaking down and preventing reoxidation of the film on aluminum module frames. Tin-plated copper lay-in lugs installed flat against the module frame will likely provide the best ground connection over time, and better resist the possibility of galvanic corrosion compared to solid copper lugs.*

Solar Woodshop?

I am planning to construct a 16- by 20-foot workshop for light woodworking projects. I am curious as to the limitations solar electricity has to service this type of structure. Electrical requirements would include lighting, tools (table saw, router, sander), and possibly occasional air conditioning. I have just completed a subscription form to your magazine, and would appreciate any support information you can provide me on my workshop endeavor. If this type of project was ever discussed in any past editions, could you please identify for me that edition? Thank you, Charlie Hensel • cjhensel@charter.net

Hi Charlie, I can think of no limitations. Designing a PV system for a workshop is just like sizing any other system. You start by either estimating or measuring your daily usage, and then size the PV array, battery, and inverter to meet that.

When designing your shop electrical system, here are a few things to keep in mind. First, many power tools have high surge requirements. For example, your table saw may draw four of five times as much power during start-up compared to when it's running. Make sure that the inverter you choose for the system has high enough surge capacity to effectively start any power tools you'll have in the shop. Second, air conditioning is a substantial electrical load. The need for air conditioning is typically during the summer months when there is usually a lot of sunshine, so small, room-sized air conditioners can often be run without much trouble. Finally, in most personal workshops, more than one tool is rarely used at a time, which means it may be easier and cheaper to meet your needs with a solar-electric system than a home that has multiple occupants and cycling loads.

Another suggestion—before you build your workshop, site it so you'll have a south-facing roof with good solar access. That way your system designer will have an excellent starting place when time comes. This sounds like a great project—best of luck. Michael Welch • michael.welch@homepower.com

Shading Kills Output

Mark Byington did some good work in his "Bypass Diodes" article in *HP107*, but unfortunately he also perpetuated a myth spread by RE foes that PVs "don't work" when shaded or under cloudy skies. In his tests, Mark didn't shade cells, he *covered* them so that they were in the dark. In shade, there is light (you can still see—right?), and the cells make electricity, just less of it. The shaded cells are not completely disabled as in Mark's tests. Raining Sky, Houston, Texas

Hello Raining Sky, A covered PV module produces about the same energy as a module in full shade—little to none. Here are *some measurements from a Daystar insolation meter to illustrate the point, measured at noon on July 27, 2005, in Los Altos, California:*

Full sun: 1,178 watts per square meter
Full shade: 33 watts per square meter
Daystar sensor covered: 0 watts per square meter

As shown in the measurements, the meter is measuring about 97 percent electricity reduction in full shade. Mottled or partial shade will produce results in between full sun and full shade. Regards, Mark Byington • markb@cobaltpower.com

Outhouse Solar Lights

I have an awesome stylish and comfortable (all my neighbors are jealous) single-seat outhouse in the Adirondack Mountains of New York. I was exploring lighting options—handheld flashlight, LED lantern, gas lantern. All had serious drawbacks: flashlight—hard to hold and read *HP* back issues; LED lantern—too dim to read *HP* back issues; gas lantern—too hot, noisy, and wasteful.

Then it hit me—solar lawn lights. Intermatic Inc. makes a three-floodlight kit with a separate PV module and attached NiMH AA battery charger that includes rechargeable batteries. The lights come with plenty of cord and each has a separate plug on the module. The lights have an option of a lawn spike or a two-screw "deck" mount. I mounted the three adjustable-angle mini-floodlights to the ceiling, neatly stapling the wire down to a small project box that has three automotive toggle switches (all from Radio Shack). Keeping the polarity in order, I then ran the remaining wire up and out a small hole under the eave of the tin roof to the module.

The circuit of the controller on the module only allows electricity to flow at night. So I suppose the switches could be eliminated and the lights left on all night. I wanted to have relatively full batteries when I turned on the lights, so I added the switches. Total costs were US$40 for the light kit, US$15 for the switches and box, and US$2 for the copper-coated adjustable pipe hanger to mount the module. The total was US$77 and the neighbors almost fainted. Soon no one will want flush toilets! Peace, Dean Russell • sunelectric@vdot.net

Grid-Tied?

I read the article on the Good Life Center in *HP108* where the caretakers said that they'd eventually like to generate all of their own electricity and disconnect from the grid. If they are meeting all of their needs, aren't they generating more than they need at times? If they stay attached to the grid, this extra would mean the utility would need to use less nuclear and coal power and they'd pollute less. Also the grid would then be available as an emergency backup generator, and it pollutes less than any small generator. David Darnell • dtd@sirresearch.com

Hi David, All that seems true, but we made an error in our terminology within that article that might have misled you, and we did not catch it before print. The Good Life center is not "grid-tied" in that they do not do sell back electricity, and the particular inverter they use is not capable of it. It only uses the grid as backup when the batteries get low. For true grid-tie, they would need a battery-based inverter that specifically does intertie, and those inverters are available at a somewhat higher price.

There are some costs associated with staying tied to the utility in the form of a monthly minimum bill. Going off-grid would eliminate those costs. Also, there is personal preference. It is important to some folks to be independent of the utility. You're correct that with their system they are wasting energy once the batteries are full, and sending the excess energy out to the grid would be a more efficient use of those solar-electric panels. Michael Welch • michael.welch@homepower.com

Rainwater Collection

Michael Durland, I enjoyed your article in *Home Power.* It is exciting to see others harvesting rainwater! Every drop of water we use in our home comes from harvested rainwater. I catch water from my metal roof in gutters protected by leaf guards. Half of my roof water is directed to one downspout and the other half flows to another. From there the water flows into a roof washer, which I made simply from a length of 4-inch PVC for each downspout, with a 1-inch ball valve on the bottom and a sweep "T" on the top. After the washer is full, the water flows directly into a series of polyethylene tanks.

Each tank is 1,800 gallons in capacity and there are three tanks. One roof washer feeds one tank, the other roof washer feeds the other, and I pump water from the third with a Dankoff booster pump, after it has passed through a 10-micron filter. After entering a pressure tank, that is the water that is used for the low-flush toilet, shower, clothes washer, and washing dishes. I have water filters installed at the kitchen sink and at the bathroom. They filter sediment, bacteria, and cysts, and the one in the kitchen additionally filters for chemicals.

Since February of this year, when I began metering the flow of water usage in our house, my family of four (two adults and two children) has averaged 48 gallons of water a day. That is only 12 gallons a person for flushing into our composting toilet, washing clothes and dishes, cooking, and bathing! Since June of this year, our household has used 3,562 gallons of water while harvesting 17,943 gallons from our roof!

Besides writing you to share my positive experience using rainwater, I am writing you to ask some questions. For some time I have desired to have my water tested, to ensure that it is safe to use and drink. You agree, as you state in your article, "To be safe, always test your harvested rainwater before using it in your home or garden." Where do you recommend getting such testing? So far, all I have been able to find is some very inexpensive and yet not very informative testing, or testing services that let you specify for each item you want tested. There is a plethora, and if you were to choose each one, it would total in the thousands of dollars.

What is your opinion on the filtration system I am using? Should I add UV? How much would that cost, and where could I get it? Rainwater is, as you say, distilled. But is it not possible for it to pick up pollutants as it falls? And does rain not form as a result of dust particles in the air, which could consist of pollutants? Thanks, Shawn Swartz, Earthaven Ecovillage • shawncs@bellsouth.net

Shawn, It sounds like you are doing a good job of catching, filtering, and using rainwater. Rainwater does collect pollutants as it falls, and rain will wash pollutants and bacteria off the roof. The county regulations where I live are very strict about using untreated rainwater for household use. If you are just using filters (not recommended), you should filter down to 0.5 micron because this is what it takes to remove cysts. Filtering alone will not remove bacteria. Water can be treated with chlorine, ozone, or ultraviolet (UV) light . If treating with an ultraviolet light, a 5-micron filter can be used. I use two large sediment filters down to 1 micron and then a 5-micron carbon filter.

I would definitely recommend using an ultraviolet light to remove all the bacteria from the water. There are several UV units on the market. I use only NSF (National Sanitation Foundation) approved units with light transmittance sensors and automatic water shutoffs. This will ensure that only treated water flows to the house in case the power fails, the lights go out, or the light transmittance is too poor for the UV light to do its job. The NSF approved units usually come with a manual bypass valve, so in an emergency situation untreated water can still be allowed to flow. The units without a sensor and automatic water shut-off will continue to pass water through even though the water is not being treated properly. I have used several different UV units and am currently using the UV Pure unit from Hallet. It is a well-engineered product. One of the things I like about it is that the two lightbulbs are outside the water stream, so changing bulbs is a snap. The list price for this UV system is almost US$2,000.

Testing your water is a valid concern. I use a local laboratory that will do basic bacteria testing for US$18 and a full inorganic test for US$290. At the very least, you should get a bacteria test done on the water. This will test for the presence of coliform bacteria, including E. coli. The time your water is in transit to the lab is a concern, so find a lab close by. If you are using a galvanized roof, you could test for zinc and if using asphalt shingles you should test for petroleum products. I hope I have answered your questions. Feel free to e-mail me with any other concerns or questions. Michael Durland, PurRain Watertanks, Deer Harbor, Washington • michaeld@rockisland.com

Cooling

Hello all, I read with interest the article titled "Be Cool" in *HP108* and have a couple of comments. We built our house using some of the ideas for keeping a cool space in summer heat, and implementation of the ideas we missed will not come soon (new roofing materials for example, or new windows). In the meantime, our summers in northern lower Michigan have grown generally warmer over the past several years. We are using an idea from our experience in southern heat, mentioned but not emphasized in the article. It claims that closing the house up after a cool night works in dry climates with a 30-degree difference between day and night temperatures. Our place a mile away from Lake Michigan assures us of high humidity, and temperature swings are often far less than optimal. But we learned in the humid South that it still helps to close up the house in the day, especially if, as we usually experience here, the hot spells are only a few days long. In the morning, as soon as we notice that the outside has gotten warmer than the house, we close it up tight. It feels like coming into an air-conditioned space when we come back in at noon.

We also have added a DC vent fan high in the ceiling (venting to the outside), which is less effective than hoped (it is on a timer, so we can run it for several hours in the late evening) and a muffin-type equipment-cooling fan (also 12 VDC), which is surprisingly effective. We set it to blow right onto us at night, and it is quiet, "white" sound with a tiny energy draw. You can find these at Radio Shack, but lots cheaper at a distributor like Hosfelt Electronics (www.hosfelt.com). As always, a great issue—thanks for consistently good articles! Jim Sluyter • csafarm@jackpine.net

Code Frustration

Hi *HP*, I have been a subscriber for the last seven years. I installed 1 KW of PV on the roof about five years ago and have been running guerilla since then. I also have two roof-mounted solar hot water panels, which have been in service for the last two years. I am planning to permit the existing system at the same time as the new equipment.

The new installation will be two trackers each with 3 KW of PV for 7 KW total. So following the manufacturers' instructions and numerous *Home Power* articles, I designed the electrical system taking into consideration ampacity, conduit fill, and required derating. I included the utility-provided second meter, as well as AC and DC disconnects. This is where the fun stopped due to unreasonable and expensive building department requirements for engineering stamps for the foundation design, soil study, and electrical system.

The building official explained that adding another outlet to an existing structure is "prescribed" by the 2002 *NEC* and doesn't require an electrical engineer stamp. So my question for you is, does the *NEC* "prescribe" adding a utility-intertie inverter, second solar utility meter, and all the other required safety stuff? If so, where? Or is it customary to jump through all these hoops?

As to foundation design for the trackers, Wattsun runs a spreadsheet when provided with the "lateral soil bearing pressure" from a boring. I have ordered a soil boring for the determination of the soil bearing pressure at US$600 cost. The city then wants an Arizona engineer's stamp for Wattsun's foundation design before it will approve a permit. For the existing equipment, a structural engineer must review and sign off on the garage roof truss calculations to certify that they will bear the weight of the eight 120 W PV panels and two hot water panels. Do you have any recommendation on how I could save the thousands of dollars in studies and engineering reports, and get this RE system producing? Name Withheld

Hi, I can tell you the engineering story on our Wattsun tracker installation. Wattsun recommends a 3-foot-diameter cylindrical hole bored 7 feet deep in their generic engineered tracker plans. In our location, there was simply no way to get the equipment *needed onto our site's wet and heavy clay soils unless we wanted the truck to be a semipermanent installation in our field until the dry season. We needed to dig our foundation by shovel so we could get started on the foundation in the winter. And because we knew we would hit a hardpan about 4 feet below the ground, we needed an alternate set of plans. The first engineer we talked with wanted US$2,000. We took it to another engineer down the street who charged us US$600.*

The county wanted us to have the engineering calculations cover 80 mph wind loads. All we needed to tell our engineer was that we have heavy clay soils (I'm guessing that they already have the soil bearing pressures calculated for our area), the height of the pole, the area of the array, and the weights involved, and he was able to do the calculations, complete with a drawing. We needed a 4- by 4- by 4-foot hole with rebar reinforcement on 1-foot grids and four, 1-inch J-bolts with a 30-inch embedment for bolting Wattsun's flanged pole.

The foundation for the tracker and the concrete pour were the biggest hurdles for our project. The rest took no more than two weeks (including 200+ feet of trenching) while working at a very casual pace. My advice is to shop for a quote from several engineers, and do as much of the legwork as possible by providing your engineer with data sheets and installation manuals so that he or she understands the project quickly without a lot of study time or research. Good luck. Linda Pinkham • linda.pinkham@homepower.com

Hello, You are not alone in your efforts to get a PV system installed where the permitting and inspection officials require all of the "I"s dotted and the "T"s crossed. I hear these stories on a regular basis from people in various parts of the country.

I am in the process of designing and building my retirement home and will be doing most of the construction, including plumbing, HVAC, and electrical, myself. As is my current home, it will more than likely be off grid, with a possible grid backup rather than a generator. Even here in the wild and wooly Southwest, I have to get engineers' stamps, apply for permits, and get inspections. Being an electrical engineer doesn't carry any weight with the local inspectors or the local regulations.

How do I work with the local inspectors? I treat them like people who know what they are doing and who are only trying to comply with various national and local codes and regulations established by others. I find that in many areas, they know far more than I do. If I do my homework and study the codes and handbooks that they suggest, they are willing to spend hours answering my beginner questions.

So, I have plumbing codes and handbooks, residential building codes and handbooks, fuel gas codes and handbooks, HVAC software, the NEC Handbook, *all New Mexico codes, plus numerous books on these subjects written by the pros in each field.*

The inspectors and I have had some very good discussions. One of their most frequent complaints is about plumbers and electricians who finish a project before taking out a permit and getting the necessary progress inspections. I would not be surprised if your guerilla PV system might be viewed the same way by your inspectors.

Over the years, many, many people have been killed by falling roofs and nearly all building codes for residential construction now require that roofing trusses be designed by a firm that will have a professional engineer stamp the plans. Of course, the local truss builder uses truss design software provided by the company who has the professional engineer who stamps the final plans. Since there are few "listed" residential roofing systems, this is the only way to ensure public safety.

A PV module and mounting rack may add up to 4 pounds per square foot to the dead load of a roof. This can represent a 40 percent increase in the design load for trusses in the Southwest—not an insignificant amount. A 40-gallon integrated-storage hot water collector can add nearly 500 pounds over a 32-square-foot area or less for a 15-pound-per-square-foot increase in the loading. Either of these could result in structural failure of an existing roof, especially during heavy seasonal rains and winds. I think it would be in your best interests to get an engineering assessment of the roofing trusses supporting your systems. The inspectors have no way of knowing that you may be using fly-weight PV modules and racks, and low-volume solar hot water collectors.

To get some inspector understanding on the electrical PV system, you might work with a local electrician. You could also download all of the "Perspectives on PV" articles that I have written for the International Association of Electrical Inspectors News *from the Web site (www.iaei.org) and give them to the local inspectors. These articles will bring the inspectors up to speed on PV systems and the code requirements for such systems. You can find the new* Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices *manual at www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html.*

A neat, detailed diagram showing all of your system, plus the code calculations and how your system meets the NEC *Article 690 PV requirements should be of help in showing the inspectors that yes, PV systems are included in the* NEC, *just like receptacle outlets.*

Many PV installers around the country routinely supply detailed diagrams and calculations to the inspectors before they start any work. In more than a few cases, the inspectors welcome the information, do some studying themselves, and make positive recommendations. Good luck. John Wiles • jwiles@nmsu.edu

Heat Pumps & Cooling

I live in Texas and plan to build a home in the next several years. Although your magazine has helped me with planning how to orient the house, and the types of windows and insulation to use, I still have not found an alternative for cooling in the *hot* Texas summers. Our summers are far too hot and humid to use evaporative cooling. I looked into solar heat absorption air conditioning units only to find them to be far too large for a single-family home. Geothermal heat pumps seem like the best option so far, but still need substantial power to run the compressor, pump, and fan motor. Am I missing anything? Christopher Deines • cdeines@satx.rr.com

Hi Christopher, You aren't missing anything. Ground-coupled (aka geothermal) heat pumps are the most efficient way to cool (and heat) your home using electricity. If you have a grid-tied PV system, then most (if not all) of the electricity consumption can be offset by sunshine.

Having said this, please pay very special attention to the thermal details of the home. Adding extra insulation (use at least R-40 in the walls and R-60 in the roof) really pays off. Sheath the home (outside of the studs and their R-16 insulation) with 2 inches of rigid foam (4- by 8-foot sheets). We've done this and it works very well. Pay special attention to windows, doors, and any place where air infiltration is present. Good luck and stay cool. Richard Perez • richard.perez@homepower.com

Change the Status Quo

I've just discovered *Home Power*, and am really impressed by all the information available in it. It truly is a gold mine of RE information. Although I can understand the magazine, I don't really see myself putting a plan into action anytime soon. Unfortunately, my background is not at all electrical or technical (I'm a cellist in the opera orchestra) and I have big RE pipe dreams.

I live in a rather large condo complex in West Palm Beach, Florida. Our parking garage is about the size of two football fields and I'm thinking it is perfect for a grid-tied PV system on top. I've gotten some information from Shell Solar in Boca Raton, but really don't know how to approach such a project. Do you know anyone that would be willing to help me come up with a rough plan for my condo owners' board?

After looking through DSIRE (Database of State Incentives for Renewable Energy; www.dsireusa.org), I get the feeling that the RE movement has a much better foothold in the Northwest and I would like to help change that. Sincerely, Benjamin Salsbury, West Palm Beach, Florida • benahm@earthlink.net

Hi Benjamin, It seems like you have a great site, and your idea is a good one. I've seen parking structures used for PV systems before, like the solar carport installed by Sacred Power at the Indian Pueblo Cultural Center in Albuquerque, New Mexico. I hope someone in your area sees your letter and helps you convince the condo owners' board that this will be a worthwhile and cost-effective project. Linda Pinkham • linda.pinkham@homepower.com

Overcurrent Protection

Dear Editor, Batteries are still dangerous. With more and more utility-interactive PV systems being installed, I see a dangerous trend evolving where stand-alone or utility-interactive systems with batteries have been installed.

The energy storage batteries in PV systems can deliver far higher current than almost any wire can withstand. If there is no appropriately rated overcurrent protection in a conductor between the battery and some device (charge controller, load, etc.), that conductor may be destroyed (and possibly start a fire) if it develops a short circuit. Short circuits happen when terminals get loose and wires contact nearby wires, or when insulation fails due to mishandling or improper installation. Please note that the rating of the overcurrent device must be consistent with the conductor ampacity. A 250-amp circuit breaker will not protect a #6 conductor. Devices connected to batteries should also have a means of disconnect, not only for installation and routine maintenance, but also to allow them to be quickly disconnected should an internal failure occur.

Please install safe RE systems with appropriately rated and located overcurrent devices on those circuits connected to batteries. The life and home you save may be yours or someone else's. John Wiles • jwiles@nmsu.edu

New to the Crew

Home Power *would like to welcome Kim Bowker and Jacie Gray to the crew.*

Kim is working with Connie Said in advertising sales and program development. She graduated from the Jordan Energy Institute in 1996 with a degree in Applied Environmental Technology. After graduation, she worked with Mick Sagrillo at Lake Michigan Wind and Sun doing everything from system design and sales to welding tower kits. More recently, Kim was operations manager with Conergy in Santa Fe, New Mexico, after working her way up through a variety of positions there.

Jacie Gray is the latest and greatest addition to our customer service department. Jacie lives in the mountains of southern Oregon in a straw bale home she and her son built from the ground up. She is concerned about saving our remaining natural resources, and it is important to her to work for what she believes in, so working on the HP *crew is a good fit.*

Welcome aboard Kim and Jacie!

Height Limitations on Top-of-Pole Mounts

Dear *Home Power*, Thank you for your article, "How to Install A Pole-Mounted Solar-Electric Array: Part 1" in *HP108*. I waited with bated breath for the issue to come in the mail because I am going to install a few such mounts in the near future and had many unanswered questions. This type of nuts-and-bolts information is often hard to come by if you are not a professional. Your article contained valuable tips that should allow me to install my own pole-mounts successfully. I still have a few questions before I install, so here goes.

In my area, a single storm can routinely dump 36 to 48 inches of snow. Snow often builds up on the ground here up to 48 inches in depth. (Our design snow load here is 100 pounds per square foot, and the peak wind speed is 80 mph, for 100 square feet of modules, on a 6-inch-diameter pole.) I feel that it would be good design, given these variables, to have the bottom of the panels at least 72 inches above the ground, so the snow that sloughs off or is removed will build up in a pile *under* the panels. Your pole and hole sizing for top-of-pole mounts chart states that 84 inches is the tallest a 6-inch-diameter pole can be above ground level. In fact, some major mount manufacturers recommend not exceeding 72 inches in height. Since the panels would hang about 40 to 48 inches below the top of the pole, that would leave their height at a mere 24 to 36 inches above the height of the ground in winter—they would be buried in snow. I have seen many photovoltaic panels pole-mounted 120 to 144 inches above ground level on 6-inch poles, and cannot figure out how it is done. What causes 72 to 84 inches to be the height limit? Is it the thickness of pipe or the weight of concrete? What strategies could I use to get that needed height? Thanks for a great publication. Lizah Eszterhas, Trinity Center, California • myjavelina@hotmail.com

Hi Lizah, The height limit imposed on pole-mounted PV arrays is a function of the strength of the materials involved, the size and tilt angle of the array, and the force exerted by wind on the array. The basic idea is that as the pole gets taller, it will sway more in the wind. When this oscillation exceeds a certain amount, the pole will begin to fatigue and eventually fail, usually by breaking at the ground level. The size of the array figures in because the more square footage of modules you have, the more force will be exerted by the wind, causing the pole to begin swaying, and the more weight you have at the end of the pole, the larger the oscillations are going to be. Also, the closer to vertical the tilt angle is, the more the array will act like a sail to catch the wind.

Going with a larger diameter pipe or a pipe with a thicker wall increases the amount of swaying that can be tolerated by the pipe. Reducing the array size, thereby decreasing the wind loading and the weight at the end of the pole, will decrease how much the pipe is affected by the wind, as will flattening the tilt angle of the array.

Those are the general facts. With the information you provided and a few assumptions I made, I did some calculations using our in-house pole-top calculator. Based on the physical characteristics of a 6-inch-diameter schedule 40 steel pipe, I determined that you could have a pole height of 120 inches with 100 square feet of modules mounted on a UniRac PoleTop rack in an 80 mph wind zone, as long as the tilt angle doesn't exceed 45 degrees. The 120-inch pole height should put the bottom edge of the array close to 72 inches off the ground, depending on what size PV module you're using. The pipe will need to be embedded 7 feet in the ground in a hole 32 inches in diameter filled to ground level with concrete.

So far, so good, but I see a big problem with that 100 pounds per square foot of snow loading. A 6-inch schedule 40 pipe at 120-inch height will be close to its maximum loading capability with just the wind pressure alone on the array. Tilting the array more towards vertical will dump the snow better, but if the wind picks up, it'll knock that big array right over. With that much snow loading, I don't see this scenario working very well. So my advice is to consider putting up two *top-of-pole mounts with half the square footage on each. Reducing the array size to 60 square feet would allow you to tilt the rack to 60 degrees, which would dump the snow much better and help maximize your winter solar energy harvest too. Steve Fain, UniRac Inc. • sfain@unirac.com*

Rainfall Energy

Has anyone researched or designed a system to capture rainfall energy in a residential setting? I mean the water from gutters, flow from roofs, and other capture devices. Thank you. Juanita Carlson • jcarlson@1040nh.com

Hi Juanita, Collecting rainwater from your roof for domestic or irrigation use is a great idea, but the energy available from water flowing off a roof is very small indeed. My late colleague Don Kulha and I once joked that you might be able to make an LED flow sensor powered by a turbine in a downspout, but that would be all you could power.

Let's see if our joke was right…A 1,000-square-foot roof will collect about 600 gallons of rainwater per inch of rain. Let's say it rains 1/2 inch in a 10-hour period. That's 300 gallons total or 30 gallons per hour or 1/2 gallon per minute. Let's say the height from your gutters to your turbine is 10 feet. We can use a simple formula of head (height) times flow divided by 13 to guesstimate that you would get an output of 0.38 watts—3.8 watt-hours for the ten hours. This is a very small amount of energy. A tiny, 1-watt solar-electric module will do this every day in most locations.

The lesson is to let large areas of land collect rainwater, and then find places with lots of head to run a pipe down, so you can generate meaningful amounts of energy. Trying to make energy for your house using the rainfall and head on your roof is like trying to make energy for your house with the tiny PV module in your calculator. Best, Ian Woofenden • ian.woofenden@homepower.com

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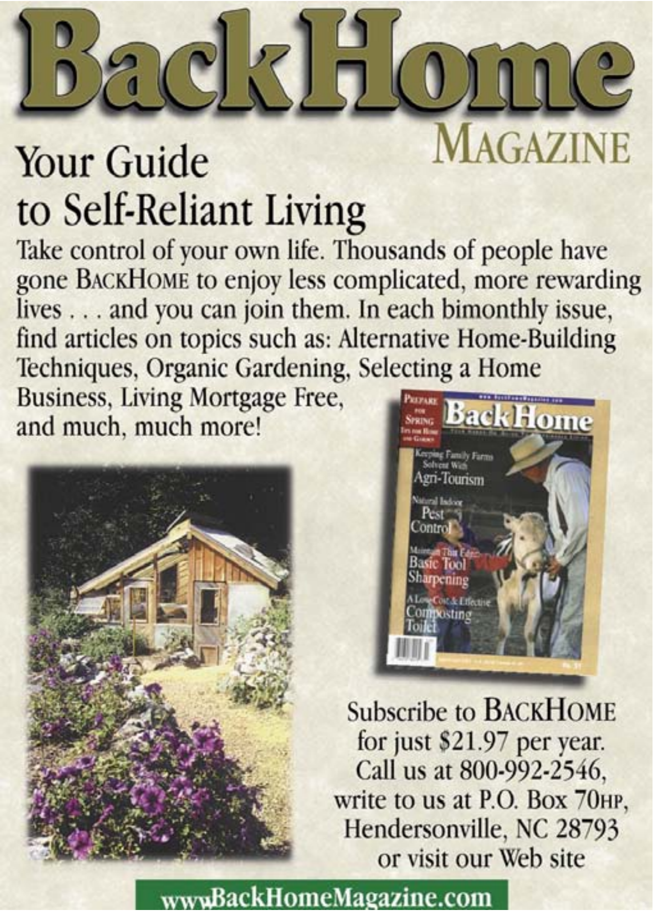
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Dueling Charge Controllers?

I have a small, battery-based, solar- and hydro-electric system. I am using a Trace C60 controller and just paralleling the solar-electric panels and hydro. The hydro can produce from 25 to 150 watts depending on the available water flow, and the solar-electric array can produce 25 to 250 watts. At anything under 25 watts (1 amp), it does not charge the batteries—it goes to run the charge controller.

I have not seen what the minimum power to run the charge controller should be in any charge controller specifications. Most of the time, I only get 1 amp out of the hydro (adds up over 24 hours)! Sometimes I only get half an amp from the solar-electric panels. It would be a shame to lose that to a charge controller.

The C60 is not in diversion mode, so when the batteries are full, the hydro runs without a load, and I have to monitor it and stop the water flow. I would like to purchase an MPPT charge controller for the solar-electric array and use the C60 in diversion mode for the hydro.

How are the two charge controllers going to get along with each other? I'm assuming that there could be problems, even if it is as simple as watching that I put both in the equalizing mode at the same time so that one charge controller doesn't argue with the other about the correct battery voltage. Does anyone have any thoughts about this? Thank you, James Wilson • jwilson@btg-tv.com

Hi James, A charge controller draw of 1 amp seems like quite a lot. For example, the Blue Sky Energy Solar Boost 3024i's consumption is quite low—for a 24 V battery it draws about 0.015 amps in standby and 0.042 amps while regulating.

It is common for there to be more than one source charging a single battery, and the likelihood that there will be undesired interaction between charge controllers is low. What basically happens is that if the battery is discharged, each of the charge controllers delivers whatever level of power it has available. Once the battery becomes highly charged, whichever charge controller wants to apply the higher charge voltage eventually wins.

Since one of the charger controllers in your system is a diversion type, you need to be certain that the diversion charge voltage setpoint is slightly higher *than the solar charge controller setpoint so the diversion controller will not inadvertently dump solar energy. Both charge controllers should have temperature compensation, and the sensors should be in the same location so that each charge controller will see the same temperature, and their charge voltage setpoints will tend to track each other. Regards, Richard A. Cullen, Blue Sky Energy Inc. • rick@blueskyenergyinc.com*

Hello James, The Xantrex C-series charge controllers have a typical total draw of 15 milliamps. You can download this and other specifications for the C-series controllers from Xantrex's Web site. The 1 amp figure you're seeing may be due to an inaccuracy with your metering setup.

The addition of a small maximum power point tracking (MPPT) charge controller would be a good investment if you're planning to expand your solar-electric array in the future. You should definitely set up the C60 controller in diversion mode for the hydro. Manual regulation of system charging is not a good idea. Running the hydro turbine unloaded will cause it to operate at approximately four times its typical rpm and cause unnecessary wear in the bearings, and possibly destroy the turbine if it's left unattended for an extended period. Best, Joe Schwartz • joe.schwartz@homepower.com

Monitoring a Hot Water System

Thanks for a great publication. Are there any metering systems that will be able to monitor the energy produced by a solar hot water system? Yours in RE, Anwar Arnold • anwar@contisocks.co.za

Hi Anwar, To monitor the Btu (kilocalorie) output of a solar heating collector, the monitor should have three inputs from remote sensors—fluid flow rate, cold, and hot. The good flow rate sensors I have used are impeller driven and installed inline. Sensors for temperature inputs are typically thermistors or thermocouples. There may be many good monitors out there, but the only models I have used are made by Data Industrial in Tulsa, Oklahoma (www.dataindustrial.com). You should expect to pay around US$800 to $1,000 for a well-made thermistor input monitor and three sensors. I hope this helps, Chuck Marken • chuck.marken@homepower.com

Hydro Troubleshooting

I am looking for help in solving a problem that I am having with my hydroelectric system. The spring-fed system has a 1,300-foot-long PVC pipeline (4 inch reduced to 2 inch) buried 4 feet deep, with about 112 feet of head.

The problem is a buildup of calcium-limestone from the hard water that we have in this area. This buildup has reduced the diameter of the interior of the pipe and has increased friction. This has cut the electric output from 15 amps to 2 amps over the last eight years. Have you dealt with this problem or do you know of someone who has? Any ideas? Any help would be appreciated. Sincerely, Mark Jungst • jungstb@libby.k12.mt.us

Hi Mark, If I understand your system, you have 1,300 feet of pipe and 112 feet of head, with some pipe being 4 inch and some being 2 inch. About eight years ago your hydro was putting out about 15 amps at 12 volts (180 watts) and now it is producing about 2 amps at 12 volts (24 watts). How much water do you have available? How much is going through the turbine? How much of the pipe is 2 inch and how much is 4 inch? What turbine do you have?

My guess is that the problem is something other than the inside diameter of the pipe, for two reasons. Except for hot water sources or hot water use, we seldom see much buildup on the inside diameter of pipes. But more important, assuming your turbine efficiency is 50 percent, water-to-wire, with 112 feet of head and 4-inch pipe with 17 gpm, you could produce about 180 watts and only lose 0.3 feet of head to friction. With 17 gpm and 2-inch pipe, you would lose about 8 feet of head to friction and reduce your output to 167 watts. With 1.5-inch pipe and

17 gpm, you would lose about 34 feet of head and reduce output to 126 watts. Your output has dropped off much more than can be accounted for by a reduction in inside diameter of your entire pipeline to 1.5 inches.

The first thing I suggest is to measure the water pressure at the pipeline just up a little way from the turbine. Measure the static pressure first with the turbine shut off, and then measure the dynamic pressure with the turbine running. This will tell you how much gross head the pipeline has, and how much friction there is when the turbine is running. If the static pressure is low, something is wrong with the pipeline. If the static pressure is high and the dynamic pressure is low, there may be a high spot in the pipeline with an air pocket in the line.

There may also be some problem with the turbine. If you measure the dynamic pressure of the water and then measure the amount of water flowing through the turbine, you can calculate the actual efficiency of the turbine and determine whether the turbine is operating as it should. I expect about 50 percent efficiency with most DC turbines.

There is an outside chance that you have too much water. How much water is available? If the nozzles are too large and too much water is flowing through the pipe, friction losses may be overwhelming the power. If most of the pipe is 2-inch, and you have more than 40 gpm available, increasing the flow will actually decrease the power output. If most of the pipe is 4-inch, you should be able to push the flow to 200 gpm or more before decreasing power output.

I would be glad to review this project with you more if you like. Knowing the length of the 4-inch pipe and length of the 2-inch pipe would help. It would also be good to know how much water is available. And finally, pressure gauge readings are an important first step for most diagnostic work. If you do not have a pressure gauge, I can describe how and where to install one. Lee Tavenner, Solar Plexus • solplex@montana.com

Electric Radiant Heat

Hi y'all, I just subscribed to *Home Power* not too long ago and I love it. There is so much to learn. One thing I need to learn about is radiant heat. We are doing a remodel and maybe a new addition, and I would like to put in radiant heat. I'm not too wild about all the components and maintenance required for a hydronic system, but I'm also not too thrilled with using more grid electricity for an electric setup either. I have read in a few places that solar electricity and resistance-type heating are not a good match. However, I noticed that at least one manufacturer of electric radiant heat products has a low-voltage system. Would this be compatible with solar electricity? I've submitted this question to the manufacturer, but I haven't received a response yet. I've also done a search of the articles on your Web site, but I haven't come up with anything that addresses this situation. Can you help? Thanks for your reply, Peter Chevalier • pjchev@lightpower.net

Hi Peter, Your first move in your remodel should be to incorporate passive solar design features if possible, and super insulation. These will give you the most bang for your buck.

In the past, my advice would have been that solar electricity and heating are unquestionably not a good match because of the high cost of the generating equipment. Renewable energy experts usually advise to shift all heating loads to other fuels—frequently to propane for cooking, heating water, and heating space. More recently, some solar-electric systems have been designed to carry some heating loads, especially with the advent of net metering, which allows you to "bank" energy on the grid in the summer and "draw" from it in the winter.

A 6 KW PV system was recently installed in my neighborhood, with the intent of generating the energy to offset electrically heated radiant floor heat for a weekend home. I'm waiting to see how the design works, but I think it has some promise. Make no mistake—the initial investment is high, and a solar thermal system may have been a better investment. But this owner/designer wanted to try this approach, and it will be interesting to see the results. Note that a low-voltage system will probably not help you. Energy is energy—there's no free lunch with low voltage. Sure, you may avoid the inefficiencies of having an inverter involved, but the line losses with low voltage might be much higher than that. Best, Ian Woofenden • ian.woofenden@homepower.com

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