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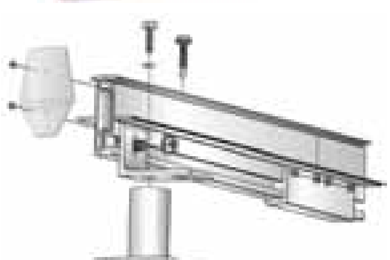

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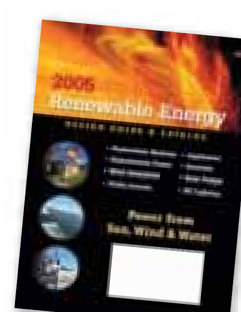

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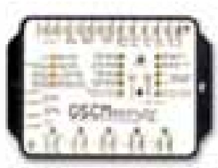

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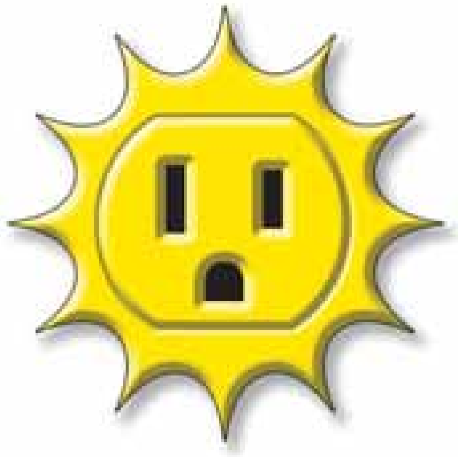

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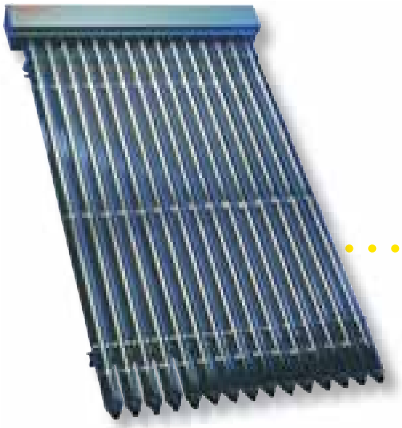

On the Cover

Michelle and Todd Cory with the solar-electric system that contributes to their goal of a "zero energy home."

Photo by Shawn Schreiner

Regulars

Energy Opportunities

Hardly a week goes by when I don't hear someone complaining about the weather. Being a renewable energy harvester makes it easier to accept what comes my way. If it's "too hot," the sun is shining, charging our batteries with solar electricity, and supplying our solar shower with hot water. If it's "too windy," our wind turbines are keeping the batteries full, allowing us to do laundry, run power tools, or show movies on the big screen. If it's "too rainy," our rainwater tanks are filling up, gathering water for our gardens and animals.

Besides making you feel better about the weather, harvesting your energy locally can make more environmental and economic sense than buying energy generated hundreds of miles away. The same is true of the building materials and other goods you use. There's no sense in buying something "natural" if you have to use huge amounts of energy to move it from China to your home in the states. Choosing simple, local materials will keep the "embodied energy" in your home to a minimum, since manufacturing and transportation use lots of energy.

This issue of *Home Power* is full of examples of people tapping into natural sources of energy and materials. You can read about harvesting sunshine for electricity, hot water, and cooking. Mark Alovert describes her biodiesel processor. Michael Durland shows you how to start collecting rainwater. And Rob Roy's cordwood primer is a fine example of using locally available materials. Even though Rob has devoted years of his life to promoting cordwood construction, he says, "I don't think that cordwood is necessarily superior to straw bale, adobe, or other building materials. It just happens to be what I have in large supply where I live." Wherever you are, there are renewable sources of energy and natural materials for you to tap.

Instead of being depressed when it's too wet, too hot, or too windy, you can be cheered by the fact that you are benefiting from the natural resources that bless our lives every day. What energy crisis? If we can tap into the "free fuel, delivered daily" and local, low-energy materials, the energy "problem" starts to look like an energy opportunity.

—Ian Woofenden, for the *Home Power* crew

Think About It...

"Sunshine is delicious, rain is refreshing, wind braces us up, snow is exhilarating; there is really no such thing as bad weather, only different kinds of good weather."

—John Ruskin, English writer and critic (1819-1900)

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APPROACHING ZERO

Working Toward a Sustainable Home

Todd Cory

For the last twenty-five years, my wife Michelle and I have been consciously working on reducing our impact on the planet. We are both vegetarians. We live simply, with solar thermal and solar-electric systems. I am self-employed, designing and installing renewable energy systems in our local area. Over the last three years, I've been reading more and more about our dwindling global oil supplies and specifically "peak oil." My research has convinced me that we must do more.

Courtesy Shawn Schreiner

Peak Oil

What is peak oil? Peak oil is when the extraction of oil from the earth reaches its highest point and then begins to decline. Unfortunately, peak oil is coinciding with escalating demand. Combine our decreasing oil supply with an increasing level of consumption, and it is easy to see the rapidly approaching "perfect storm."

Twenty-five years ago, we started to read about the serious need to prepare for this situation. To date, world "preparation" has gone in the opposite direction. Our global population has increased by more than 2.3 billion to 6.5 billion people! Here in the United States, wasteful, oversized homes have become the standard, and we have seen the widespread proliferation of low-efficiency vehicles.

With its fantastic fuel economy, the Corys' hybrid-electric Toyota Prius helps them achieve their energy conservation goals.

Look around you and try to find one thing that was not made possible by hydrocarbon energy. Even in the food we eat, every calorie has been produced with around 10 calories of fossil fuel. This very sobering issue is beyond the scope of this article. You can research peak oil and educate yourself: to start, see *HP81* for an excellent article on the topic by Randy Udall.

What to Do?

With an increased awareness of peak oil, my wife and I decided to see what we could do in our personal lives to retrofit our existing home to reduce its impact. For the last eight years, we have enjoyed net zero electricity use with our grid-tied, 1.4 KW solar-electric system. But we still consumed fossil fuel energy (kerosene) for winter space heating.

A 960 W array of twelve, Shell 80 W panels overshadows the power shed, which houses the inverter, controller, and batteries.

Courtesy Shawn Schreiner

I was curious to find out what it would take to heat our 1,600-square-foot (150 m^2) home with solar electricity. This is not as crazy as it may sound. For eight months of the year, we have abundant, renewable sunshine. A net-metered photovoltaic (PV) system with an annual billing cycle could "store" that energy over the summer for use during the winter. How much additional solar-electric input would we need to replace our kerosene consumption to a point where our home would use no outside energy?

Step One—Reduce Waste

The first step is always reducing waste. While we had done this with the home's electrical system, we had not done much to the house's thermal system. Because this is a retrofit, it is harder than if the house had been built with energy efficiency in mind from the start.

We blew R-60 cellulose insulation into the attic and put 2 inches (5 cm) of rigid foam on the outside of the north wall, with new siding on top. We weather-stripped and sealed air leaks. We installed pleated, R-4 insulating blinds on all the windows.

We also changed the way we heat the house, only heating the spaces when we are in them. We close doors to unused areas and program the heater's setback timers to change the temperature at different times of the day. This provides comfortable temperatures when spaces are used and reduces heat loss when they are unoccupied. The changes resulted in a dramatic 55 percent annual reduction of kerosene use, from 265 to 120 gallons (1,000 to 450 l)!

Step Two—System Changes

The *proper* way to get to zero energy would be to first determine the amount of additional energy we need, and then design a system to accommodate those needs. Because our space for added PVs was limited, I decided to install what was possible, and see how close that brought us to our desired goal.

PV System Tech Specs

Overview

System type: Battery-based, grid-tie PV

Location: Mount Shasta, California

Solar resource: 4.5 average daily peak sun hours

Estimated average production: 410 KWH per month

Utility electricity offset: 100 percent

Photovoltaics

Modules: Twelve Solarex MSX-60, 60 W STC, 17.5 Vmp, 12 VDC nominal; twelve Shell SQ80, 80 W STC, 17.5 Vmp, 12 VDC nominal; eight Sharp 185, 185 W STC, 36.2 Vmp, 24 VDC nominal

Array: Six sets of four 12 VDC nominal module series strings, 70 Vmp; and four sets of two 24 VDC nominal module series strings, 72.4 Vmp; 3,160 W STC total, 48 VDC nominal

Array combiner boxes: Three OutBack PSPV

Array disconnects: Two OutBack OBDC 40 A breakers

Array installation: Three Array Technologies, dual-axis active trackers

Energy Storage

Batteries: Eight Trojan L-16H, 6 VDC nominal, 420 AH at 20-hour rate, flooded lead-acid

Battery bank: 48 VDC nominal, 420 AH total

Battery/inverter disconnect: OutBack PS2DC with 175 A breaker

Balance of System

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

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

Performance metering: Xantrex Link-10 (only provides relevant data when the grid is down)

In July 2004, I retired our ten-year-old, grid-tied, Trace SW4024 inverter and replaced it with an OutBack GVFX3648 inverter. (We are using a battery-based inverter system because our utility often goes down during severe winter snowstorms.) The battery-based OutBack inverter has a higher conversion efficiency when feeding solar energy to the grid. It also has the intelligence to shut itself off when it's not needed, instead of constantly floating the batteries. The original Trace SW series inverters always floated the battery bank using energy from the grid. This amounted to a huge phantom load on my system, averaging about 250 KWH a year!

In October 2004, I added a third tracked rack of panels, increasing our grid-tied solar-electric system from 1.4 KW to 3.2 KW (STC). In Spring 2005, we began "banking" our surplus solar-electric generation (spinning our meter backwards). This winter, we will use that "stored energy" in electric heaters to offset the fossil fuel heating.

The 3.2 KW PV system will generate around 5 megawatt-hours (MWH) a year. We have historically used about 2.5 MWH a year (about 210 KWH a month) to operate the house's nonheating, electrical loads. This leaves around 2.5 MWH for resistance electric space heating. A ground-source heat pump would produce a higher KW-to-Btu energy return than resistance heaters. Our calculations demonstrate that the house should now be close to net zero energy on an annual basis.

The Numbers

Last year we used 120 gallons (450 l) of kerosene. Our Monitor brand kerosene heater delivers 19,500 Btu per hour using 0.16 gallons (0.6 l) of fuel. So 120 gallons allows the heater to run for 750 hours, delivering 14,625 KBtu.

The 2.5 MWH of available electrical storage used as resistance electrical heat is equal to 8,532 KBtu (2,500 KWH x 3,413 Btu per KWH = 8,532,500 Btu). This leaves us with an energy deficit (14,625 - 8,532) of 6,093 KBtu per year.

So, our banked solar-electric energy will take care of about 58 percent of our heating needs, or an equivalent of about 70 gallons (265 l) of kerosene. This will reduce our annual consumption to about 50 gallons (190 l).

Two solar thermal collectors mounted on the garage roof provide the Corys with most of their domestic hot water. A small PV panel (between the collectors) powers the pump.

Courtesy Shawn Schreiner

The PV power shed houses an OutBack inverter, charge controller, AC and DC disconnect panels, and the battery bank.

Estimated Costs

Because this system has evolved over the last twenty years, it is difficult to determine the exact costs. Most dealers estimate the cost of installed PV at around US$10,000 per rated kilowatt, so a rough cost for our system would be about US$30,000.

Conventional thinking would laugh at spending US$30,000 on a system that would mitigate only US$500 a year of "brown" (nonrenewable) energy costs. However, let's remember that brown energy is subsidized and does not include environmental, social, and military expenses. We still pay those costs, but they are hidden—in our taxes, our budget cuts, our declining standard of living, and our decreasing international popularity.

Step Three—Solar Thermal Heating

In the spring, summer, and fall, we have a surplus of hot water available from our solar thermal system. This summer, I installed a commercially manufactured hydronic heater to dump this waste heat into the house. This is a length of coiled, copper fin tube that you run hot water through. A fan forces air through the fins and exchanges water heat to air heat. When the solar thermal system heats the water in our storage tank above 130°F (54°C), the fan and pump turn on if the thermostat calls for heat. This system shuts off at 110°F (43°C), leaving the rest of the hot water for domestic use.

Empirical testing has shown that when the sun is shining, this unit typically runs for about four hours a day, delivering 5,000 Btu per hour. This equals about 20,000 Btu per day, or an equivalent of 0.16 gallons of kerosene a day. This surplus, solar thermal heat is used for approximately three months a year, which amounts to about 14 gallons (53 l) of mitigated kerosene.

Calculated Conclusions

Our calculated, annual net energy load will still require close to 36 gallons (136 l) of kerosene (50 - 14 = 36). These 36 gallons of kerosene burned in our Monitor brand heater would equal about 4,387 KBtu.

Our house is not "zero energy," but it's getting close. The kerosene we still end up using would require almost 1.3 MWH of additional annual electrical generation, or about 700 more watts added to the current 3.2 KW array. So for our home's typical energy requirements, 3.9 KW of solar-electric capacity would make us "zero energy." Of course, these are calculated numbers; seeing how this performs in the "real world" this year will be interesting.

Solar Hot Water System Tech Specs

Overview

System type: Antifreeze, PV-direct pumping

Climate: Extreme to hard freezes throughout the winter

Production: Estimated at 1,200 KBtu per month average

Number of people in household: Two

Percentage of hot water produced annually: Approximately 80 percent

Collectors: Two, used, 4 x 10 ft., black chrome

Heat transfer fluid: Ethylene glycol

Collector installation: Roof mount, SSW orientation, 35-degree tilt

Storage: Existing 80-gallon electric hot water tank

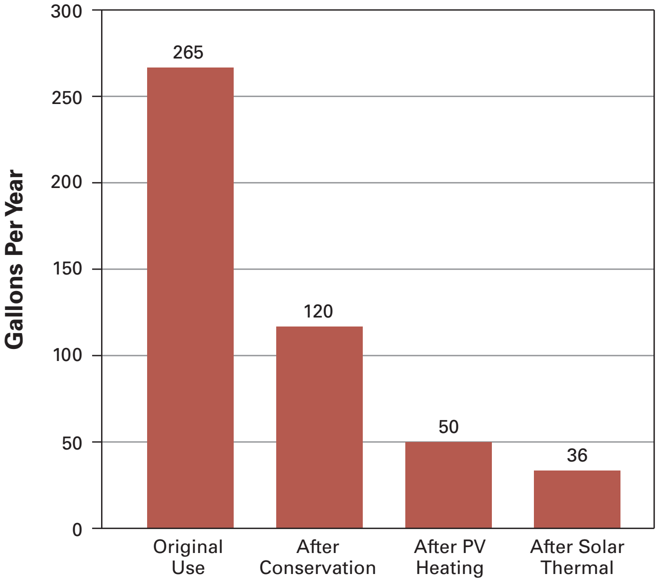
Heat exchanger: Used, flat plate

Circulation pumps: Glycol loop; Hartel, 24 VDC, brushless, high-speed pump, model #MD10HEH. Potable loop; Hartel, 24 VDC, low-speed pump, model #MD10DCL

Pump controllers: Glycol loop runs array direct. Potable loop runs array direct via a used Independent Energy C-30 differential controller

Performance metering: Two, GC brand thermometers and a pressure gauge

Kerosene Usage



Short-term thinking says "green" energy is more expensive. But what you are buying is not typical brown energy, subsidized by future generations. You are purchasing a renewable energy generation appliance that may still be capturing usable energy 100 years from now, when oil costs may have climbed from US$50 a barrel to US$500 a barrel!

Peak Oil Revisited

For about the last hundred years, we have been surrounded by the luxuries provided through cheap energy. With the arrival of global peak oil, this is about to change. As fossil fuel production declines, so goes the easy, comfortable, and unsustainable life on which it was founded. We cannot drill our way out of this.

Some credible estimates show petroleum production peaking—with demand exceeding supply—sometime around 2007. Global peak oil is a brick wall we are traveling towards, full speed. While I have worked at covering our home's electric and heating needs, I have not addressed our other energy consumptions. These include transportation and the food we eat. This year we purchased a Toyota Prius and have expanded our garden to provide a greater percentage of homegrown food. A greenhouse is also on the project list.

Peak oil represents a profound impetus for our planet to awaken to the necessity of living sustainably. Gandhi said it best: "You must be the change you wish to see in the world."

Access

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Solar SIMPLIFIED Hot Water

John Patterson

I was dazzled on a cold November morning in 1979 to see my new solar water heater turn on. The gauges showed 50°F (10°C) water going to the collectors and 60°F (16°C) water coming back. At that moment, I became a believer.

Even in the cloudiest climates, the sun can provide 50 to 60 percent of a household's annual water heating, and in sunnier places, 80 percent or more. How does it work? Here is a simple breakdown of the most common solar water heating systems and their main components.

Systems vary—not all equipment is necessary for every system type. For the sake of simplicity, some lesser yet necessary, components have been omitted. Equipment such as drain and fill valves, temperature and pressure relief valves, air vents, check valves, and temperature and flow gauges are important to the safety and function of these systems. See past *Home Power* articles for detailed descriptions of the importance, placement, and use of these components.

System Types

Five main types of solar water heating systems are sold today. These five are a distillation of dozens of types sold over the past 25 years. They are:

- Batch
- Thermosyphon
- Open-loop direct
- Pressurized glycol
- Closed-loop drainback

The proven winners are simple, reliable, and long lasting. Some systems are "open loop" (the domestic water itself is directly heated) and some are "closed loop" (a heat transfer fluid is heated by the collector and the heat is passed on to the domestic hot water by means of a heat exchanger). Some systems are "active," using moving parts such as pumps and valves, and others are "passive," using no mechanical or moving parts.

SDHW System Characteristics

Characteristic	Batch	Thermosyphon	Open-Loop Direct	Glycol	Drainback
Low profile—unobtrusive in appearance			✔	✔	✔
Lightweight			✔	✔	✔
Freeze tolerant				✔	✔
Easy installation & infrequent service	✔	✔	✔		
Passive operation—no pumps or controls	✔	✔			
Space saving—storage tank unnecessary	✔	✔			

1 Solar Collectors *AKA: Solar thermal panels*

A solar collector consists of a network of pipes through which water (or in colder climates, antifreeze) is heated. Collectors come in various sizes, with 4 by 8 feet (1.2 x 2.4 m) the most common.

On a typical summer day (sunny and warm), the fluid in the collectors reaches 140 to 180°F (60–80°C). On a clear winter day (sunny and cold), it can reach 120 to 150°F (50–65°C). When it's cloudy and warm, it can reach 70 to 90°F (20–30°C), and when it's cloudy and cold, 50 to 60°F (10–15°C). As long as the temperature in the collector is greater than that of your incoming cold water (usually about 50°F; 10°C), your solar hot water system is saving you energy.

Flat plate collector

Several types of solar collectors are on the market. Flat plate collectors are often compared to skylights. They are thin (3–4 in.; 7–10 cm), black, and covered with glass to hold in the sun's energy.

In evacuated tube collectors, a glass tube surrounds each individual pipe in a vacuum. This nearly eliminates the influence of ambient air temperature. Evacuated tubes perform better than flat plate collectors in cloudy weather, and can achieve higher temperatures compared to other collector types, but are typically more expensive. All active systems and some thermosyphon systems may use either flat plate collectors or evacuated tube collectors.

Evacuated tube collector

A third type, called integrated collector storage (ICS) or batch, combines the solar collector and storage tank into one unit. An ICS panel can resemble a flat plate collector with greater depth (6 inches; 15 cm). A simple batch heater can be a tank within a glazed box.

Collection and storage in one unit: thermosyphon (left) and batch (right)

2 Collector Mounting System *AKA: Mounts, racks*

The three most common mounting systems for solar collectors are the roof mount, ground mount, and awning mount. Roof mounted collectors are held by brackets, usually parallel to and a few inches above the roof. Ground mount systems can be as simple as four or more posts in the ground, lengths adjusted to affect optimal tilt. An awning mount attaches the collectors to a vertical wall. Horizontal supports push the bottoms of the collectors out to achieve the desired tilt.

When choosing a mounting system, roof mounts are usually the cheapest option, provided tilt and orientation are within acceptable parameters. If weight is an issue, ground mounts can be a good choice. Wall mounts are another solution that can work well in some situations.

Find the sunniest spot for your collectors. Generally, you want no shading between 9 AM and 3 PM. Facing collectors up to 30 degrees east or west of true south, and at your site's latitude plus 15 degrees tilt, generally will still yield results within 15 percent of optimum. Any nominal losses from tilt, orientation, or even shading can usually be overcome by adding more collector area.

3 Solar Storage Tank

AKA: Solar water tank, solar tank

A solar water tank is an insulated water storage tank. Cold water that used to go directly to your conventional water heater enters the solar tank and solar-heated water exits. In closed-loop systems, the water is heated by contact with a coil of pipe containing the water or antifreeze that circulates through the collectors. In open-loop systems, the potable water is directly circulated up through the collectors and back.

The preheated solar water is then plumbed back to the cold side of your existing heater, which now functions as a backup. Whenever hot water is turned on in the house, preheated solar hot water is moved from the solar tank to the backup heater.

4 Water Pump

AKA: Circulating pump, circulator

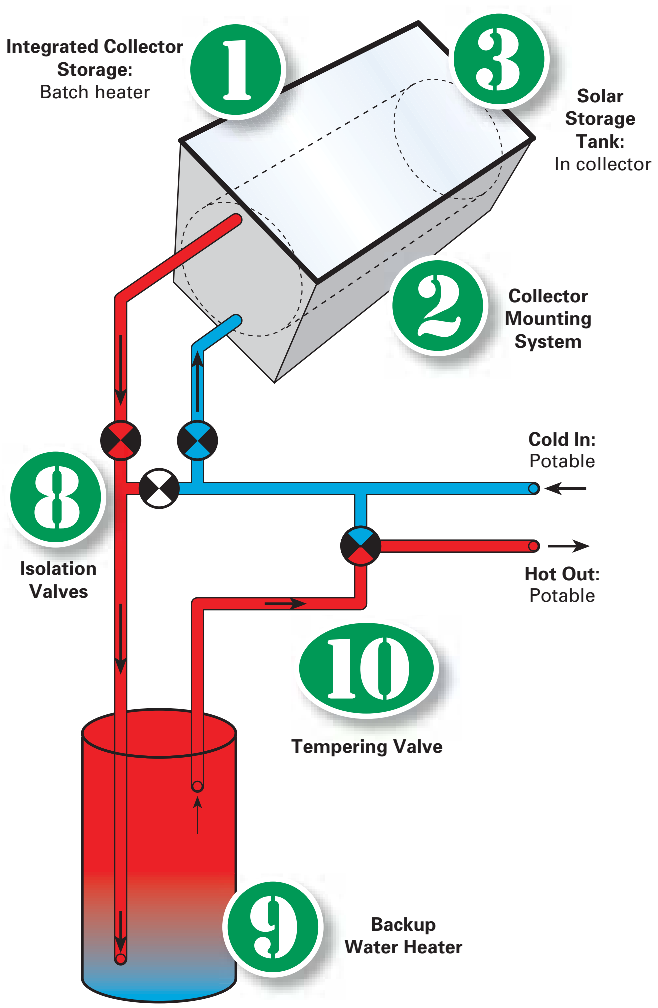
Pumps are used in active systems, but are not required in batch or thermosyphon systems. They circulate water or antifreeze between the solar collector and the storage tank. The right pump for the job depends on the size of the system and the distance and height between the collector(s) and the storage tank. AC pumps plug into a wall outlet while DC pumps are powered from a DC source, such as a photovoltaic panel. Good pumps can last as long as 20 years with heavy use.

SOLAR BATCH HEATERS

For a hundred years, simple solar batch heaters have been used in the United States. The term ICS (integrated collector storage) tells us that the collector and storage tank are combined into one unit. A tank of water, enclosed in an insulated box covered with glass, is placed in the sun facing south. Cold water is piped to the bottom of the tank; hot water is taken off the top. Whenever there's a call for hot water, water pressure from the home moves hot water from the top of the solar batch heater as cold water is pushed into the bottom.

Since the potable water is heated directly, this system is open loop. And since no pump is used to move the water from collector to end use, it is passive. The batch heater is a popular choice for homes in moderate climates where freezing is not much of an issue. Commercially manufactured batch heaters are relatively low cost. Crude batch heaters can even be homemade. If batch heaters are installed on the roof, weight has to be taken into account. Commercial batch heaters can weigh 200 pounds (90 kg) dry, and when filled with 40 gallons (150 l) of water, more than 320 pounds (145 kg) is added.

Because of their relatively low cost and simplicity, for those living in moderate climates with good sunshine available, the batch heater is probably the best value for heating domestic water.



5 Heat Exchanger

Heat exchangers are used in closed-loop solar hot water systems. They enable the transfer of heat from one fluid to another without the two mixing. Internal heat exchangers are inside the tank and not visible. They can be as simple as a coil of pipe resting in the bottom of the tank, or wrapped around the outside beneath the insulation and cover. As the heated fluid from the solar collector travels through the coil, the heat is passed from the hotter fluid to the cooler potable water.

An external heat exchanger is usually a pipe within a pipe. The solar fluid and potable water flow counter to one another, and heat is transferred within the heat exchanger pipe. Fluid may be moved with pumps, thermosyphoning, or a

6 Expansion Tank

Closed-loop systems require an expansion tank. An expansion tank has a chamber in which air is locked inside a bladder or diaphragm. It screws into standard 1/2-inch or 3/4-inch threaded plumbing fittings. When pipes are filled with heat transfer fluid (water and glycol), and the operating pressure of the system is set, the fluid will occupy a given volume based on the temperature. As the fluid is heated by the sun, it expands. This is where the expansion tank is critical. Without it, something would blow!

The expansion tank allows the fluid to safely expand by compressing the air in the chamber. The size of the expansion tank needed depends on the total volume of fluid, which is determined by the number and size of collectors, and the length and diameter of the pipes in the solar loop.

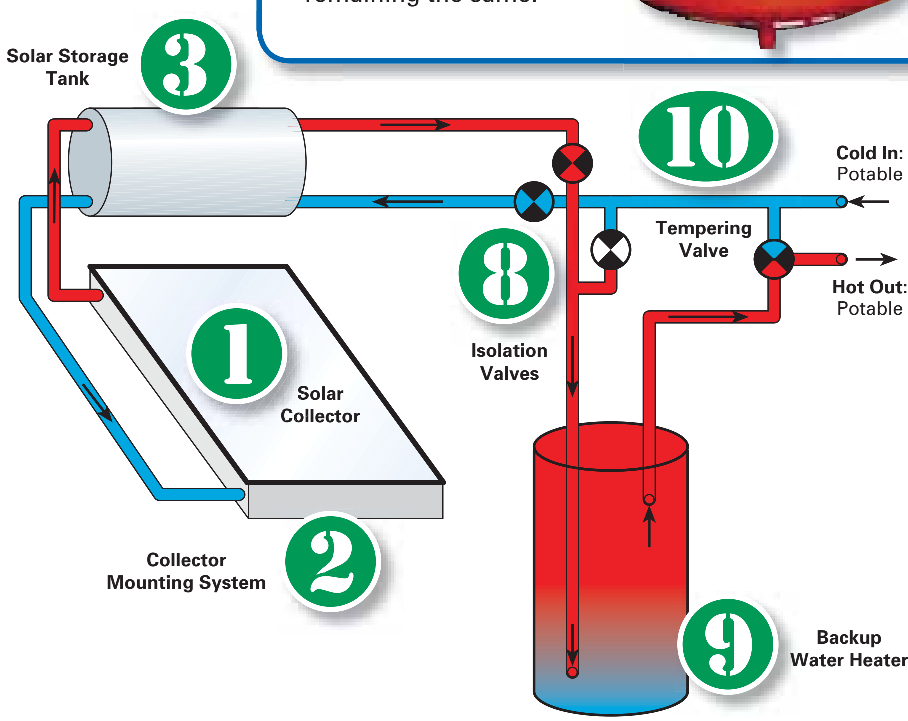
In most cases, a total of 3 to 6 gallons (11–23 l) of fluid is in a solar loop. A #15 (2 gal; 7.6 l) expansion tank is usually adequate. It never hurts to go larger, especially for systems with more than 60 square feet (5.6 m^2) of collectors. A #30 has twice the expansion capability. With the proper expansion tank in place, the fluid can go from 0 to 200°F (-18–93°C) with the pressure in the solar loop remaining the same.

THERMOSYPHON SYSTEMS

Another relatively simple, passive system, and the most popular solar water heater worldwide is the thermosyphon. Common in Japan, Australia, India, and Israel, they are easily recognizable by the fact that the tank must be located directly above the collector.

Thermosyphon systems work on the principal of heat rising. In an open-loop system (for nonfreezing climates only), the potable water enters the bottom of the collector and rises to the tank as it warms. In colder climates, an antifreeze solution, such as propylene glycol, is used in the closed solar loop, and freeze-tolerant piping, such as cross-linked polyethylene (PEX), is used for the potable water lines in the attic and on the roof.

Several international manufacturers make thermosyphon systems. The advantage of this system over the batch heater is that solar heat is stored in a well-insulated tank, so hot water can be used any time, without the penalty of overnight losses.



7 Controls

AKA: Differential controls, PV module

In active systems using pumps, whenever the collector is hotter than the storage tank, the pump should be on and the system circulating. When the tank is hotter than the collector, the pump should be off. This function is performed by either a differential thermostat control system or the use of a PV-powered pump. The differential thermostat controller compares heat sensor readings from the storage tank and collectors and switches the pump accordingly.

With a PV-powered pump, a solar-electric panel is connected directly to the pump. It's a simple setup—when the sun comes out, the pump comes on. The brighter the sun, the faster it pumps. Controls are not needed in batch heater systems, where energy is moved by simple water pressure, or in thermosyphon systems, where energy is moved naturally by heat rising.

8 Isolation Valve

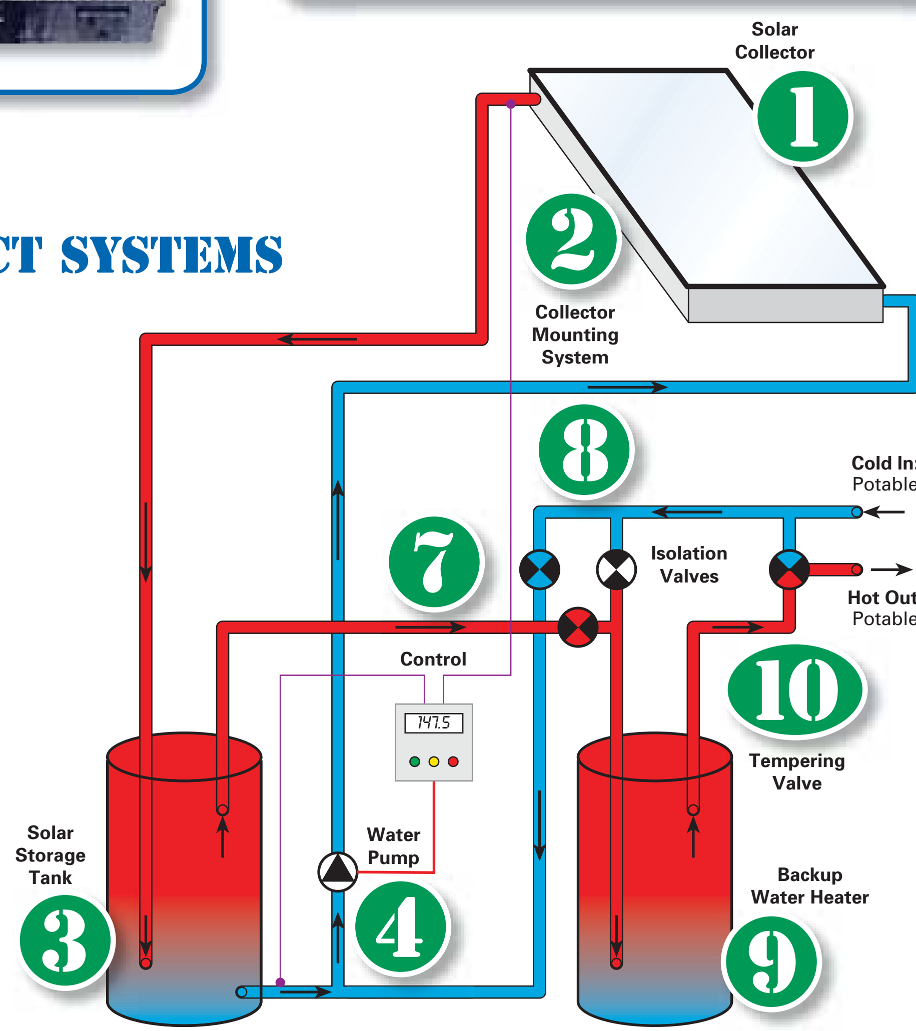
AKA: Solar bypass

An isolation valve should be a part of every solar water heater to isolate the solar tank in case of a problem, while still allowing the backup water heater to remain in service. The isolation valve is a manual valve or valves placed in both the incoming and outgoing potable water lines to the solar tank. It can be a three-valve configuration, or a three-port and two-port valve. Manually turning the valve or valves will place the solar tank "on line" or "off line." It works by directing the flow either through or past the solar tank. These valves can also be plumbed to bypass the backup gas or electric water heater, allowing them to be turned off (eliminating standby heat loss) during the seasons when the SDHW system can supply 100 percent of the household's hot water.

OPEN-LOOP DIRECT SYSTEMS

Used in tropical settings where freezing never occurs, this is the simplest of the active systems. A standard, 52-gallon (200 l) electric tank can be used, teamed with a 40-square-foot (3.7 m^2) solar thermal collector. Normally the electric element is not hooked up, so this tank becomes a storage tank only, for preheated water feeding an existing backup water heater.

An air vent, automatic or manual, is installed at the high point of the solar thermal collector to initially purge air. The pump, a small circulator pump using as little as 10 watts, can be powered directly by a 10-watt PV module, or a thermostatically controlled AC pump can be used. If desired, a snap-switch sensor can be installed to limit the temperature the solar tank reaches. Standard snap-switch sensors are available for 160 or 180°F (71 or 82°C).



9 Backup Water Heater

AKA: Natural gas, propane, electric, or wood water heater

Tank water heater

The backup water heater ensures that hot water is at the tap whether the sun shines or not. On a sunny, hot day, if the sun has preheated the water to 140°F (60°C) or more, the backup water heater uses no energy at all because the solar preheat temperature is greater than the typical 120°F (49°C) thermostat setting. On a day when the solar preheat is 85°F (29°C), the backup heater boosts the temperature the remaining 35°F (19°C). Since incoming cold-water temperatures are at ground temperature (usually about 50°F; 10°C), 85°F represents 50 percent of the energy needed to bring the water from 50 to 120°F.

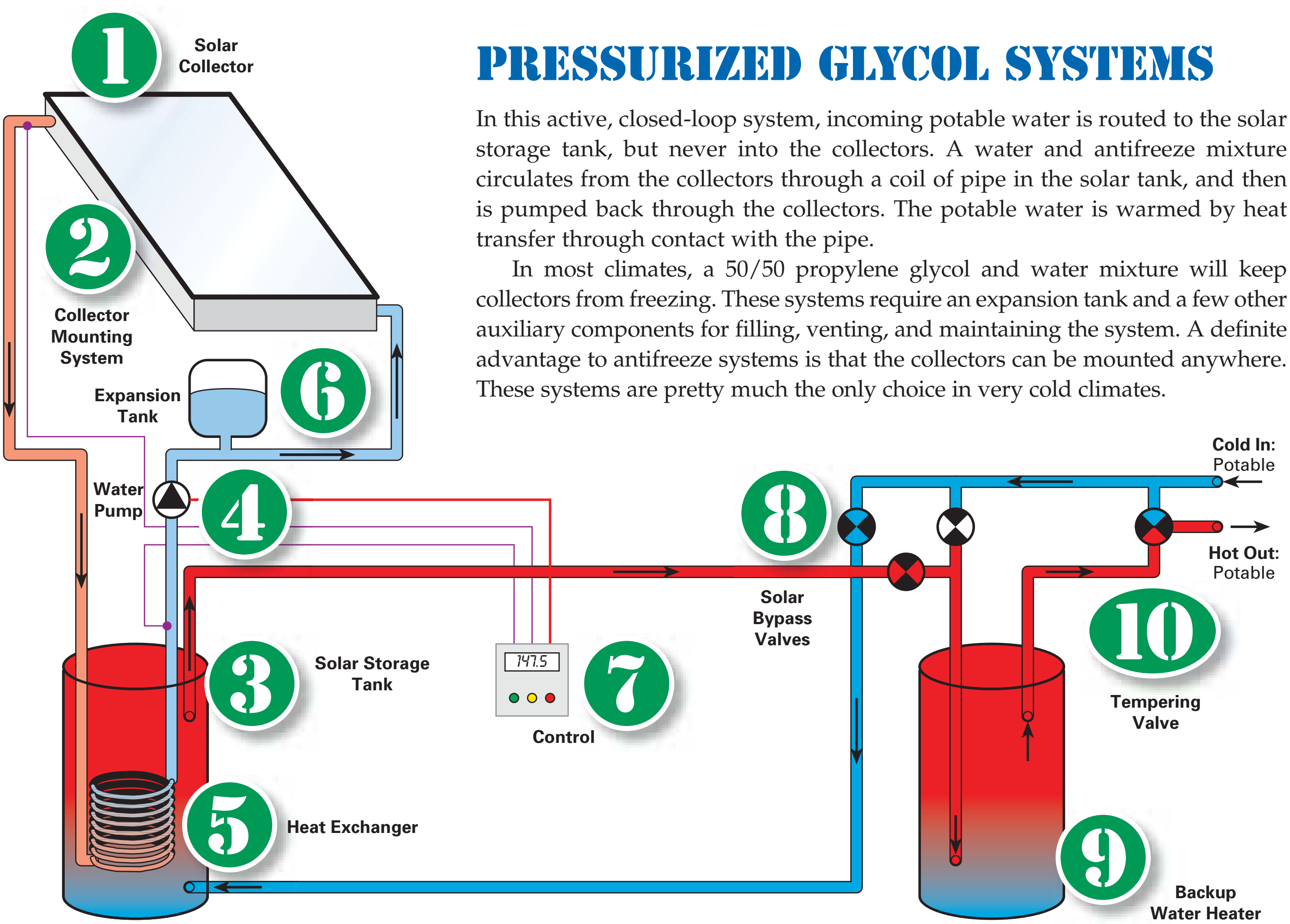
Not all backup water heaters use a tank. Keeping a tank of water warm between uses can account for 15 percent or more of the total energy expended for hot water. Tankless water heaters eliminate this standby loss. Solar hot water systems and tankless water heaters are a winning combination. If you're in Seattle, for instance, and can reduce your water heating cost by 60 percent using solar energy, and save another 15 percent by going tankless, this results in a 75 percent total savings. The household that used to spend US$300 per year to heat water now only spends US$75. In sunnier climates, this number can approach zero. Not all tankless heaters can be used as a backup heater for solar. Check with the manufacturer.

Tankless water heater

PRESSURIZED GLYCOL SYSTEMS

In this active, closed-loop system, incoming potable water is routed to the solar storage tank, but never into the collectors. A water and antifreeze mixture circulates from the collectors through a coil of pipe in the solar tank, and then is pumped back through the collectors. The potable water is warmed by heat transfer through contact with the pipe.

In most climates, a 50/50 propylene glycol and water mixture will keep collectors from freezing. These systems require an expansion tank and a few other auxiliary components for filling, venting, and maintaining the system. A definite advantage to antifreeze systems is that the collectors can be mounted anywhere. These systems are pretty much the only choice in very cold climates.



10 Tempering Valve

AKA: Mixing valve

On a sunny day, the water in your collectors can reach scalding temperatures. A tempering valve can save you from a 160°F (70°C) shower. Ouch! The tempering valve goes at the very end of the chain, right after the backup water heater and before the faucet. If the water coming out of the backup heater is too hot, the tempering valve opens to mix cold water back in and prevent scalding. The temperature of the hot water can be set by the user on most valves. For instance, a popular valve allows setting between 120 and 160°F (49–71°C).

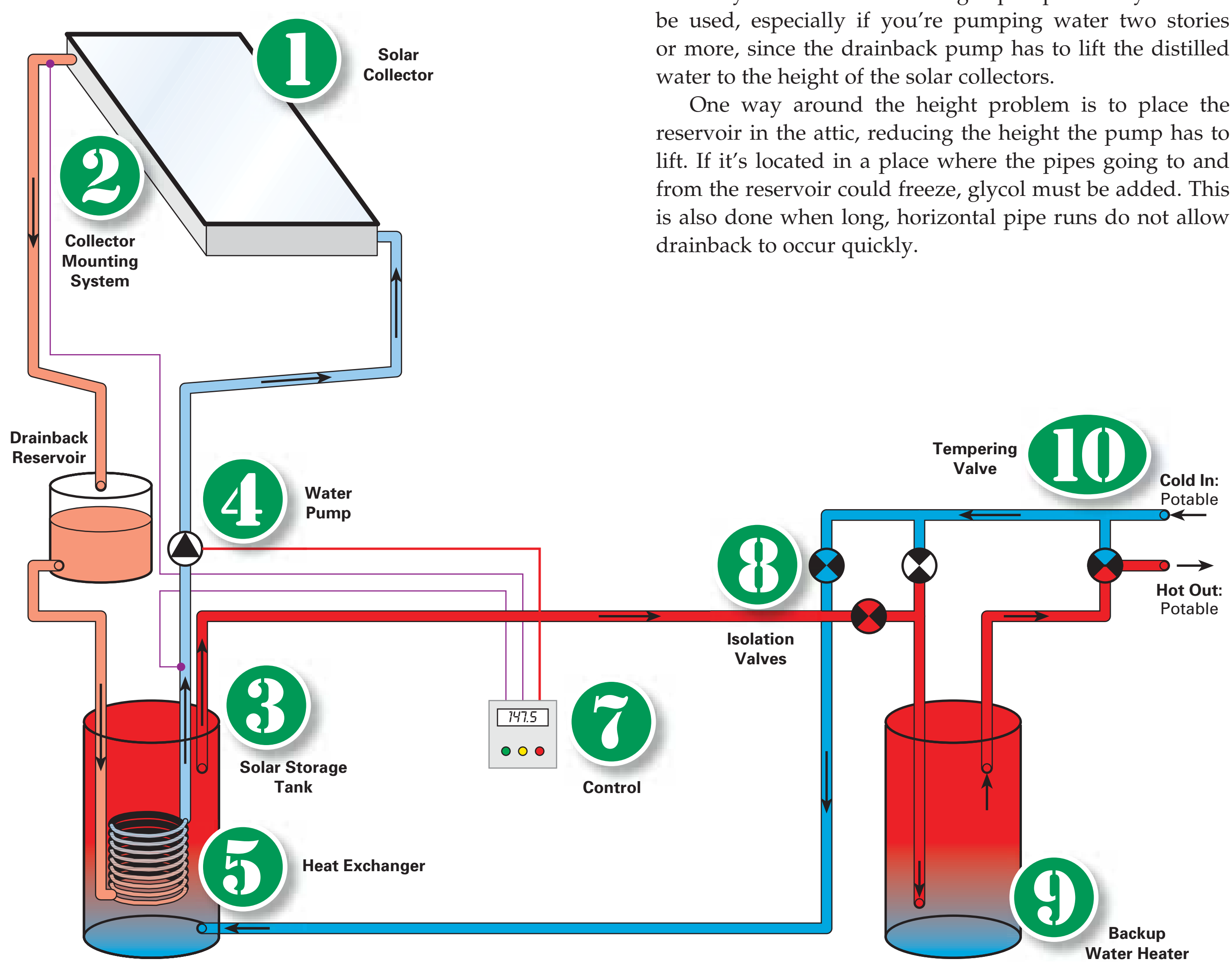
CLOSED-LOOP DRAINBACK SYSTEMS

The closed-loop drainback system requires perhaps the least routine service of any active system. The heat transfer fluid is distilled water, which seldom has to be changed. When the system is at rest (not pumping), the solar collector is empty and the distilled water is stored in a 10-gallon (38 l) reservoir tank, usually located just above the solar storage tank. Higher capacity reservoir tanks are typically required in large systems.

When the pump turns on, the distilled water is circulated from the reservoir back through the collector and heat exchanger, passing heat to the potable water in the solar tank. When the pump shuts off again, the distilled water drains back into the reservoir. The collector must therefore always be higher than the storage tank, and there must be sufficient continuous slope in the piping to ensure against freezing.

Drainback systems are effective and reliable. They work great, even on the hottest and coldest days of the year, and can go twenty years in operation without needing service. The only downside is that larger pumps usually have to be used, especially if you're pumping water two stories or more, since the drainback pump has to lift the distilled water to the height of the solar collectors.

One way around the height problem is to place the reservoir in the attic, reducing the height the pump has to lift. If it's located in a place where the pipes going to and from the reservoir could freeze, glycol must be added. This is also done when long, horizontal pipe runs do not allow drainback to occur quickly.



Hot Water Options

So now you know how solar domestic water heating works. There are many considerations in choosing the right system for a home. I have installed all of the major system types. Often the client and the situation will dictate the right system.

For instance, for a one- to two-person household in a temperate climate where hard freezing rarely occurs, I might propose a batch heater, especially if the hot water will be used more at the end of the day rather than first thing in the morning. In a household with three or more people, where aesthetics and weight are not an issue, the thermosyphon system might fit the bill, especially if there's no room for an additional tank near the existing water heater.

The drainback system, my personal favorite here in the Northwest, requires continuous fall between the solar collector and the solar storage tank. If continuous fall is not possible, there's always the pressurized glycol system where piping can go up, down, over, and around without concern, since the entire loop will be pressurized. Usually more than one option can work for any situation.

The number of people in the household will dictate how large the system will need to be, and which systems are even possible. Rebate and incentive programs may only qualify certain systems in a given area. Some systems are relatively easy to install for do-it-yourselfers, while others most laypeople shouldn't attempt. See the comparative chart showing features of the different system types. Make your choice, and enjoy using solar energy to heat your water!

Access

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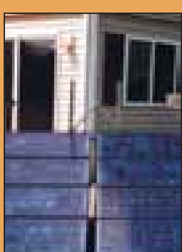
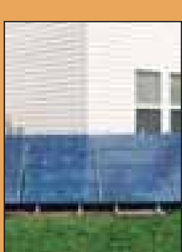
Growing with the Sun





We have all heard that one of the advantages of a photovoltaic (PV) system is its ability to grow and expand as new resources—time, money, desire—become available, and demand for clean, solar electricity increases. This article describes the growth of my system, from its humble beginnings almost ten years ago as a two-panel system installed on the balcony of my apartment, to the medium-sized system it is today, firmly anchored in the backyard of my home in Indianapolis.

Ralf Seip

Even though I have always been interested in eventually generating the majority of my family's electricity with a photovoltaic system, I must say that I did not specifically design my initial system with this goal in mind. I was pleasantly surprised, however, to find out how easy it was to add components as I expanded my system and new technology became available.

Throughout this growing process, panels, power centers, batteries, and controllers have been wired, rewired, taken down, relocated, and put back up many times. This work was fun and a great learning experience, but would have been a bit easier if future expansion had been considered from the very beginning!

Planting the Seeds

My earliest system saw its first rays of the sun in February 1996. At that time, I was living in a second-floor apartment. I mounted my first two Solarex MSX-60 panels on the balcony, without worrying too much about true south, panel shading, the perfect mounting angle, or even what other tenants or the landlady might say. I was harnessing the energy of the sun to power my computer and two compact fluorescent lights—that's all that mattered at that time!

From the very beginning, this system included an automatic transfer relay commonly used to switch loads to a generator when the battery voltage is low. I used it to switch loads between the solar-electric system and the utility. This allowed me to install this system in an apartment without modifying any of the existing AC wiring, and provided automatic switching to the utility to give the panels time to recharge the battery bank.

The first solar-electric "seeds" of the Seip system—two 60-watt PV panels—were installed on an apartment balcony.

The system began to grow as two panels were added, and the array was relocated to the Seips' first house.

At the time, I made two decisions that proved invaluable—I configured the system as a 24-volt system, and I chose a sine wave inverter. This allowed me to use thinner and less expensive wires, and run practically all sensitive loads without having to worry about noise or interference. Systems at 24 volts were just coming on the market then; today, most systems use this or higher voltages.

Add Plenty of Sun

Later that year, we purchased our first house, and with it, of course, two additional panels! I got my first experience at tearing my system down and reassembling it at its new location. The panels found a new place under the sun, and my little power center remained unchanged, but it and the batteries were moved to the basement.

Rather than rewiring the house to accommodate the new system, I decided to stick to the transfer relay setup, and installed "solar-only" receptacles where possible. I was now powering my computer, a printer, TV, VCR, radio, two lights, and an electric weed whacker. I was happily surprised that the little 500 W Exeltech inverter was up to the task.

I monitored the batteries with an E-Meter, another good investment that I purchased at the very beginning. It has allowed me to keep track of the batteries' state of charge from the day that they were purchased, and I never allowed discharges greater than about 30 percent. If the batteries did fall below this level, I would turn the inverter off. The transfer relay would immediately switch all connected loads to the grid, with barely a flicker. The transfer from solar electricity to grid electricity was thus simple and easy. The

E-Meter also showed me how much the various loads were consuming, important knowledge for anybody wanting to use solar electricity to charge batteries, no matter how big or small the system.

It also showed me one other thing—I was consuming energy faster than I could produce it! The inverter spent many hours in its "off" position, waiting for the sun to recharge the batteries. This was solved a year later by the addition of four more panels. I now had a fairly respectable, small-sized system—480 W of solar-electric panels, 5.3 KWH of battery capacity, 500 W of sine wave AC, and state-of-the art battery monitoring capability—powering many small loads in my house.

This year, we moved again, this time into my wife's dream home. With its long, south-facing backside, it's also my dream home.

Watch It Grow

Two years later, I took a new job in a different state. Tearing down the system turned out to be simpler than expected. I was able to take everything down and pack it up in about a day, except for the extra solar-only wiring that I had installed in our house—that stayed. I was now getting good at mounting and rewiring the modules. Subarrays consisting of four modules each (two series strings of two modules) turned out to be excellent building blocks to assemble the full array, consisting of three subarrays.

Some interesting things were beginning to happen. Systems at 24 V were becoming more commonplace, the price per module was dropping (from US$398 for 60 W in 1996 to US$282 for 60 W in 2001), and my demand for clean electricity kept on increasing. I was now truly hooked on solar energy!

I added Hydrocap recombiner caps to reduce the amount of water I needed to add to my now aging battery bank, and discovered additional interesting ways to run separate solar-only wiring and receptacles throughout the house. This was made especially easy because the new place for the batteries and inverter panel in our second home was underneath a centrally located stairwell. I was now powering a few additional loads, including another light, a DVD player, and my wife's sewing machine. My demand had again outgrown my supply—it was time for a major overhaul!

Again, this turned out to be simpler than I thought, especially because of the 24 V choice, the four-module subarrays, and the relay transfer box setup. I added a new 1,800 W sine wave inverter, increased the battery bank to 11 KWH of storage, and added 512 W of solar-electric modules.

During this expansion, only one originally purchased item had to be outright replaced. The 20 A charge controller was undersized for the 1,232 rated W at 24 VDC of solar generation capacity. The Heliotrope charge controller was retired after more than six years of excellent service. I

Demand quickly outgrew supply, prompting the addition of four more panels.

Why Not Grid-Tie?

Grid-tie systems were not common in 1996 when I started planting the seeds of my first solar-electric system. Besides, batteries provided a nice backup and true feeling of independence when grid outages did occur. These were quite frequent during our stay in Michigan, so a battery-based system made sense. Outages have not been common in Indiana, reducing the need for batteries since then.

Hassles, regulations, and requirements associated with utility-interactive systems have also kept me from using them. Furthermore, grid-tie systems require a much larger initial investment than small, battery-based systems. It is not uncommon to read in *Home Power* about "entry level" grid-tie systems that require at least 500 watts of PV (preferably more) and at least a 700-watt inverter before any electricity can be produced at all, with initial investments approaching US$5,000.

It is, of course, still possible and easy to further grow such systems by adding more modules and inverters, while following similar guidelines as those outlined in this article. Growth with these systems, however, typically comes in larger "spurts," rather than the more affordable and smaller steps that I took with my battery-based systems. Our current home does have a larger, south-facing roof that looks a bit empty without solar-electric panels. Finances permitting, a grid-tied system could definitely be a nice addition to our current solar-electric farm!

Seip System Costs

Initial System: February 1996	Cost (US$)
2 Solarex MSX-60 panels	$796
Exeltech SI500 inverter	580
E-Meter (RS232, with shunt)	233
4 Trojan T105 batteries, 220 AH, 6 V	228
Heliotrope CC20 charge controller	175
TS-30 transfer relay, 30 A	60
Cables	50
Mounting hardware	40
Battery box	25
Subtotal	$2,187

First Enhancement: September 1996	
2 Solarex MSX-60 panels	$760
Battery box vent fan	50
Mounting hardware	40
Subtotal	$850

Second Enhancement: April 1999	
4 Solarex MSX-60 panels	$1,040
Mounting hardware	80
Exeltech inverter repair	50
Cables & hardware	50
Subtotal	$1,220

Third Enhancement: January 2001	
4 Solarex MSX-60 panels	$1,130
4 Lightning arrestors	140
12 Hydrocaps	100
Mounting hardware	80
Cables & hardware	50
Subtotal	$1,500

Fourth Enhancement: June 2002	Cost (US$)
8 Solarex MSX-64 panels	$2,260
Prosine 1800 inverter, 24 V	1,109
Solar Boost SB50 controller, with display	398
4 Trojan T105 batteries, 220 AH, 6 V	272
DC250 disconnect	231
TCB10 Combiner box & fuses	192
Mounting hardware	160
12 Hydrocaps	104
Cables & hardware	100
TS-30 transfer relay, 30 A	58
2 CD60 DC breakers	54
Battery box	40
Lightning arrestor	35
Subtotal	$5,013

Fifth Enhancement: June 2004	
4 Solarex BP365 panels	$1,040
Mounting hardware	60
Cables & hardware	25
Subtotal	$1,125
Grand Total	$11,895

constructed a new battery box and a new power panel, and the new inverter was mounted beside the older 500 W model, with its own transfer relay.

The new panels (again set up as subarrays of four modules each) were added in parallel to the existing array. A new array combiner box simplified this setup, and has left ample room for future expansion.

The price of solar-electric panels and related equipment had dropped again (the same US$282 for a 64 W module in 2002), and we were now powering the home refrigerator with this system, and sun permitting, an older washing machine. This new system also permitted us to plug in an iron (1,200 W!), and newly installed solar-only receptacles in the house allowed for plugging in the vacuum cleaner every once in a while.

This was great! Seven years into the expansion of my initial two-panel solar-electric system and about US$11,000 later, we had transferred a lot of our everyday loads to solar electricity, increased our electrical independence, and were reducing our electricity bill to the tune of US$13 to $15 each month (about 30% of our total consumption).

Reap the Fruits

This year, we moved again, this time into my wife's dream home. With its long, south-facing backside, it's also *my* dream home. It is located in a subdivision governed by covenants that actually permit solar installations, as long as they have "a minimum detrimental effect on adjoining properties."

After the architectural committee approved my solar-electric system proposal and we closed escrow on the home, it was time to dismantle my system yet again and prepare it for the move. During this disassembly and reassembly, I took the time to recheck and tighten all of the electrical connections of the overall system. The array racks were anchored in concrete. (We are planning to stay here for a while.)

Outfitting this new home with solar-only receptacles had now become second nature, and now the solar-electric system loads included two computers, two printers, four lights, two TVs, two VCRs, two DVD players, the refrigerator, a few small tools in the workshop, and the washing machine. The final enhancement occurred last year with the addition of 260 more watts of solar generating capacity.

Now some more interesting things were beginning to occur. The price for solar-electric modules had dropped

Tips for Growing a System

System voltage. Choose the highest system voltage to reduce resistive losses in the wiring and allow the use of thinner and cheaper wires. Changing system voltage later during system expansions can become costly, since battery-based inverters need to be replaced, and the system's panels and batteries need to be rewired completely.

The voltage setting of some charge controllers available today is user selectable. This allows you to purchase one charge controller and initially configure it to operate at 12 V, for example, and later reuse the same charge controller in a 24 or 48 V system, all with a simple jumper setting change. In addition, some maximum power point tracking (MPPT) charge controllers are designed to convert a higher PV array voltage to a lower battery voltage. These controllers allow a variety of array voltages, which may mean that modules can be added in smaller increments.

Array mounts. Choose an array mounting scheme that can be easily duplicated as more panels are added, allowing the aesthetics of the system to remain unchanged. Also, choose an initial array location that will accommodate more panels in the future. It can be costly to add additional wiring or combiner boxes to accommodate arrays located in a different place than those previously installed.

Wire size. If permanently installing and burying power cables/conductors, choose the correct gauge wire for the maximum planned capacity. Increasing wire gauge or adding additional conductors later to accommodate larger arrays or battery banks is more trouble than it is worth.

Inverter. I did not find it necessary to purchase a large inverter from the very beginning. Inverters can be added as demand increases, connecting a few subcircuits to one inverter, and moving other circuits to the new inverter as needed.

One big advantage of multiple inverters is increased system reliability. If one unit fails, the other inverter continues to power loads until the defective inverter is repaired. The disadvantage of multiple-inverter systems is that idle consumption increases with the number of inverters added. Multiple inverters will also usually cost more for the same total capacity.

Charge controller. Invest in a larger charge controller, to handle the higher charging current from added solar-electric panels. Most small systems could easily use more panels to provide more energy from the very beginning; a larger controller allows for just this.

Battery bank. Make sure that you have enough space available around the present battery location to allow for expansion. Moving the power center to a different location when you upgrade the battery bank can be expensive.

Overall system design. Finally, always design your system with expansion in mind, even though it seems adequate (or maybe even excessive) for your present needs. Believe me, once solar seeds have been planted, they keep growing!

The battery capacity doubled after the last major system expansion.

again (to US$260 for 65 W in 2004), and I noticed that I could no longer obtain the MSX-60/64 modules with which I had started building my array back in 1996. They had been discontinued! BP365 panels (with aluminum frames I painted black) were the closest replacement for size, and worked nicely, allowing for more expansion in the future.

So far, this has been the only drawback of growing my system slowly—specific solar-electric modules may become obsolete. This has been offset, however, by the smaller investments over time, and the ability to buy better and more state-of-the-art hardware as the system grows. Over the years, I've spent almost US$6,000 on solar-electric modules, at an average price per watt of US$4.86.

My system now consists of 1,492 W of solar-electric panels, 2,300 W of inverters (sine wave), a 10.6 KWH battery bank (in dire need of expansion), a 50 A maximum power point tracking charge controller, and code-compliant interconnect and overcurrent protection hardware.

The new power panel with two inverters, charge controller, transfer relays, and overcurrent protection breakers for safety.

For all practical purposes, our living room, home office, game room, basement, and half of the kitchen and laundry room are now completely powered by this solar-electric system. This midsize system is now able to provide approximately 35 percent of the electricity we consume in our household, and it has been a pleasure watching it grow over time. It is amazing what the right seeds and a little bit of sun can do. May your growing season and harvest be as rewarding and plentiful as ours has been!

Access

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Backwoods Solar Electric Systems, 1589 Rapid Lightning Creek Rd., Sandpoint, ID 83864 • 208-263-4290 • Fax: 208-265-4788 • info@backwoodssolar.com • www.backwoodssolar.com • PVs, charge controller, inverter, transfer relay

Electron Connection, PO Box 203, Hornbrook, CA 96044 • 800-945-7587 or Phone/Fax: 530-475-3401 • bob-o@electronconnection.com • www.electronconnection.com • E-Meter and shunt

Sun Electronics International Inc., 511 NE 15 St., Miami, FL 33132 • 305-536-9917 • Fax: 305-371-2353 • info@sunelec.com • www.sunelec.com • PVs

Mr. Solar/Online Solar, PO Box 1506, Cockeysville, MD 21030 • 877-226-5073 or 410-308-1599 • Fax: 410-561-7813 • sales@mrsolar.com • www.mrsolar.com • Inverter, charge controller, array combiner box, lightning arrestors

Northern Arizona Wind & Sun, 2725 E. Lakin Dr., #2, Flagstaff, AZ 86004 • 800-383-0195 or 928-526-8017 • Fax: 928-527-0729 • windsun@windsun.com • www.windsun.com • Hydrocaps

Affordable Solar, PO Box 12952, Albuquerque, NM 87195 • 800-810-9939 or 505-244-1154 • Fax: 505-244-9222 • sales@affordable-solar.com • www.affordable-solar.com • PVs

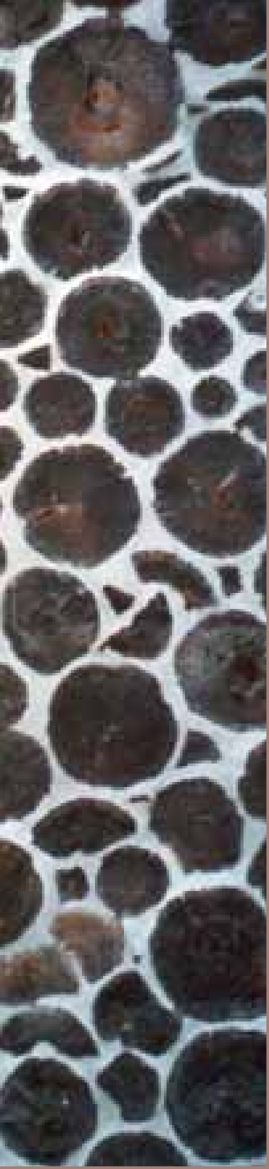
BP Solar, 630 Solarex Ct., Frederick, MD 21703 • 800-521-7652 or 410-981-0240 • Fax: 410-981-0278 • info@bpsolar.com • www.bpsolar.com • PVs

Xantrex Technology Inc., 5916 195th St. NE, Arlington, WA 98223 • 360-435-8826 • Fax: 360-435-3547 • info@xantrex.com • www.xantrex.com • Inverters, breakers, DC disconnect

Exeltech, 2225 East Loop 820 North, Fort Worth, TX 76118 • 800-886-4683 or 817-595-4969 • Fax: 817-595-1290 • info@exeltech.com • www.exeltech.com • Inverter

Blue Sky Energy Inc. (formerly RV Power Products), 2598 Fortune Way Ste. K, Vista, CA 92081 • 760-597-1642 • Fax: 760-597-1731 • sales@blueskyenergyinc.com • www.blueskyenergyinc.com • Charge controller

Trojan Battery Co., 12380 Clark St., Santa Fe Springs, CA 90670 • 800-423-6569 or 562-946-8381 • Fax: 562-906-4033 • marketing@trojanbattery.com • www.trojanbattery.com • Batteries



Cordwood CONSTRUCTION

Rob Roy
Adapted from *Cordwood Building: The State of the Art*

Cordwood masonry—the art of building a wall using log-ends laid within a mortar matrix—is an old building technique found in Europe, Canada, and the Upper Midwest. Today, cordwood buildings still offer many practical benefits to owner–builders, homeowners, and the environment. Unskilled owner–builders find working with cordwood to be relatively easy, and some find it less expensive to build with than conventional materials. Designed right, cordwood structures also can be energy efficient, providing effective insulation and significant thermal mass. Cordwood buildings can use lesser quality, small second-growth logs or even used building materials. And then there's the unique beauty of cordwood, which many people love!

Rob and Jaki Roy's Earthwood house in West Chazy, New York.

Cordwood Style

Cordwood easily incorporates into three structural styles: buildings with load-bearing curved walls, post-and-beam frames, and stackwall corners.

My wife Jaki and I built Earthwood, a round house that uses cordwood masonry as a load-bearing structure. A heavy earthen roof, which sometimes bears the additional weight of snow, sits on two full stories of cordwood masonry. This bears witness to cordwood's good compressive strength—its ability to withstand heavy loads without crushing.

Cordwood also is well suited for use as infill between posts in a post-and-beam or timber-framed structure. For building in earthquake-prone regions, using cordwood as infill in a post-and-beam structure is the only type of cordwood building I recommend.

Stackwall corners consist of alternating corner pieces called *quoins* or Lomax corners.

Another cordwood building technique uses stackwall corners, which enable builders to make extremely thick cordwood walls of 24 inches (60 cm) or more. This method uses squared log-ends called *quoins*.

Cordwood building suits a wide variety of skill levels and abilities. Here, Marjan Koleric, Earthwood Building School student and octogenarian finishes pointing a cordwood wall.

How Much Wood Is Enough?

For cordwood building, the best measure to work in is—no surprise—the cord. A full cord is a stack of wood that measures 4 feet tall by 4 feet wide by 8 feet long (1.2 x 1.2 x 2.4 m), or 128 cubic feet (3.6 m^3). But full cords and cubic feet confuse the issue of cordwood building. The calculations are easier and more accurate in "face cords." Face cords are also 4 feet high and 8 feet long. But the depth or thickness of the stack is whatever uniform length the wood is cut into—usually 12, 16, or 24 inches (30, 40, or 60 cm).

Your climate, the type of wood you choose, and the shape of the house you're building will determine how thick you'll need to make cordwood walls. Our upstate New York home's 16-inch-thick white cedar walls have an insulation value of about R-19 or a little better, which works well in our climate. In Canada and Alaska, 24-inch-thick walls are quite common. In the South, where the energy costs of cooling can equal or exceed heating costs, 12-inch-thick walls are adequate, but the thermal mass provided by thicker walls might also help to make the home even easier to cool. Homeowner George Adkisson tells me that the 12-inch-thick cordwood masonry walls of his home on the Gulf Coast of Texas reduce his air-conditioning costs to about half that of similarly sized, conventionally built homes in the area.

Choosing Cordwood

The best choices for cordwood building are woods that shrink and expand the least. Woods such as white cedar, larch (or tamarack), white pine, spruce, cottonwood, lodgepole pine, and quaking aspen are considered more stable woods for cordwood building. Red pine, Virginia cedar, and red cedar also have been used with success. These woods can be used fully dry, without serious expansion or shrinkage problems. Avoid using dense, heavy, fine-grained woods, which tend to both shrink and expand a lot.

In cordwood building, the problem that occurs most often is log-end shrinkage. While this problem can be irritating, inconvenient, and aesthetically unpleasing, it won't impact the building's structural integrity. However, wood expansion, while much more rare, can be a critical problem. In a curved cordwood wall, wood expansion will cause the wall to go out of plumb. Within a post-and-beam framework, the expanding wood can push corner posts out, no matter how they are fastened, and cause plate-beams to lift at the top of the cordwood wall. Stackwall corners, made of alternating quoins (or Lomax corners), will be pushed out in both directions by expanding cordwood.

Woods more prone to shrinkage are also the ones most prone to expansion. Hemlock is prone to great shrinkage. Hardwoods, such as oak, maple, birch, beech, and elm, as well as some dense Southern pines have potential expansion problems, particularly if they are dried too long before building.

Split or Round?

Whether you want to use round or split log-ends is generally an aesthetics issue. The main reasons for splitting wood are to accelerate the drying process, to eliminate the large "primary checks" seen in rounds, and to reduce the size of shrinkage gaps. Shrinkage is proportional, so the smaller the log-end, the smaller the shrinkage between wood and mortar. But smaller pieces require more handling of materials, and mixing more mortar too.

Beautiful cordwood walls can result from using all split wood, all rounds, or a combination of the two. The important thing is to maintain a consistent style, which means making a conscious effort to deplete the various sizes and shapes of log-ends in your stock at the same rate.

De-Barking

The space between the bark and the epidermal layers of the wood can trap moisture and provide habitat for fungi and bugs. De-barking remedies this potential problem. Almost any sharp or flat tool can serve as a peeling spud—an axe, pointed trowel, scraper, or even a flattened garden hoe. When de-barking is difficult, the tool of choice is a drawknife, a two-handled tool with a sharp blade edge. Using a drawknife—normally a killer of a job—is safer and easier with the long logs supported at a convenient height.

Goldec International Equipment manufactures a chain saw attachment for "barking wood," called a Log Wizard. This device adapts to both 3/8-inch and 0.325-inch-pitch chain, and allows your saw to be used for de-barking, post sharpening, or as a notcher–planer.

Cutting Cordwood

Most people use a chain saw to cut long logs into log-ends. Another good way to cut cordwood is with a large circular saw, typically 30 inches (76 cm) or so in diameter. These saws are commonly connected to a tractor's power take-off (PTO) by a belt. The long length of wood is set on a movable table tilted towards the saw, which cuts off the ends quickly with a nice, straight cut.

Cutting log-ends, by any means, must be considered a dangerous activity. Always use proper ear and head protection. Wear logger's safety chaps to protect your legs. Keep all

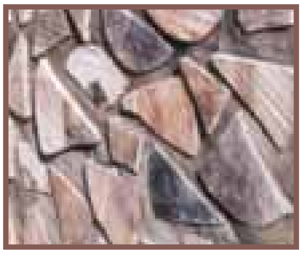
Figuring Face Cords

The area of a face cord's side is always 32 square feet (3 m^2)—this is the magic number to use in your calculations. From your building plans, figure the square footage of wall area that will be cordwood masonry. Subtract doors, windows, and heavy timber framing from the gross wall area to arrive at this figure.

For example, a house with a perimeter of 125 feet (38 m) and a wall height of 8 feet (2.4 m) has 1,000 square feet (93 m^2) of gross wall area. For this example, let's say the windows, doors, and post-and-beam frame make up 20 percent of the wall. (You can figure this accurately from your plans.) Subtracting 20 percent—200 square feet (19 m^2) in this case—leaves 800 square feet (74 m^2) of actual cordwood masonry. Now divide by the magic number—32 square feet—that gives, in this example, 25 face cords. You can safely discount 20 percent from this number, because the area of coverage increases by at least that much when the cords are restacked with mortar. So if you had 20 face cords cut to a length to match the thickness of your wall, you will have plenty of wood, and enough to reject misshapen pieces that you don't like or that are troublesome to use.


All rounds.


Splits and rounds.


All splits.

children, animals, and unnecessary people away from the cutting area. Before using any kind of cutting equipment with which you are unfamiliar, get training from an expert.

Drying Wood

With the more suitable woods, drying the wood a year or more usually causes no problems. A year's drying at log-end length will go a long way toward preventing shrinkage, and will help alleviate expansion problems. If you must use a denser species of wood, split the wood and dry it for about six weeks in good drying conditions. Although some shrinkage will still occur, most expansion will be curtailed.

Because wood dries ten times faster on end-grain than through the outer layers of the wood, the real drying will take place after longer logs are cut into their final log-end length. Split wood also dries faster than unsplit wood. Dry the wood in single ranks, keeping it off the ground by using wooden stringers or pallets. Cover only the top of the rank, not the sides. Covering the sides traps moisture, making conditions ripe for rot-producing fungi.

Putting It Together

At the Earthwood Building School in West Chazy, New York, we have refined a mortar mix that incorporates soaked sawdust to slow the mortar's initial set. Mortar that dries slowly will shrink less or not at all, which eliminates shrinkage cracks between log-ends. The sawdust should be passed through a 1/2-inch screen and immersed at least overnight in an open-topped 55-gallon drum or other soaking vessel.

Sturdy cordwood walls provide beauty inside and out.

This timber-frame building in British Columbia uses cordwood as infill.

"Suitable" sawdust, in our experience, is larger and less dense particles of softwood sawdust. White cedar, white and red pine, spruce, and even poplar sawdust works well. Oak and other dense hardwood sawdust has not proven to be successful. Hardwood sawdust doesn't hold and store the moisture the same way that the softer, lighter, softwood sawdust does, and mortar shrinkage is the result. In fact, hardwood sawdust seems to make the mortar more grainy, crumbly, and harder to use. If you cannot get suitable sawdust, use a commercially available cement retarder such as Daratard 17 or Plastiment (see Access).

Two mixes work well with suitable sawdust—Portland cement mix and masonry cement mix. The proportions given are equal parts by volume, not weight.

- Portland cement mix: 9 parts washed masonry sand, 3 parts soaked sawdust, 3 parts lime, 2 parts Portland cement
- Masonry cement mix: 9 parts washed masonry sand, 3 parts soaked sawdust, 3 parts masonry cement, 2 parts lime

Use washed masonry sand, not coarse-grained sand. The sawdust should be the softer, lighter type, already discussed. Portland cement, Type I or Type II, is full-strength cement. I've had good luck with Types M and N masonry cement. The lime is builder's lime, also known as Type S or hydrated lime.

(continued on page 42)

Step-By-Step Cordwood Construction

You will need strong, cloth-lined rubber gloves throughout the project, including during the mortar mixing process. Cementitious products, wet or dry, will eat nasty little holes in your hands that can be painful and take a long time to heal.

The first course of wood laid on top of the first layer of mortar.

Dry-mix the mortar materials in a wheelbarrow with an ordinary garden hoe until everything is a uniform color. Then make a little crater in the center of the mixture and add water. How much depends on how wet the sand and sawdust is. For the first batch of mortar, go easy on adding water, perhaps only a quart or two. Mix it in thoroughly and test the mixture by tossing a baseball-sized glob of mortar three feet in the air—one meter in Canada—and catch it in your gloved hand. If it shatters or crumbles, it is too dry. If it goes "sploot!" like a fresh cow pie, it is too wet. If it holds its shape, doesn't crack, and is plastic, it is just right. If the mortar is too dry, add more water, remix, and test again until it is right. If it's too wet, add more dry goods in the same proportions until it is right. You can leave out the wet sawdust if the mix is really soupy, or you'll never dry it out enough.

The second course of wood laid on top of the second course of mortar.

Bring the mortar to the site in the wheelbarrow. You can work out of the barrow or load up a metal or plastic mortar pan for convenient access to the "mud."

The foundation should be swept and dampened slightly. Several sizes of prepared log-ends should be within arm's reach. For discussion, we'll assume a 12-inch-thick wall. Picture that wall's footprint divided into thirds—a mortar and sawdust sandwich. We use MIM (mortar–insulation–mortar) sticks to help gauge this proportion. The MIM divisions are marked right on the stick, which can be a 12-inch-long piece of scrap board. Make two or three for your project.

The timesaving building mantra is: Mortar. Insulation. Wood. Using your gloved hands, grab a glob of mud and plunk it down on the foundation, about an inch thick. (If your MIM stick is made from 1-inch-thick material, it can double as a mortar depth-checker!) Keep adding more mud, extending the 4-inch-wide (10 cm) mortar bed for 3 or 4 feet (91–122 cm). Now do the same thing for the other parallel mortar bed.

Next, with a small, spouted bucket, pour in the lime-treated sawdust insulation up to the same level as the mortar.

Now grab a log-end and set it on the mortar, spanning the insulation. A slight, vibrating, back-and-forth motion is all that is needed to establish a suction bond to the mortar. (Later, this suction bond becomes a friction bond, which is the best you can hope for—no chemical bond between wood and mortar will occur.) The next log-end is placed beside the first, leaving about 1 inch between log-ends. Continue until all the mortar is covered.

Work laterally around the home, a course or two at a time, or in the case of cordwood panels within a post-and-beam frame, work three or four courses high at a time. Remember, avoid mixing up more wet mortar than you can comfortably use before it sets up.

The mantra doesn't change on the second course—put the mud down first, following the hills and valleys formed by the first course. Then add the sawdust. Use your gloved fingers and thumbs to pre-settle the sawdust in the spaces between log-ends. Bring the sawdust up to the level of the mud.

Now, select a log-end that has fits the shape defined by the previous mortar course. If you keep a variety of large and small log-ends nearby, choosing the right log-end will become easy with experience. Again, place it with a gentle, vibrating set. You don't have to pound it in, although sometimes a gentle tap with a small hammer is helpful. If the log-end doesn't seem to want to "sit," it is almost always because you've used too much sawdust, which is now trying to spring the log-end back up again. Remove a little sawdust and try again. The other possibility, although rare, is that an irregularity on one or both of the log-ends is getting in the way.

Leave about an inch of space between log-ends, so that you can work with your pointing knife. With cordwood masonry, pointing serves to maximize the friction bond between wood and mortar, as well as beautify the wall. Even a poorly laid wall can be salvaged with some good pointing. Good pointing also smooths the mortar, creating a more water-repellent exterior surface, and a less dusty interior wall. If the pointing is recessed slightly, and all the log-ends in the wall shrink, it will be easy to conduct a repair. Recessed pointing also looks better—the log-ends are the defining features of a cordwood wall, and having them "proud" of the mortar is what gives a pleasing surface texture.

You'll need a few pointing knives. Raid your local thrift stores or garage sales for nonserrated butter knives. I like the ones that are almost an inch wide, but it is good to have a variety. Bend the last inch of the knife to a 15- or 20-degree angle, so that you can get the business end in close to the work without your knuckles getting in the way.

First, "rough point" the wall, using just your gloved fingers. Remove excess mortar and catch it in your gloved hand. Then use your knife to press the excess mortar into any gaps. For the finished pointing, press quite stiffly with the knife blade, and draw the mortar out smooth, removing knife marks, if possible. How fussy you want to be is up to you, but be consistent. Above all, don't over-point— repeatedly going over the work will bring a lot of water to the surface, causing the mortar to crack within a few days.

Smoothing and pointing the mortar is the final step.

Don't forget to wash your gloves and tools, and cover the work for the night.

As mortars, these two mixes are very similar in terms of hardness, strength, workability, and smoothness. The main difference is color. The Portland mix tends to be lighter and more of a green-gray shade; the masonry mix usually is a blue-gray color.

Mortars mix well in a wheelbarrow. Add the dry ingredients to the barrow by the shovelful. Following the series below will help ensure a uniform mixture. For the Portland mix, combine:

- 3 shovelfuls sand, 1 shovelful sawdust, 1 shovelful lime, 1 shovelful Portland
- 3 shovelfuls sand, 1 shovelful sawdust, 1 shovelful lime, 1 shovelful Portland
- 3 shovelfuls sand, 1 shovelful sawdust, 1 shovelful lime

With the masonry mix, a good cadence for adding material is:

- 3 shovelfuls sand, 1 shovelful sawdust, 1 shovelful masonry, 1 shovelful lime
- 3 shovelfuls sand, 1 shovelful sawdust, 1 shovelful masonry, 1 shovelful lime
- 3 shovelfuls sand, 1 shovelful sawdust, 1 shovelful masonry

The numbers in these mixes refer to equal parts by volume, so always use the same size shovel and load it the same way each time. Reserve a separate shovel of the same size for the soaked sawdust—and keep this wet shovel out of the dry cementitious materials.

What about Rot?

Within a cordwood wall, fungi have access to nutrients and air, but not moisture—the third ingredient they need to thrive. The exposed log-ends are permeable along their end-grain and readily release any moisture. To further diminish the chance of wood rot, follow these four easy strategies:

- Start the cordwood masonry at least 4 inches (10 cm) above grade, on a good foundation made from concrete, cement blocks, earth bags, or stones. In wet climates, increase this to 12 inches.
- Design ample roof overhangs: 16-inch overhangs are good, but 24-inch overhangs or more are even better.
- Keep adjacent log-ends from touching each other. Prevent log-ends from contacting the surrounding post-and-beam frames.
- Build only with de-barked, dry log-ends. Reject wood that shows any sign of existing rot or deterioration.

The Importance of Insulation

A cordwood wall derives its resistance to heat flow from the insulated space between the inner and outer mortar joints. If this space is uninsulated, the house will be very difficult to heat.

Several insulation options exist. Fiberglass is a readily available material, but it can be nasty to work with (gets in the eyes and lungs); it has a high embodied energy; and, if it mats down with moisture, it may not fluff back again. Vermiculite, perlite, and other loose-fill insulation work quite well, but can be costly. Using shredded beadboard insulation, made out of expanded polystyrene beads, may seem like a good way to recycle this material, but it is virtually impossible to direct it into a wall cavity. The little beads stick to the mortar, your gloves, your clothes—they go everywhere, it seems, but where you want them. And the slightest wind causes an insulation disaster.

Sawdust is cheap, makes use of a "waste" material, and has an insulation value of about R-3 per inch, about the same as fiberglass. And it's easy to pour into the space with soup cans or small buckets. To retard against vermin, mix builder's lime into the sawdust at a ratio of twelve parts sawdust to one part lime. An additional benefit to adding lime is that if the wall takes on moisture, the lime will set up with the sawdust in the wall, forming a kind of rigid insulation.

Cordwood Basics & Beyond

Now that you have the basic background on cordwood, start experimenting! Small cordwood structures are fairly straightforward and easy to build, and cordwood easily lends itself to whimsical structures—from children's playhouses to potting sheds. For more details on building with cordwood, read *Cordwood Building: The State of the Art* or consider attending a workshop for hands-on experience (see Access).

Access

Rob Roy, Earthwood Building School, 366 Murtagh Hill Rd., West Chazy, NY 12992 • 518-493-7744 • robandjaki@yahoo.com • www.cordwoodmasonry.com • Rob Roy has written thirteen books about alternative building techniques, including five about cordwood masonry.

Continental Cordwood Conference in Merrill, Wisconsin, July 30 & 31, 2005. Lectures & demonstrations by Rob Roy, Alan Stankevitz (see *HP105*), Jack Henstridge, Cliff Shockey & others. Tour cordwood homes. For info, go to www.daycreek.com, e-mail organizer Richard Flatau at flato@aol.com or call him at 715-536-3195. Registration: US$100 for an individual, US$180 per couple.

Goldec International, Box 3299, Spruce Grove, AB, Canada T7X 3A5 • 877-640-2240 or 780-960-2727 • Fax: 780-960-2767 • info@logwizard.com • www.logwizard.com • Log Wizard chain saw attachment for de-barking wood

Sika Corp., 30800 Stephenson Hwy., Madison Heights, MI 48071 • 248-577-0020 • Fax: 248-577-0810 • sikainfo@sika-corp.com • www.sikausa.com • Plastiment cement admixture

Grace Construction Products, 62 Whittemore Ave., Cambridge, MA 02140 • 617-876-1400 • Fax: 617-234-7548 • concrete@grace.com • www.graceconstruction.com • Daratard 17 cement admixture

Cordwood Building: The State of the Art, by Rob Roy, 2003, Paperback, 240 pages, ISBN 0-86571-475-4, US$26.95 from New Society Publishers, PO Box 189, Gabriola Island, BC, Canada VOR 1XO • 800-567-6772 or 250-247-9737 • Fax: 250-247-7471 • info@newsociety.com • www.newsociety.com

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Harvesting Rainwater

Michael Durland

Photos by Kat Fennell

These two, 2,800-gallon polyethylene storage tanks can provide about a three months' supply of rainwater for a water-conserving household of two.

Rainwater catchment is a simple and cost-effective practice that we all can do, whether it's small scale, providing water for a few tomato plants—or large scale, supplying all of a household's needs.

As the world's population continues to grow, so has our appetite for resources, especially water. All over the world, groundwater levels are falling as water is pumped out and consumed faster than it is naturally replenished. Everyday human activities—such as sewage disposal—as well as heavy industry and agriculture, continue to pollute and deplete groundwater sources. To add injury to insult, in the United States more than 50 percent of the wetlands that recharge and purify groundwater have been destroyed. On islands and in nearshore regions, pumping too much water from wells can result in saltwater intrusion into aquifers, rendering the water unfit for drinking or irrigation. Once saltwater is drawn into a well, freshwater will not likely ever replace it; in many cases, the well must be abandoned.

Collecting and using rainwater can help protect aquifers and groundwater tables, as well as offer better quality water for drinking, cooking, bathing, washing, and irrigation. Because it's captured before it hits the ground, rainwater is far less contaminated than most surface and underground water supplies.

Rainwater, being naturally distilled, does not have the minerals that groundwater contains, making it ideal for showering and clothes washing. Rainwater lathers and rinses better than most groundwater, and clothes washed with rainwater are often softer.

Having a barrelful of rainwater can tide you through an emergency, such as a power outage or if your well pump fails. And having a tank of rainwater handy could save precious fruit trees or vegetables during a drought, when restrictions are placed on municipal water use.

After the initial investment of storage and filtration equipment, harvested rainwater is free, which may be one of the best reasons to invest in a catchment system.

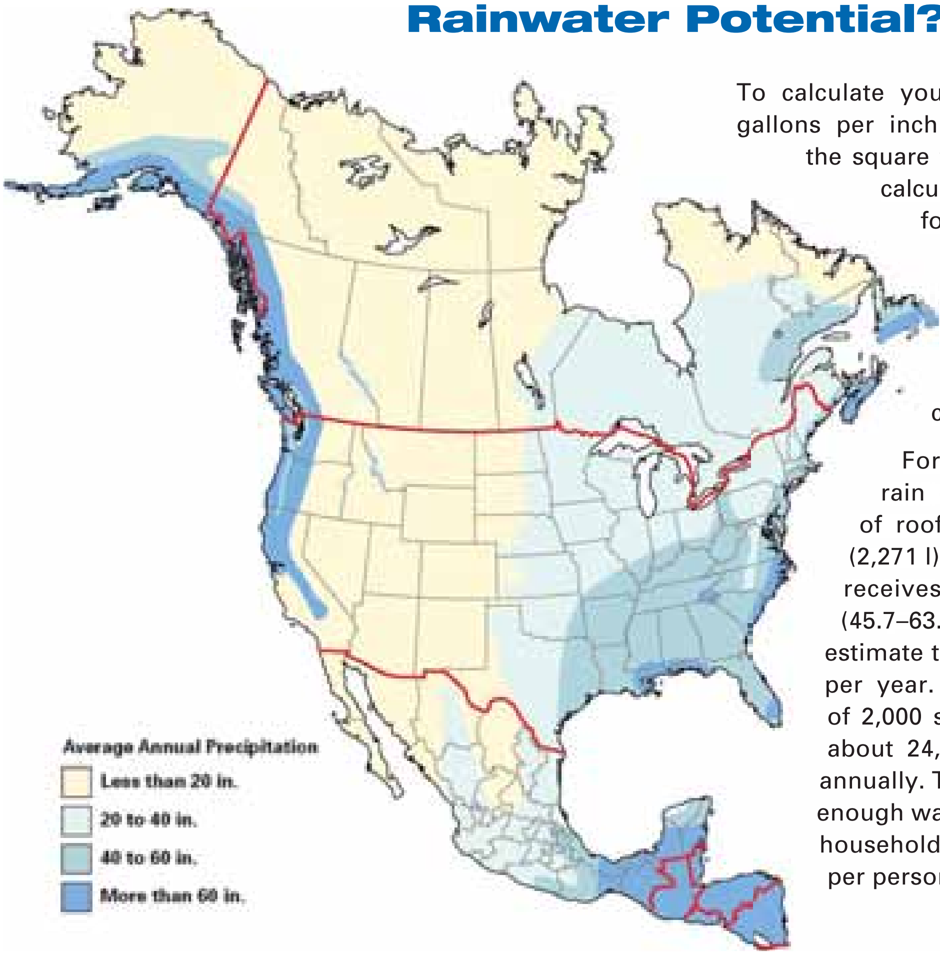
Catch & Store

The best surfaces for catching rainwater are smooth, enameled metal or tile roofs. All roofs should be tested for lead and other contaminants if the rainwater is intended for potable use or for watering edible plants. Asphalt-shingled roofs are not recommended because they may shed unwanted compounds into the water. Cedar shake roofs will catch more dirt and leaves, which may end up in the water, and may also impart a yellowish color to the water due to tannins leached from the wood. This yellowish color stains clothing and fixtures, and can reduce the transmittance of ultraviolet (UV) light and may diminish the effectiveness of a UV-light treatment system used to purify rainwater for drinking. Avoid harvesting rainwater off of treated wood-shingle roofs, which may leach toxic chemicals into the water. To be safe, always test your harvested rainwater before using it in your home or garden.

A rainwater storage system can be as basic as an old, watertight whiskey barrel or 55-gallon (208 l) plastic drum. Folks with greater rainwater aspirations may choose to use large polyethylene ("poly"), potable water, FDA approved, tanks, which are lightweight and relatively low cost. These tanks come in a range of sizes, the most cost effective being the 2,500- or 2,800-gallon (9,463 or 10,599 l) size. Poly tanks also come in larger sizes (5,000 and 10,000 gallons; 18,927 and 37,854 l), but shipping costs often outweigh the cost savings in purchasing a large tank. Some states

The basic components of a rainwater irrigation system, including pump and pressure tank, in an insulated box.

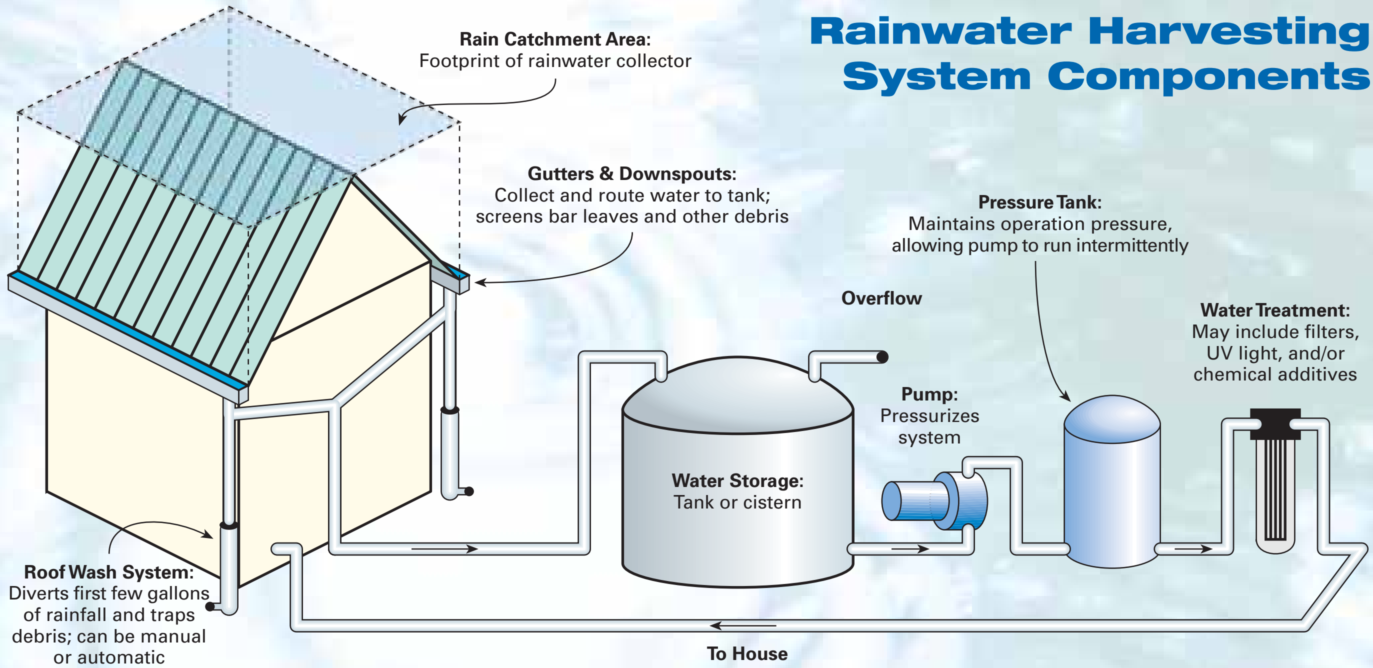
What's Your Roof's Rainwater Potential?



To calculate your roof's rainwater potential in gallons per inch of rainfall, multiply 0.6 times the square footage of your roof. Be sure to calculate the roof area by the roof's footprint, rather than by the roof's surface area. (For the same-sized home, an A-frame-style roof has more square feet of roofing, but has the same amount of rainwater collection capability as a flat roof.)

For example, 1 inch (2.5 cm) of rain on 1,000 square feet (92.9 m^2) of roofing area will yield 600 gallons (2,271 l) of water. I live in an area that receives between 18 and 25 inches (45.7–63.5 cm) of rain per year. I usually estimate the rainfall at 20 inches (50.8 cm) per year. Using this figure, a roof area of 2,000 square feet (185.8 m^2) will yield about 24,000 gallons (90,850 l) of water annually. This roof area will capture almost enough water to supply a water-conserving household of two using 35 gallons (132 l) per person, per day.

Rainwater Harvesting System Components



require a building permit for tanks with more than a 5,000-gallon capacity. Instead, smaller polyethylene tanks can be plumbed together to increase storage capacity. (Note: Do *not* use tanks designed for septic systems for rainwater storage.)

Larger tanks made of wood, concrete, ferro-cement, fiberglass, steel, or steel with a liner can be used to hold greater volumes of water. Whatever type of storage tank is selected, well-designed systems include an overflow pipe that is directed away from the base of the tank to prevent excess water from washing out the tank's foundation.

The simplest systems place barrels or tanks directly under a downspout. Another option is to route multiple downspouts to a small catchment basin and pump the water to a tank or tanks located away from the house. On properties with varied topography, tanks may be placed on high ground, enabling gravity flow back to the point of use. Every 2.3 feet (0.7 m) of elevation or head produces 1 pound (0.45 kg) of pressure. This means that a head of 23 feet (7 m) will produce a gravity flow of 10 pounds (4.5 kg) of pressure—enough for faucets, but not enough to push the water through most filters. Most rainwater harvesting systems will need a pump and a pressure tank, since the vertical distance between the tank and the point of use usually is not great enough to provide adequate pressure for normal household use.

Filter First

The more organic matter you can prevent from entering the storage tank, the better your water quality will be. Even if you just want to use the water for irrigation, having a filtration system to remove large leaves and other debris helps prevent pipes and fittings from clogging.

Gutter screens, downspout traps, or strainers in the top of the tank can all be used to filter out coarse debris. Screens on the gutter are the first line of defense, and are simple

In this multiresidence, potable water system, rainwater first passes from the pump to a pressure tank, and then is routed through a sediment filter, two carbon block filters, and a UV-light purifier before being distributed.

and inexpensive to install. A manufactured downspout clean-out, which replaces a section of downspout with a screened catch, also works well. A larger basket-strainer of 20 mm (0.79 in.) mesh, which fits inside a barrel or polyethylene tank, also is effective. For best results, use all three methods.

Roof washers collect and discard the first few gallons of water that wash from the roof, and protect your storage tank from debris that slips through the screens. Several types are available, ranging in price from US$100 to about US$600. One simple roof washer consists of a small reservoir, which fills with the first batch of roof water. After it fills, a floating ball plugs the reservoir's opening and water is diverted to the storage tank. A small hole in the bottom of the reservoir allows the water to slowly drain and readies the roof washer for the next rainfall. Other roof washers combine filtration and pumping in one unit. Although roof washers remove some debris, washers can never completely remove all of them. All require regular maintenance to prevent clogging.

Rainwater Uses

Water used for irrigation can be pumped directly out of the storage tank. If you are using drip irrigation or soaker hoses, consider filtering the water after the pressure pump. Most drip systems function best with 10- or 20-micron filtration.

Rainwater destined for potable use requires both filtration and treatment to remove bacteria and viruses. Three common methods of treatment are chlorination, ozonation, or UV-light treatment. For a whole-house water purification system, UV-light units typically are the most trouble-free and easiest to maintain.

When rainwater systems are the only source of water for a whole-house water system, local health departments usually require that the storage capacity must maintain the household for a period of three months without any recharge of the storage tanks. On a backup system, this requirement is not usually enforced. In Washington State, San Juan and Jefferson counties have approved building permits with rainwater catchment systems based on a usage of 35 gallons (132 l) per person per day. (The average American uses about 100 gallons; 378 l of water per day.) This requires using water-saving appliances like low-flow showerheads, low-flush toilets, and horizontal-axis clothes washers. Minimal or no outside watering is allowable if the rain catchment storage capacity is close to the minimum yearly usage calculated.

The best time to plan for rainwater catchment and use is during the design phase of your home. Rainwater can be used with minimal filtration for flushing toilets. And, in some areas, rainwater is permitted for use in showers or for laundry. It is important to understand your local regulations when designing and building a system. If you are retrofitting rainwater catchment to an existing system or using it to supplement an existing potable water supply, such as a community or municipal water system or well, be sure to install an approved backflow preventer between the existing system and the rainwater system.

This 27-foot-diameter, 14-foot-tall, steel storage tank, lined with an FDA-approved PVC liner, can store about 58,000 gallons of rainwater.

Many states, as well as municipalities, have regulations governing rainwater catchment. A few states require a water right for large-scale rainwater catchment systems. Check with your local agencies to determine the level of control on rain catchment in your area.

Costs

A small rain barrel to put under a gutter can cost as little as US$25. Larger polyethylene tanks, which hold more roof runoff, cost from US$950 for a 1,500-gallon (5,678 l) tank to US$1,200 for a 2,800-gallon tank. The 2,800-gallon size is the largest polyethylene tank that can be easily transported, and it is also the best value for your dollar. Larger steel tanks with liners cost from US$0.35 to US$0.65 per gallon of storage capacity. In addition to storage tanks, a whole-house rainwater catchment system with a booster pump, filters, and UV-light treatment can cost a few thousand dollars.

Rainwater harvesting systems are most economical in areas where the water supply is expensive, unreliable, or of questionable quality; in drought-prone climates; or in places lacking access to a municipal water supply. But whatever your situation or size of your wallet, a rainwater harvesting system can be installed almost anywhere for a cheaper and cleaner water supply.

Access

Michael Durland, PurRain Watertanks, 155 Channel Rd., Deer Harbor, WA 98243 • Phone/Fax: 360-376-2552 • michaeld@rockisland.com • www.purrain.com

Rainwater Collection for the Mechanically Challenged, by Suzy Banks & Richard Heinichen, Paperback, 108 pages, ISBN 0966417062, US$19.95 from Tank Town, 2770 Hwy. 290 W, Dripping Springs, TX 78620 • 512-894-0861 •

Fax: 512-858-2321 • info@rainwatercollection.com • www.rainwatercollection.com

Texas Guide to Rainwater Harvesting, Second Edition, by the Texas Water Development Board • Download at: www.twdb.state.tx.us/assistance/conservation/Alternative_Technologies/Rainwater_Harvesting/Rain.asp

NSF International, 789 N. Dixboro Rd., PO Box 130140, Ann Arbor, MI 48113 • 800-NSF-8010 or 734-769-8010 • Fax: 734-769-0109 • info@nsf.org • www.nsf.org • NSF-approved components for rainwater harvesting systems

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Biodiesel Appleseed

Homebrew Open-Source Reactor Design

Maria "Mark" Alovert

The author with the Appleseed, a community-designed biodiesel reactor.

A biodiesel reactor system can be built in as many ways as there are types of barrels, kegs, and tanks. This can be a blessing or a curse.

For a long time, biodiesel Web sites focused on chemistry more than on equipment. Limited details about reactor equipment left nonfabricator novices in the dark, especially when it came to recommendations for using salvaged materials. Then, along came some early vendors of homebrew "production" systems, selling an immature technology (see "Tank Talk" on the next page). Their advertising often exaggerated the difficulty of building homebrew equipment, quite possibly to justify their high prices for fairly unimpressive products.

The homebrew community responded by embracing the "open-source" concept borrowed from software engineers. This community-based method of developing safer and higher-quality products is founded on completely disclosing plans, encouraging changes, and not limiting either the free or the commercial use of the resulting products. Open-source philosophy believes in the power of many poring over a design—"many eyes make problems shallow."

Appleseed Biodiesel Reactor

In our case with the Appleseed biodiesel reactor, it was a smashing success. We began publishing detailed plans on the Internet for standard systems that anyone could build, and then incorporated changes submitted by users. This eventually lowered the entry barrier for biodiesel homebrewing and has made the process safer, after much discussion of the safety "bugs" in homebrewing equipment. The would-be "Microsofts" of biodiesel equipment have recently adopted many of our safety improvements as well, and a couple of businesses have sprung up around sales of the open-source reactor.

The Appleseed—a pressure-resistant, insulated, no-fumes, no-weld, metal reactor—uses parts found at hardware stores or available through a few U.S. catalogs. Parts cost between US$150 and US$350. A full system based on this design can be built for between US$250 and US$600. These easy-to-build systems require no special skills. They take about a day to put together, and can make for a nice work party. Be sure to serve barbecue, and remember the party part.

Amber Crowley and Keiko Suda assemble their first water heater tank-based biodiesel reactor at an East Bay biodiesel internship class.

Tank Talk

The flammable plastic tanks used by all of the ready-made biodiesel reactor vendors are an inferior material for reactors. Companies use them because they are the cheapest, lightest, conical-bottom tank available off-the-shelf. An early book on biodiesel suggested that these tanks made "ideal" reactors, leading biodiesel beginners to believe that white, plastic, and uninsulated are what a homebrew reactor should look like. In reality, you will never see plastic reactors in professional biodiesel plants, and they can be dangerous as home reactors.

Heating. As the photo below left demonstrates, directly heating the mixture to reaction temperatures in plastic tanks is unsafe. To avert the obvious dangers, some reactor vendors advise against heating at all. This significantly

When bad things happen to bad plastic—the remains of an early, ready-made reactor marketed in California. Luckily no one was hurt when this one leaked and caught fire. The Appleseed reactor offers an economical alternative.

Surrounded by a small orchard of Appleseeds, Rachel Nelson of Tucson, Arizona, puts the finishing touches on her reactor at a reactor-building work party.

The vent assembly at the top of this tank is set up for methanol recovery using a condenser.

reduces biodiesel quality. An unheated reaction does produce some biodiesel and glycerol, but the emissions and long-term effects of burning that kind of poor-quality fuel are unknown. Heating ensures a more complete reaction and helps produce a high-quality fuel.

Insulation versus translucency. Many people like plastic tanks because, if left uninsulated, they are somewhat see-through. But because you'll want to insulate the tank, which lowers the energy required for heating, there's no point in buying a translucent tank. Without insulation, heating time is increased by many hours. An uninsulated tank can also lose heat during the reaction, which can result in a lower quality fuel. You don't need to see into the tank. You will see the contents as they drain through plastic tubing, so you will know when you have reached a different layer of the mixture.

Keep 'em sealed. Many people also make the incorrect assumption that they'll need a lid opening for their reactor to clean it out. You should never open your reactor, because potentially dangerous methanol fumes are always present. *No* respirator or filter will stand up to methanol fumes for more than a few minutes without methanol breakthrough.

There's no need to clean the tank manually. If anything solidifies in your tank, heating will remelt it, so the tank can be drained normally. If your reactor doesn't contain a heater, you should be extra careful to prevent batches of "soap glop" or solidifying glycerol.

The lower plumbing manifold allows the single drain hole of a water heater to be used for multiple purposes—filling and draining the tank, and for mounting the sight tube and temperature gauge.

Water Heater Prep

The Appleseed reactor is one-half of an inexpensive biodiesel brewing system. It is designed for use with a no-weld wash tank built from an upside-down, 55-gallon (210 l) drum. With a heat exchange system, the reactor is easy to solar heat, and with a condenser, it can be converted to a methanol recovery still.

Pros & Cons of the Appleseed Design

Advantages

- Sealed, no-fumes design
- Ceramic-lined water heaters resist biodiesel chemical corrosion
- Thermostatic control of oil heating
- Threaded plumbing—no welding, safer and less leak-prone than plastic plumbing and gasketed bulkhead fittings
- Quick assembly
- Universal off-the-shelf parts
- One pump accomplishes several tasks
- Low cost
- Handles vacuum for methanol recovery and handles some pressure
- Inexpensive scalability of system (just keep adding more US$20 wash tanks to increase output)
- Open-source design, with a number of people adding improvements

Drawbacks

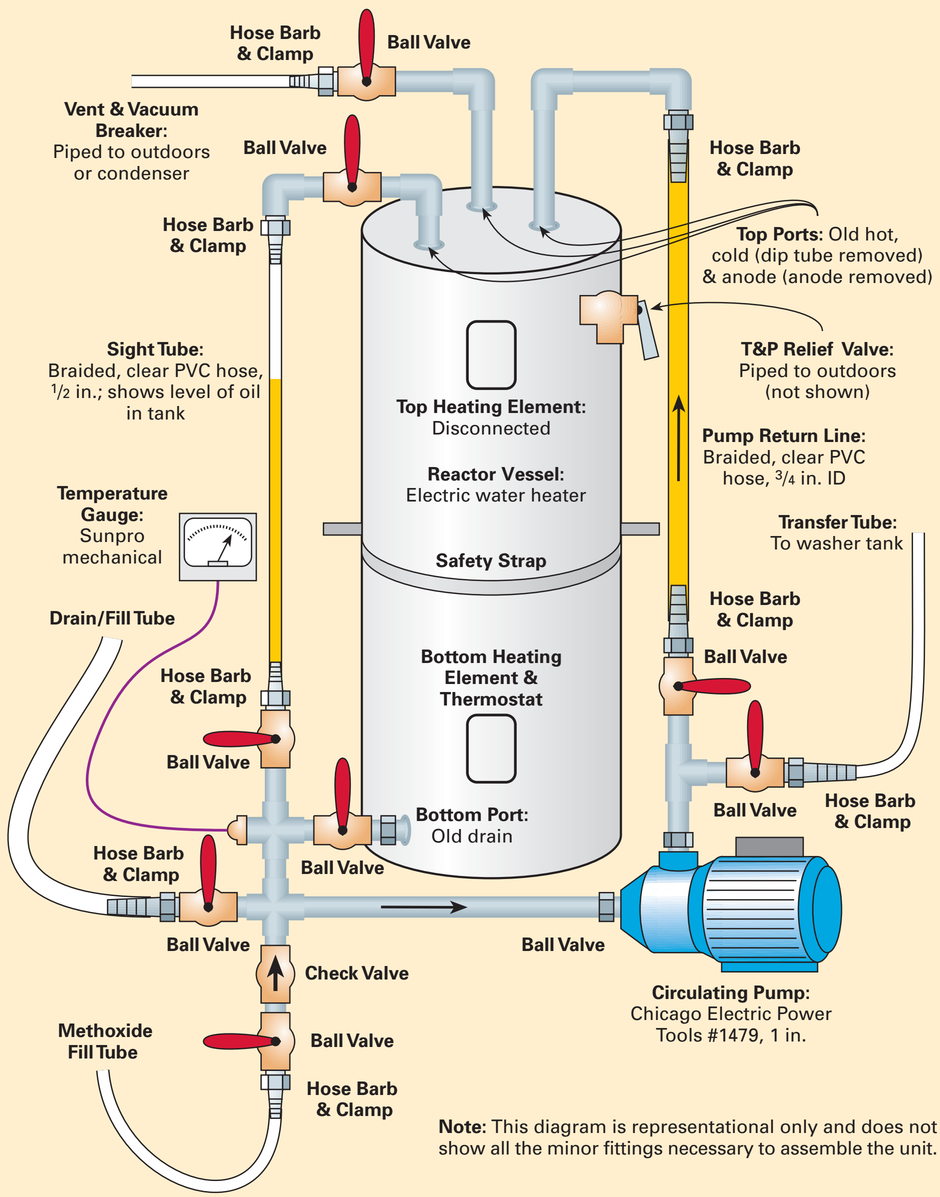
- Brass, zinc, or iron plumbing may shorten biodiesel's shelf life
- Some plastic is used, which is a weak link in the system
- Many valves can lead to confusion
- Cheap centrifugal pump is fairly weak, and may mix only moderately well

Electric water heaters are commonplace scrap, and well suited for the Appleseed design. They resist high pressures, drain well, come already-insulated, and are thermostatically controlled.

First, remove the zinc or magnesium anode rod and the plastic dip tube from the top of the water heater. The anode is sometimes hidden below a knockout or plastic plug. You will need a $1^1/_{16}$-inch socket wrench to remove it. You'll find the dip tube underneath one of the nipples threaded into the tank. Flush out any mineral buildup with water or acetic acid, but don't worry excessively about cleaning the tank.

Be sure to rewire the water heater to bypass the upper heating element. Water heater elements will burn out if they are not submerged while energized.

The Appleseed Biodiesel Reactor



Note: This diagram is representational only and does not show all the minor fittings necessary to assemble the unit.

Pipe Particulars

Homebrew reactor materials are usually a compromise among several factors—cost, availability, compatible materials, and safety. Obviously, safety trumps all other factors.

Use nongalvanized mild steel ("black pipe") or stainless steel—the ideal material if you can afford it. Try to stay away from zinc (galvanized pipe fittings), and definitely avoid copper. Zinc, copper, and iron can shorten the shelf life of your biodiesel by acting as catalysts for oxidation of the fuel. This is not a big problem for homebrewers, who do not usually store their fuel for a long time. The compromised shelf life will vary with the type of oil used for the feedstock.

I sometimes break the "no-zinc, no-iron" rule in favor of safety and cost. It's easy to avoid copper, but zinc in galvanizing or in brass valve bodies and cast iron fittings are harder to avoid if cost is the major consideration.

You also can use some types of plastic pipe. But heavy-duty, cross-linked polyethylene (PEX) is not available as fittings. And PVC has some limited problems withstanding the corrosive nature of biodiesel.

Using the Appleseed Reactor

Making biodiesel with the Appleseed reactor is a straightforward procedure. First, fill the reactor with vegetable oil. With some prodding, the Appleseed's pump will transfer oil from buckets (close the tank isolation valve first). Alternatively, you could transfer the oil with an inexpensive, manual barrel pump plumbed into the reactor's drain tube. A sight tube will allow you to monitor the level of oil in the tank.

Next, heat the oil to 130°F (54°C) in the heater. Then mix methanol with a potassium hydroxide or sodium hydroxide catalyst to form a sodium or potassium methoxide. The simplest way is to add the catalyst to the methanol. I use 5-gallon (19 l) carboys (jugs) of heavy, high density polyethylene (HDPE) plastic as a passive mixer for methanol and the catalyst, providing no mechanical agitation beyond occasional rocking. Our supplier pumps the methanol directly into our carboys, which eliminates one methanol-handling step at home. The carboys have a convenient feature—the lids contain an optional, plugged set of $^3/_4$-inch NPT threads. I buy an extra lid and use it to attach plumbing to the jugs. Rock the carboy every 10 minutes until the catalyst is completely dissolved.

Use the circulating pump to gradually mix the methoxide into the preheated oil for a couple of hours. The same pump can be used to draw oil from the storage tank, and to draw methoxide from a carboy. To provide more complete mixing, it also can be used to circulate the mixture from the bottom to the top of the tank.

After a 24-hour settling period, a glycerol/soap mixture will drop to the bottom of the reactor. Open the valve to drain off the glycerol. Tall, thin tanks are better than wider ones for reducing the amount of intermixed material from the junction between glycerol and biodiesel layers. The floor of a water heater tank isn't flat—it has an inverted dome shape with a drain at the pointed tip, which helps with separation of the layers.

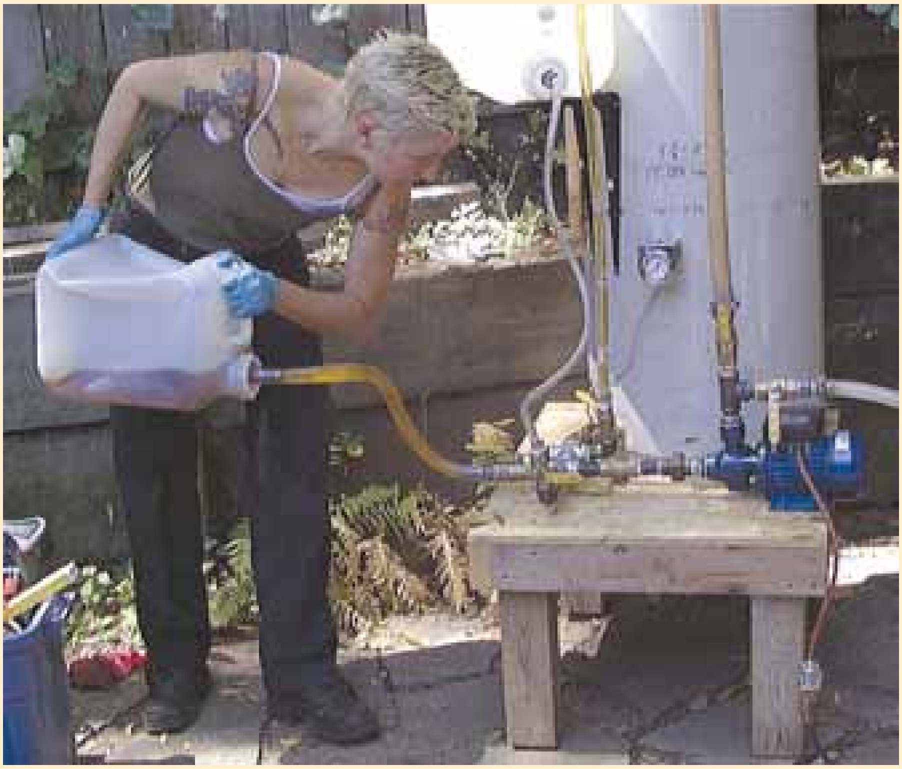
Provide a system to water-wash the biodiesel, to remove the water-soluble impurities that are formed in the process. The Appleseed reactor has a fluid-transfer manifold, which is basically an inexpensive substitute for a three-way valve. This allows you to transfer biodiesel into a standpipe wash tank, where you can bubble-wash or mist-wash to your heart's content. The water carries the impurities to the bottom of the tank, and the clean biodiesel floats on top of the water and flows through the top of the standpipe into your container.

You will also need a filter, lab glassware for testing, and a means of collecting oil from restaurants (a pump or a pitcher). If you isolate the tank from the lower plumbing manifold (close the tank isolation valve), and switch the fluid-transfer manifold to its transfer position, the same reactor pump can be used to move biodiesel through a filter on its way to storage or to your car's fuel tank.

Reactor Parts Costs

Item	Cost (US$)
Water pump, 1 in. clear	$34.99
2 FortPak carboys	24.00
Ball valves	23.00
Shipping	16.00
Sunpro temperature gauge	14.99
Misc. 3/4-in. plumbing fittings	13.50
Power cord	10.00
Misc. 1/2-in. plumbing fittings	8.50
Electrical plug ends	5.34
PVC-reinforced, heavy-wall tubing, 3/4 in.	5.20
Hose clamps	5.08
2 Carboy lids	1.88
PVC tubing, 3/4 in.	1.25
PVC tubing, 1/2 in.	0.95
PVC tubing, 3/8 in.	0.65
Total	$165.33

A carboy lid is plumbed into the drain/fill tube of the reactor, the tank isolation valve is closed, and the pump draws right from the carboy for its first filling. A carboy for the methoxide, which is mounted to the left side of the tank, is drained using the same process.



Creative Solutions

Some people will build the basic unit, be done with wrenching, and move on to the nuances of processing and washing biodiesel. Other, more tinker-prone individuals have been kind enough to share their ideas and equipment redesigns, which have saved a lot of trial-and-error experimentation.

Share any changes you come up with! Homebrew biodiesel techniques didn't develop in a vacuum. The rise of homebrewing as a hobby coincided with the spread of information on the Internet and with the biodiesel discussion forums, where information such as equipment plans has been freely shared. Homebrewing *is* appropriate technology. The open-design philosophy, with many authors sharing all the techniques and equipment plans that were appropriate for their needs, enriches the process for the benefit of all homebrewers.

Publishing our easy-to-replicate equipment plans has brought out many

David Probert tucked his beautiful system into a cabinet, insulated for Maine winters. In this small system, based on a 19-gallon, mobile-home water heater, several parts perform more than one job.

different people's creative contributions, and safe solutions, to newcomers' equipment questions. Seeing dozens of people build these units with ease over the past year has been truly inspiring. I really look forward to seeing what modifications *Home Power* readers come up with!

Access

Maria "Mark" Alovert, PO Box 2994, Berkeley, CA 94702 • alovert@b100.org • *Biodiesel Homebrew Guide: Everything You Need to Know to Make Quality Alternative Diesel Fuel from Restaurant Fryer Oil*, 110 pages, US$15 • Available from www.localb100.com

Appleseed reactor plans & open-source homebrew tutorial • www.localb100.com

Energy Self-Sufficiency newsletter • www.rebelwolf.com • Monthly series on homebrew biodiesel

Homebrew Biodiesel Discussion Forum • http://biodiesel.infopop.cc

Open-source biodiesel equipment, plans, and photos • www.veggieavenger.com/media

Iowa State University technical papers on biodiesel production • www.me.iastate.edu/biodiesel

LIGHTNING HAPPENS

How to Protect Your Renewable Energy System

Windy Dankoff

Lightning is a common cause of failures in photovoltaic (PV) and wind-electric systems. A damaging surge can occur from lightning that strikes a long distance from the system, or even between clouds. But most lightning damage is preventable. Here are some of the most cost-effective techniques that are generally accepted by power system installers, based on decades of experience. Follow this advice, and you have a very good chance of avoiding lightning damage to your renewable energy (RE) system.

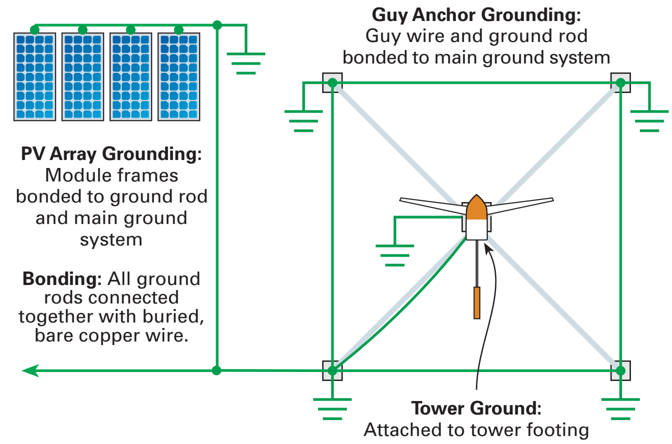
Get Grounded!

Grounding is the most fundamental technique for protection against lightning damage. You can't stop a lightning surge, but you can give it a direct path to ground that bypasses your valuable equipment, and safely discharges the surge into the earth. An electrical path to ground will constantly discharge static electricity that accumulates in an aboveground structure. Often, this prevents the attraction of lightning in the first place.

Lightning arrestors and surge protectors are designed to protect electronic equipment by absorbing electrical surges. However, these devices are not a substitute for good grounding. They function only in conjunction with effective grounding. The grounding system is an important part of your wiring infrastructure. Install it before or while the power wiring is installed. Otherwise, once the system is working, this important component may never get checked off on the "to do" list.

Step one in grounding is to construct a discharge path to ground by bonding (interconnecting) all the metal structural components and electrical enclosures, such as PV module frames, mounting racks, and wind generator towers. The *National Electrical Code (NEC),* Article 250 and Article 690.41 through 690.47 specify code-compliant wire sizes, materials, and techniques. Avoid sharp bends in ground wires—high current surges don't like to turn tight corners and can easily jump to nearby wiring. Pay special attention to attachments of copper wire to aluminum structural elements (particularly the PV module frames). Use connectors labeled "AL/CU" and stainless steel fasteners, which reduce the potential for corrosion. The ground wires of both DC and AC circuits will also be connected to this grounding system. (Refer to *Code Corner* articles on PV array grounding in *HP102* and *HP103* for more advice.)

Solar- and Wind-Electric Grounding Techniques



Ground Rods

The weakest aspect of many installations is the connection to the earth itself. After all, you can't just bolt a wire to the planet! Instead, you must bury or hammer a rod of conductive, noncorrosive metal (generally copper) into the ground, and make sure most of its surface area contacts conductive (that means moist) soil. This way, when static electricity or a surge comes down the line, the electrons can drain into the ground with minimal resistance.

In a similar way to how a drain field dissipates water, grounding acts to dissipate electrons. If a drainpipe doesn't discharge adequately into the ground, backups occur. When electrons back up, they jump the gap (forming an electrical arc) to your power wiring, through your equipment, and only then to ground.

To prevent this, install one or more 8-foot-long (2.4 m), 5/8-inch (16 mm) copper-plated ground rods, preferably in moist earth. A single rod is usually not sufficient, especially in dry ground. In areas where the ground gets extremely dry, install several rods, spacing them at least 6 feet (3 m) apart and connecting them together with bare copper wire, buried. An alternate approach is to bury #6 (13 mm^2), double #8 (8 mm^2), or larger bare copper wire in a trench at least 100 feet (30 m) long. (The bare copper ground wire also can be run along the bottom of a trench that carries water or sewer pipes, or other electrical wires.) Or, cut the ground wire in half and spread it in two directions. Connect one end of each buried wire to the grounding system.

Try to route part of the system into wetter areas, like where a roof drains or where plants are to be watered. If there is a steel well-casing nearby, you can use it as a ground rod (make a strong, bolted connection to the casing).

In moist climates, the concrete footers of a ground- or pole-mounted array, or a wind generator tower, or ground rods encased in concrete will not provide ideal grounding. In these locations, concrete will typically be less conductive than the moist soil surrounding the footings. If this is the case, install a ground rod in earth next to the concrete at the

Lightning Strikes

Location: Rocky Mountain region, west of Denver, Colorado. Elevation: 9,200 feet (2,804 m). Homesite is on a hillside with much higher ground nearby.

System: Remote, off-grid residential PV system installed in 1999.

Date of occurrence: July 2004. The ground was dry from lack of rain.

Damage: Lightning struck a pine tree and traveled along a stream of water flowing next to the corner of the nearby garage. At the garage, it found a path to ground through the rebar in the garage's foundation, blasting a hole through the wall. The PV power center is located at the far side of the garage, and connected to a single 8-foot-long (2.4 m) ground rod. Lightning traveled from the rebar near the power center, to the power panel, and then to ground, primarily through the ground rod and the well pump.

A surge also entered the house, melting the DC wiring that led to a Sun Frost refrigerator and a TriMetric system monitor. It melted telephone cables, blasted a phone box off the wall, and blew out portions of drywall. It destroyed the submersible well pump and even blew the plastic pipe off of the top of the pump.

The entire power panel was fried, including the inverter, charge controller, and associated wiring. Many electronic devices in the house were damaged. No damage occurred to the solar-electric array.

Insurance: The full cost of repair was covered by homeowner's insurance.

Property owner inspects the pine tree that took a direct hit from lightning.

Courtesy Otto Van Geet & Kevin Umlauf (2)

Attracted to the rebar in the building's foundation, the lightning induced surge traveled to and blew out the corner of this garage.

Courtesy of www.transtector.com

A variety of high-quality DC surge arrestors manufactured by Transtector.

base of an array, or at the base of your wind generator tower and at each guy wire anchor, then connect them all together with bare, buried wire.

In dry or arid climates, the opposite is often true—concrete footings may have a higher moisture content than the surrounding soil, and offer an economical opportunity for grounding. If 20-foot-long (or longer) rebar is to be embedded in concrete, the rebar itself can serve as a ground rod. (Note: This must be planned before the concrete is poured.) This method of grounding is common in dry locations, and is described in the *NEC*, Article 250.52 (A3), "Concrete-Encased Electrode."

If you are unsure of the best grounding method for your location, talk with your electrical inspector during the design phase of your system. You cannot have too much grounding. In a dry location, use every opportunity to install redundant ground rods, buried wire, etc. To avoid corrosion, use only approved hardware for making connections to ground rods. Use copper split-bolts to splice ground wires reliably.

Grounding Power Circuits

For building wiring, the *NEC* requires one side of a DC power system to be connected—or "bonded"—to ground. The AC portion of such a system must also be grounded in the conventional manner of any grid-connected system. (This is true in the United States. In other countries, ungrounded power circuits are the norm.) Grounding the power system is required for a modern home system in the United States. It is essential that the DC negative and the AC neutral are bonded to ground at *only* one point in their respective systems, and both to the same point in the grounding system. This is done at the central power panel.

Producers of some single-purpose, stand-alone systems (like solar water pumps and radio repeaters) recommend *not* grounding the power circuit. Refer to the manufacturer's instructions for specific recommendations.

Array Wiring & "Twisted Pair" Technique

Array wiring should use minimum lengths of wire, tucked into the metal framework. Positive and negative wires should be of equal length, and be run together whenever possible. This will minimize induction of excessive voltage between the conductors. Metal conduit (grounded) also adds a layer of protection. Bury long outdoor wire runs instead of running them overhead. A wire run of 100 feet (30 m) or more is like an antenna—it will receive surges even from lightning in the clouds. Similar surges can still occur even if the wires are buried, but most installers agree that buried transmission wiring further limits the possibility of lightning damage.

The slip ring/brush assembly on this wind generator was blasted by lightning.

Courtesy Chris Worcester

A simple strategy to reduce susceptibility to surges is the "twisted pair" technique, which helps equalize and cancel out any induced voltages between the two or more conductors. It can be difficult to find suitable power cable that is already twisted, so here's what to do: Lay out a pair of power wires along the ground. Insert a stick between the wires, and twist them together. Every 30 feet (10 m), alternate the direction. (This is much easier than trying to twist the whole distance in one direction.) A power drill can sometimes be used to twist wiring as well, depending on the wire size. Just secure the ends of the wiring into the drill's chuck and let the drill's action twist the cables together. Make sure to run the drill at the lowest possible speed if you try this technique.

The ground wire need not be twisted with the power wires. For burial runs, use bare copper wire; if you use conduit, run the ground wire outside the conduit. The additional earth contact will improve the grounding of the system.

Use twisted-pair cable for any communication or control cables (for example, a float-switch cable for full-tank shutoff of a solar water pump). This smaller gauge wire is readily available in pre-twisted, multiple, or single pair cables. You also can purchase shielded twisted-pair cable, which has a metallic foil surrounding the twisted wires, and typically a separate, bare "drain" wire as well. Ground the cable shield and drain wire at one end only, to eliminate the possibility of creating a ground loop (less direct path to ground) in the wiring.

Additional Lightning Protection

In addition to extensive grounding measures, specialized surge protection devices and (possibly) lightning rods are recommended for sites with any of the following conditions:

- Isolated location on high ground in a severe lightning area
- Dry, rocky, or otherwise poorly conductive soil
- Wire runs longer than 100 feet (30 m)

Lightning Arrestors

Lightning (surge) arrestors are designed to absorb voltage spikes caused by electrical storms (or out-of-spec utility power), and effectively allow the surge to bypass power wiring and your equipment. Surge protectors should be installed at both ends of any long wire run that is connected to any part of your system, including AC lines from an inverter. Arrestors are made for various voltages for both AC and DC. Be sure to use the appropriate arrestors for your application. Many system installers routinely use Delta surge arrestors, which are inexpensive and offer some protection where the threat of lightning is moderate, but these units are no longer UL listed.

PolyPhaser and Transtector arrestors are high quality products for lightning-prone sites and larger installations. These durable units offer robust protection and compatibility with a wide variety of system voltages. Some devices have indicators to display failure modes.

A low-cost, non-UL-listed Delta surge arrestor.

Lightning Rods

"Lightning rods" are static discharge devices that are placed above buildings and solar-electric arrays, and connected to ground. They are meant to prevent the buildup of static charge and eventual ionization of the surrounding atmosphere. They can help prevent a strike, and can provide a path for very high current to ground if a strike does occur. Modern devices are spike-shaped, often with multiple points.

Lighting rods are typically only used at sites that experience extreme electrical storms. If you think your site falls into this category, hire a contractor who has experience in lightning protection. If your system installer is not so qualified, consider consulting with a lightning protection specialist before the system is installed. If possible, select a North American Board of Certified Energy Practitioners (NABCEP) certified PV installer (see Access). Although this certification isn't specific to lightning protection, it can be an indication of an installer's level of overall competence.

Out of Sight, Not Out of Mind

A lot of lightning protection work is buried, and out of sight. To help ensure that it gets done correctly, write it into your contract(s) with your system installer, electrician, excavator, plumber, well driller, or anyone who is doing earthwork that will contain your grounding system.

No matter what you do, an "act of God" can blast through any barrier. Insurance companies generally compensate for lightning damage, unless it happens repeatedly. I had a direct strike to my home PV system in the 1980s, and lost almost everything electronic that was plugged in, including telephone devices, fluorescent light ballasts, and a refrigerator controller. My homeowner's insurance covered the costs. After that, I improved my grounding system, and it didn't happen again. Once was enough!

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Access

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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/products.htm

PolyPhaser Corp., PO Box 9000, Minden, NV 89423 • 800-325-7170 or 775-782-2511 • Fax: 775-782-4476 • productmanagement@polyphaser.com • www.polyphaser.com

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"PV Grounding," *Code Corner* by John Wiles in *HP102* & *HP103*

electric TORO

Al Latham

I've been trying to wean my garden off gas-powered equipment for a long time. The first step was to replace the gas-powered water pump with one that would run off our solar-electric system (see "The Little Pump that Could" in *HP72*). A 120 VAC shredder and edger that run off the same system have become part of the operation. The garden has been worked enough that we no longer need the gas rototiller. That left mowing the grass paths between the beds. Each time I cranked up the gas lawnmower, flights of fancy about cutting the grass with solar electricity danced through my head.

PV charging system the in shed: fuse box, ammeter, charge controller, charging cord, and mower.

The options for doing this boiled down to a 120 VAC mower with a cumbersome cord, buying an off-the-shelf battery powered lawnmower (US$450 and up), or converting a gas-powered lawnmower to battery power. Converting a gas lawnmower appealed to my techno-twit tendencies, so I began researching motor and battery sizes that would be appropriate.

First stop was the Internet, but there was little to be found on the subject. I did learn an important conversion rule—a 1 hp electric motor is equivalent to about a 4 hp gas engine. One site, where a fellow was keeping a diary of his car conversion, had a brief mention of converting a gas mower using a car starter motor, but not much detail. That seemed like a cheap option, so I procured a mower with a dead engine and went to find a starter motor.

Unfortunately, everyone I talked to said that it would probably work, but not for long. A starter motor is not made for continuous use and would probably burn up quickly, if the small shaft didn't bend first. A friend who had converted mowers (as well as cars, motorcycles, and boats) in the past suggested that a 1 hp permanent magnet motor would be the best bet. He also donated a "split-taper bushing" for mounting the blade on a motor with a 5/8-inch (16 mm) shaft.

I went back to the Internet where sticker shock awaited—12 VDC, 1 hp permanent magnet motors are not very common, and new ones aren't cheap. Eventually, I found some motors for US$260 plus shipping, but that was a bit too spendy for me. Scouring the Internet for used or surplus cheap motors was not productive until a 3/4 hp, 12 VDC motor appeared on eBay for US$125.

This was not as cheap as I'd planned, but what project doesn't quickly move into the realm of "more than you told your spouse it would cost?" The question was, would a 3/4 hp motor running at 1,800 rpm be adequate? Gas mowers run at about 3,600 rpm. There was only one way to find out—build it and see if it works.

Deck & Motor

The dead mower was a Toro Commercial Recycler, rear-bagging, 21-inch (53 cm) blade, self-propelled model with a good deck. Stripping the engine and self-propelled gear left a platform very conducive to the conversion, since there was a flat space for a battery between the motor and the rear bag. Many mowers have a hump where the bag attaches that would be in the way. A piece of 3/8-inch (10 mm) plywood was used as a motor mount and to provide a platform for battery mounting.

The motor is a Leeson Electric Corp. 3/4 hp, 12 VDC permanent magnet motor with a 5/8-inch (16 mm) shaft, rated at 1,800 rpm and 58 amps (model C4D17FK7D, catalog #108048). Rotation is reversible by switching the

The new, electric Toro's motor and battery (with battery cover removed).

connections. (Mower blades cut in only one direction, so the motor needs to rotate correctly.) The motor is bolted to the plywood, which is bolted to the mower deck.

Wiring & Battery

I used #6 (13 mm^2) wire from the motor to a salvaged, DC-rated circuit breaker mounted on the handles, which serves as an on/off switch as well as breaker. The wires run from the motor/battery through conduit, which runs through the mower deck's belt-drive channel under the plywood.

Of course a project has to have meters (it's not a project without duct tape and meters) so a voltmeter and ammeter are mounted on the handle so I can monitor the battery and draw. I ran #10 (5 mm^2) wire through the conduit, from the battery to a female plug on the handle for a battery charging connection.

Every project needs meters! A voltmeter and ammeter are mounted on the mower. The mower plugs into a small PV system for charging.

Initially, a 12 VDC car battery was used to see what kind of electrical load would be generated by mowing. The motor sucks 25 amps spinning the blade, and 30 to 60 amps when cutting. While mowing the lawn with the mower deck set at its highest cut, the mower was averaging about 30 amps. The minimum mowing time I was shooting for was 20 minutes.

Al Latham with his charging shed and El Toro.

I bought the lightest battery that would do the job—a small, Interstate, 35 amp-hour, deep-cycle battery (USRMU1), weighing 21 pounds (9.5 kg). A square plastic bucket was modified to serve as a battery/connections cover.

Blade Mounting

How to mount the mower blade to the motor shaft was beyond my technical capabilities. I figured an adapter would need to be machined. So I took it to a locally renowned backyard machinist, who figured out how to mount it without doing any machining.

It turned out that the split-taper bushing that my friend had donated had the same bolt pattern as the blade mounting bolts. Split-taper bushings are used to mount some types of pulleys on a shaft. With two of the spacers from the gas engine blade–mount between blade and bushing, the blade was attached at the precise distance from the bottom of the mower deck that it had been when mounted on the gas engine.

The Test

With the battery charged up and the blade mounted, I was ready to give the mower the test to see if it would mow the grass paths in the garden on one charge. But it was raining. My wife Susan couldn't believe that I was actually looking forward to mowing. Finally the grass dried out enough and off I went with the mower. First impression—how quiet! The grass had last been mowed a week ago and the mower cut right through it, even bagged it.

Mowing the garden paths took about 20 minutes and the mower still had plenty of pep. So out into the yard for another 40 minutes before it (and I) started pooping out—after another 10 minutes, it was barely cutting. Running it so long is hard on the battery, so I try to keep my grass-cutting sessions at about 20 minutes, which keeps the battery above 50 percent state of charge.

Mower Conversion Rules

- Don't use it for clearing land. A gas mower has a larger shaft and can take more abuse.
- Keep the blade sharp. A gas mower will cut grass with a dull blade, though "cut" might not be the correct term. A sharp blade on this conversion means more efficient cutting, and a dull blade will bog down and discharge the battery in a shorter time.
- Turn the mower off when you let go of the handle. I'm considering adding a "dead man" switch, so the motor turns off when you let go of the handlebars.
- If you undertake a project like this, be *extremely careful* that your blade is securely attached to the motor shaft—you don't want the blade to fly off the shaft.

Battery Charging

You've probably been asking yourself, "Why 12 volt?" since the manufactured battery mowers are 24 volt, and 24 VDC motors that would work might be more common. The reason is that all my charging systems are 12 VDC, and a 24 VDC system would require two batteries.

An old piece of $^5/_8$ -inch (16 mm) salvaged plywood was cut in half diagonally to make a mower shed. A Shell SP75-watt solar-electric panel was mounted on the roof. A Sun Selector 16-amp charge controller, and a DC ammeter and fuse box from an earlier phase of our solar-electric system were wired in to complete the project. Since I only use the mower once a week, it has plenty of time to charge back up. After 20 minutes of mowing and one sunny day of charging, the battery is back to 12.5 volts at rest—full. I could also charge the battery using an AC battery charger, through our main system inverter.

Lawnmower Conversion Costs

	Cost (US$)	
Item	**Retail**	**Actual**
Shell SP75 panel	$300	$0
Leeson 12 VDC, $^3/_4$ hp motor	280	125
Misc. electrical	70	30
Interstate USRMU1 battery, 35 AH	65	65
Split-taper bushing	10	0
Mower (used)	0	0
Total	$725	$220

Solar Mowing

The bottom line is that it works, it's quiet, is adequate for my needs, and was a fun project. The $^3/_4$ hp motor is the minimum size I would recommend. Anything smaller would have marginal power. It will cut through tall (knee-high) grass, but slowly.

It isn't self-propelled, so pushing it around provides a bit of a workout. A 1 hp motor might provide enough power to use the self-propelled option. It works so well that it has already inspired the next project—converting a 12 hp riding mower for the rest of the yard.

Access

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Leeson Electric Corp., PO Box 241, Grafton WI 53024 • 262-377-8810 • Fax: 262-377-9025 • leeson@leeson.com • www.leeson.com • Motors

eBay • www.ebay.com • Good source for used electric motors

Electric Motor Warehouse, G1460 E. Hemphill, Burton, MI 48529 • 877-986-6867 or 810-744-1240 • Fax: 810-744-1424 • info@electricmotorwarehouse.com • www.electricmotorwarehouse.com • New Leeson motors

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RV Comfort

Anywhere the Sun Shines

Darrell Murtha

Now that my wife Gayle and I have purchased a Class A motor home, I have to admit that the learning curve of owning and operating it wasn't all that steep. The experience I acquired from owning an 8-foot-long (2.4 m) travel camper served me well, in a limited fashion.

Road-ready: Photovoltaic panels mounted on the RV's rooftop give the Murthas the energy independence to camp almost anywhere.

A Little History

Gayle's idea of "roughing it" and mine are fundamentally different. Many years before meeting Gayle, I camped with a good ol' fashioned tent, a sleeping bag, a flashlight, a steak on the barbecue, and some beer! Now *that* was living.

As is human nature though, I yearned for more. I purchased a used camper for the back of my pickup truck. It had a propane stove, a three-way fridge, and a propane heater! Friends chided me about how "soft" I was becoming. It really was a very comfortable and refreshing way to get out of town and relax. I sold that camper, but in my mind, the full measure of camping comfort was that little camper.

Fifteen years passed. Gayle and I were talking one day about camping. I related to her my story about my old camper and how I had perfected this pursuit of outdoor living. Yes, she liked the great outdoors too. She also had a version of camping. She had experienced a small camper, and had indelible memories etched into her mind as well. However, they weren't the same pleasant memories I enjoyed. It was obvious that we would need a motor home.

The Big Leap

We took a good look at all the variations of RVs. Eventually Gayle and I decided on a 30-foot-long (9 m), Class A motor home. We are both still working and knew trips would be limited to weekends and annual vacations. A high-end motor home was out of the question. This Coachmen 30-footer would fit the bill!

The deficiencies in the electrical system were almost instantly obvious. I have looked at a lot of motor homes and can say that most (not all) are designed to be plugged in. That is, as long as you have AC to plug into, you are very content, electrically speaking. If you prefer to "boondock" out in the woods where there are no utility lines, and your electrical reserve is undersized, you soon discover that the lights dim and the carbon monoxide (CO) monitor's low-voltage alarm complains loudly.

The author and his wife soak up some sun.

In my case, this happened at 3 AM on one of our first trips, after the single deep-cycle battery had become depleted. I live in Calgary, Alberta, Canada, and there is a lot of camping around these parts, as much unplugged as there is serviced. I prefer to boondock, since the crowds are much smaller and I find the experience much more satisfying. Gayle's only request was that the forced-air heater work all night long and the depletion of the battery not be announced by the howling of the CO monitor!

Stock RV for Solar Upgrade

When purchased, our RV was delivered with a stock "converter," an AC battery charger that incorporates AC and DC load panels. A transfer switch in the converter automatically switches between external sources of AC, derived from either the onboard Onan 4,000-watt generator or the local utility.

The RV came with two batteries. One was the starting, lighting, and ignition (SLI) battery, commonly called the chassis battery. This battery's function is to start the RV and supply DC to the headlights, taillights, and other chassis loads.

To minimize electrical losses, the inverter was installed in a cabinet next to the sealed batteries, which are located under the couch.

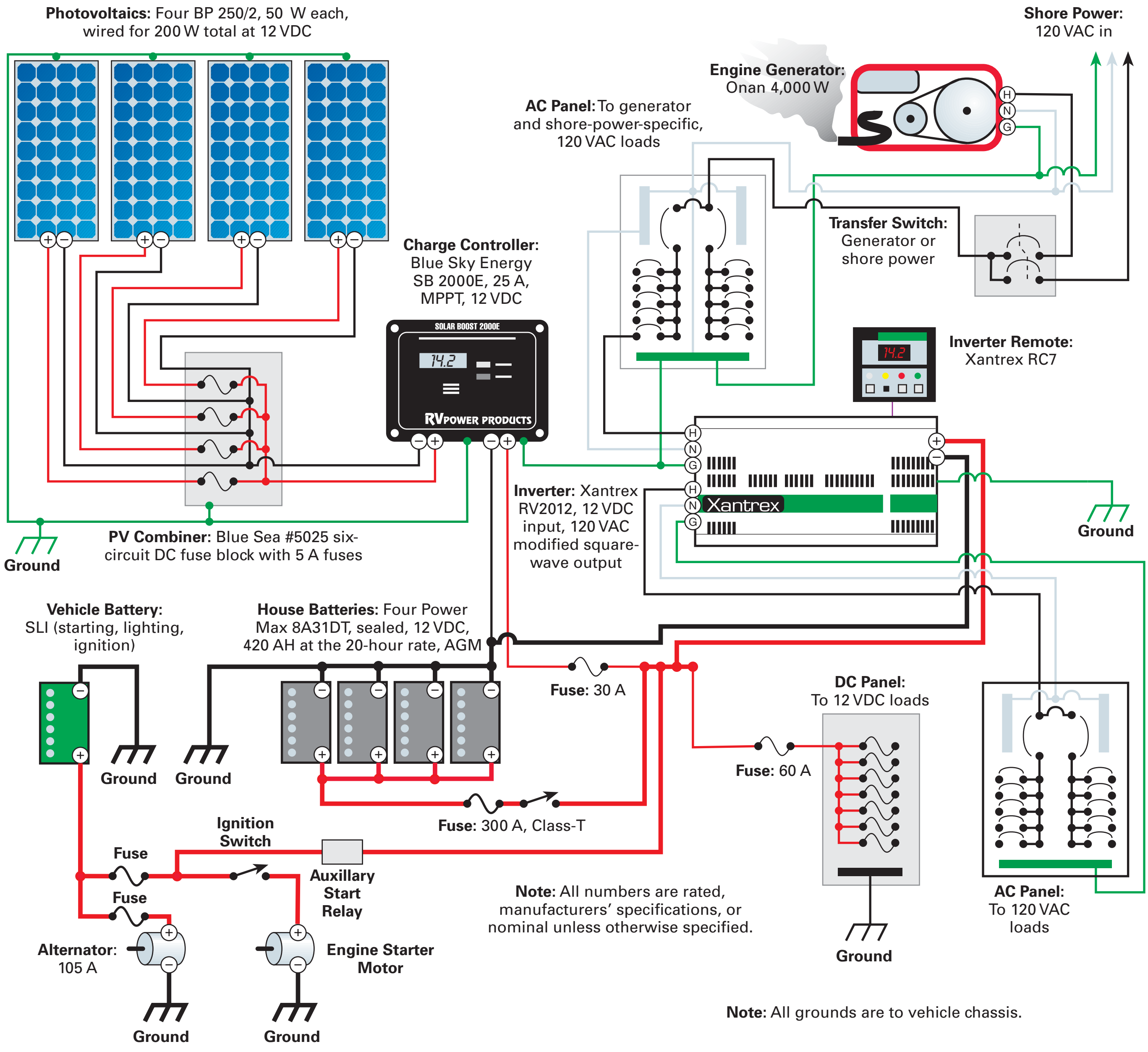
The other battery that came stock was a garden-variety, "no maintenance" 80 AH deep-cycle unit for the 12 V lights, forced-air furnace, and other DC loads in the RV. This battery is commonly referred to as the "house" battery. These two batteries are isolated from one another so that the house battery can never deplete the chassis battery. This ensures that you can start your RV and not be stranded.

The most obvious liability in this particular setup was the lack of electrical storage. That single, undersized deep-cycle battery was expected to run the entire house system. The forced-air furnace itself draws about 100 watts and may cycle eight to ten times a night for ten to fifteen minutes per cycle here in the foothills of the Rocky Mountains. This and some other loads can quickly deplete the battery.

When the RV was plugged into 120 VAC, the converter would do what converters do. It converted AC to DC to power the house loads. It also would pass 120 VAC through to the AC panel for the TV, microwave, and other AC loads. The converter, with this external source of AC, would also charge both my batteries. As long as we were plugged in, life was good and everyone was happy. If we were boondocking and the battery needed recharging, we had the generator, which could be run to recharge the battery.

Unless the generator was running or we were plugged in, we had no AC. Whether you are alone in the woods or have neighbors nearby, you don't want to run a generator for any length of time. Even after tweaking the voltage adjustment on the converter, I found that the length of time running the generator to recharge the battery was excessive. A more efficient system was needed.

My choice was a photovoltaic (PV) system sized to meet our boondocking desires. I would upgrade the battery bank for more energy storage. I would add an inverter/charger with much better battery recharging capability. And I would



The original "converter" was converted to a breaker panel and junction box.

include a better way to monitor battery state of charge and other system conditions, which would ultimately allow me to take better care of my new gear.

System Design

Having lived with the stock electrical system for two seasons showed me where improvement was needed. Several considerations influenced my design.

More autonomy to facilitate boondocking. To achieve my goal of less dependence on plugged-in camping, I needed more battery capacity. To recharge the new battery bank, I have three sources of electricity. Solar energy comes, via an MPPT charge controller, from four 50-watt PV modules mounted on the roof. DC charging is also available from a new inverter's three-stage battery charger, which can be powered by either the 4,000-watt generator, or the utility when it's available.

Murtha RV System Loads

AC Loads	Watts	Hours Per Day	WH Per Day
Hair dryer	1,000	0.75	750
Microwave	1,000	0.50	500
Coffee pot	1,100	0.25	275
Toaster	1,000	0.25	250
Television	70	2.00	140
Curling iron	23	1.00	23
		Total AC WH Per Day	1,983
DC Loads			
Furnace	90	2.00	180
Lights	10	6.00	60
		Total DC WH Per Day	240
		Grand Total WH Per Day	2,178

While boondocking, I rely on good 'ol Sol to keep my batteries charged up. When the weather does not cooperate, the generator charges through the inverter, which has a better battery charger than the old converter. When at home or at serviced campgrounds, we plug in to 120 volts, which the inverter passes through to the 120-volt loads and at the same time recharges the batteries.

Incorporate as much existing equipment as possible for economy. As in most projects, there is a delicate balance between safety, efficiency, and cost. Safety requires no explanation. I would not compromise safety for economy. Neither should economy be the decisive factor.

A six-circuit DC fuse box serves as a PV combiner box.

Tech Specs

System Overview

System type: Mobile, battery-based PV

System location: Calgary, Alberta, Canada

Solar resource: Varies with travel

Photovoltaics

Modules: Four BP 250/2, 50 W, 17 Vmp, 12 VDC nominal

Array: Four modules wired in parallel, 200 W STC at 12 VDC

Array combiner box: Blue Sea #5025 six-circuit DC fuse block with 5 A fuses

Array disconnect: Blue Sea #7222, 30 A (High AIC) circuit breaker

Array installation: Four Soltek ARM-SQ/BP adjustable RV mounts

Energy Storage

Batteries: Four Power Max 8A31DT, 12 VDC nominal, 105 AH at the 20-hour rate, AGM

Battery bank: 12 VDC nominal, 420 AH total

Battery/inverter disconnect: 300 A Class-T fuse

Balance of System

Charge controller: Blue Sky Energy SB 2000E, 25 A, MPPT, 12 VDC nominal input

Inverter: Xantrex RV2012, 12 VDC nominal input, 120 VAC modified square wave output

System performance metering: Xantrex RC7 Remote Control, plus SB 2000E panel

I already had an AC and DC load panel incorporated in the converter. This setup was compact and code compliant. I disabled the charging function of the converter and removed the transfer switch. The AC inputs for this transfer switch were moved over to a new AC mains panel. What's left is a CSA-approved, combined AC/DC electrical subpanel. I added new components and wiring to my electrical bay, but none of the existing wire had to be altered.

Clever and efficient design to preserve space in the RV. After determining what my new system requirements were, consideration was made for physical placement. Space is at a premium in RVs. Placement of components was a challenge. Safety, efficiency, and economy were played against one another again.

PV Installation

The placement of the four BP 50-watt solar-electric modules on the RV's roof was not too much of a task. I contacted Coachmen in Indiana and they faxed me the appropriate diagrams, which depicted existing wiring in the roof that I definitely wanted to avoid. The four PVs were placed so that there was no shading from other fixtures mounted on the roof.

I ran a separate positive wire from each PV to a combiner so that each solar-electric module had its own fuse. I couldn't find a small, fused combiner box, so I made one by modifying a Blue Sea #5025, six-circuit DC fuse block with 5 A fuses. In the unlikely event that the array performance degrades, I will be able to isolate and troubleshoot each module from the array by removing fuses. From the PV combiner, the circuit was run to the Blue Sky Energy Solar Boost 2000E MPPT charge controller. The positive leg is run through a 30-amp AIC breaker and then through to the batteries.

Circuit Scheme

Circuit design and protection was one of the biggest challenges I faced. I researched and read, and researched some more. Before becoming a firefighter in Calgary, I was trained in the telephone industry. That exposure to DC electricity was helpful. I didn't relish the idea of the boys from work showing up to put out a fire in my RV. *That* I would never live down! I definitely would have circuit protection to protect my investment. Kudos go out to John Wiles who writes for *HP*. I wrote to him and asked if he would go over my circuit design, and he was very helpful.

Another addition to the electrical bay is a new mains panel, which employs a mechanical interlock, preventing utility and generator AC coming on-line at the same time. I enjoy fireworks at the fairgrounds, not in my RV. The interlock replaces the transfer switch that I removed from the converter.

The new AC mains panel.

An RC7 Remote Control and SB 2000E charge controller monitor the system's performance.

There are only two circuits on my mains panel. One is for roof air conditioning and the other is for the inverter. The roof air for the coach is so energy hungry that the 2,000-watt inverter and battery bank would never satisfy its demands. So the roof air conditioning is only powered from the generator or the utility. The other circuit in the mains panel allows AC electricity from the selected source to the inverter. The inverter passes AC to the loads from either the grid or the generator. When no utility electricity is available, we get AC from the inverter and batteries. If we want air conditioning, we run the generator.

Batteries

My decision on battery type was dictated by space. I decided to place my inverter and my batteries inside the coach. The new, sealed AGM batteries can live in areas that we humans inhabit. Concerns about hydrogen gas emissions are mitigated if the AGM batteries are charged properly. The proper charging of this new battery bank is handled by the three-stage charger incorporated into the inverter, or the PWM charge regime of the solar charge controller.

My choice was four Power Max 8A31DTs wired in parallel for 12 volts DC. That provides about 2.6 KWH of capacity at 50 percent depth of discharge. The voltages required for bulk, absorption, and float charging are different than what you would use for conventional flooded lead-acid batteries. One of the programmable settings in my inverter is for sealed batteries.

I am a gauge-watcher now. I monitor the information provided by the charge controller and the remote panel for the inverter very closely. I occasionally check voltages and amperages with my clamp meter. Pricey batteries do this to you.

I placed the batteries under my couch and secured them to an equipment tray that can be wheeled forward for ease of removal. The Xantrex RV2012 modified square wave inverter is in a cabinet separate from the batteries for good measure. Some effort was required to pull in new wire and keep the installation neat. I used #4/0 (107 mm^2)

After much deliberation, Darrell decided to install the batteries under the sofa.

Murtha RV System Costs

Item	Cost (Can$)
Xantrex RV2012 inverter	$1,249
4 Power Max 8A31DT AGM batteries	952
Misc. panels, switches, fuses, breakers	852
4 BP 250/2 PV modules, 50 W	780
Cables & connectors	528
4 Soltek ARM-SQ/BP adjustable PV racks	346
Solar Boost 2000E MPPT controller	210
Battery tray	71
Total	$4,988

wire, which is big and heavy. These wires were the hardest of the bunch to pull in.

Do It Yourself

The installation is doable as a one-person project. Only on one occasion did I need an extra set of hands. Anyone undertaking this type of installation should take the time to thoroughly go through the existing systems and wiring. You must know exactly what each existing component and wire's function is.

I started the planning for the RV transformation in January and finished up in August. Some components were acquired locally while others were purchased through eBay. I was unable to devote all my spare time to this project, which contributed to the overall installation time. I wouldn't do it differently though. Take your time and get it right.

Darrell and the RV, boondocking in style.

On our early trips, the performance of the PVs was just as expected. The meter on the Solar Boost showed predictable declines in PV amperage output in 90°F (32° C) temperatures. Conversely, amperage output on cloudy, cooler days was pleasantly surprising. On one occasion, a rather cool night cycled the forced air furnace enough times that the inverter remote panel showed the battery bank was at 86 percent in the morning. A cooler, sunny day had my batteries back to 100 percent in a couple of hours.

All the Comforts of Home

All that is left is to go out and enjoy! We've been out four or five times since the project's completion. The true acid test was whether Gayle noticed any difference in roughing it. The test was anticlimactic, which meant success! One morning Gayle had her coffee on, the curling iron plugged in, and the hair dryer running. This AC was provided by the inverter, powered by the battery bank! Gayle doesn't care where the AC electricity comes from, nor do the appliances. To her, this was the expected norm.

To my great satisfaction, life carried on out in the boonies as if we were in some serviced campground and plugged in. The sun was recharging the battery bank; the inverter was changing DC into AC. All of this electrical magic was happening in the background. The transition was seamless for us. That was the most gratifying part for me.

Access

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Blue Sky Energy Inc. (formerly RV Power Products), 2598 Fortune Way, Ste. K, Vista, CA 92081 • 800-493-7877 or 760-597-1642 • Fax: 760-597-1731 • sales@blueskyenergyinc.com • www.blueskyenergyinc.com • MPPT charge controller

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BP Solar, 630 Solarex Ct., Frederick, MD 21703 • 800-521-7652 or 410-981-0240 • Fax: 410-981-0278 • info@bpsolar.com • www.bpsolar.com • PVs

The Bus Converters Bible, by Dave Galey, 2002, Paperback, 328 pages, ISBN 1-890461-20-2, US$49.95 from Winlock Publishing, 26135 Murrieta Rd., Sun City, CA 92585 • 909-943-0014 • dave@winlock.com • www.winlockgaley.com

RVers Guide to Solar Battery Charging, by Noel & Barbara Kirkby, 1987, Paperback, 164 pages, ISBN 0-937948-08-X, US$12 from RV Solar Electric Inc., 14415 N. 73rd St., Scottsdale, AZ 85260 • 800-999-8520 or 480-443-8520 • Fax: 480-443-0742 • rvse@mindspring.com • www.rvsolarelectric.com

RV Electrical Systems, by Bill & Jan Moeller, 1995, Paperback, 288 pages, ISBN 0-07-042778-X, US$21.95 from McGraw-Hill • 877-833-552 • pbg.ecommerce_custserv@mcgraw-hill.com • www.mcgraw-hill.com

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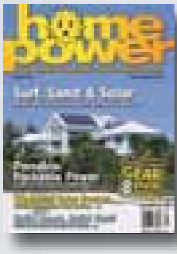

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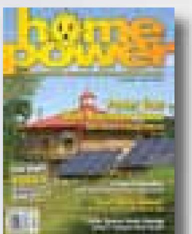

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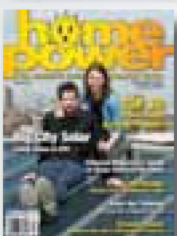

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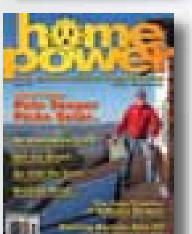

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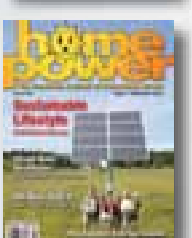

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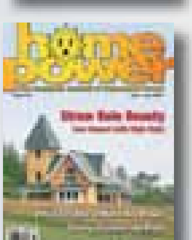

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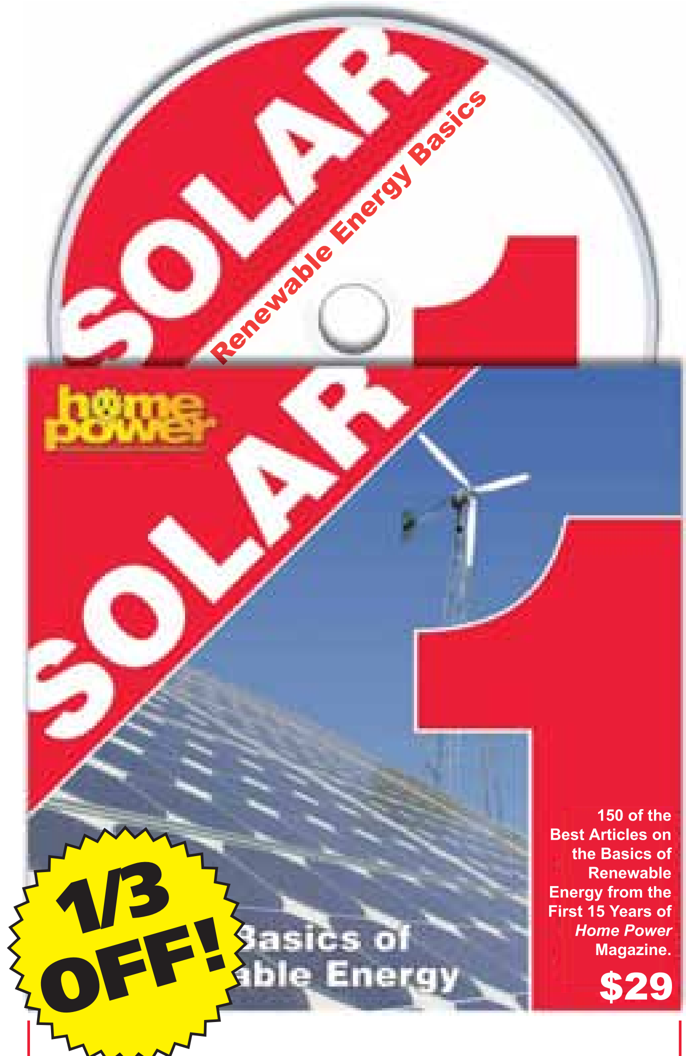

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SunDanzer DCF225

8.1-Cubic-Foot Chest Freezer

Ian Woofenden

Application: We've used the SunDanzer 8.1-cubic-foot (229 l) DC chest freezer for 2 1/2 years in our off-grid home, which is powered by solar-electric arrays and wind generators.

System: Our off-grid electrical system has 1,220 W of photovoltaic panels (PVs) in two arrays, two 9-foot-diameter wind generators, and eight L-16 batteries. We have multiple DC and AC loads. We have a DC engine generator that we use on rare occasions (6 or 8 times per year).

Off-Grid Freezer

When you're growing an off-grid renewable energy (RE) system, a good rule to follow is not to add significant electrical loads without adding production capacity. If you bend or break this rule, you'll end up working your batteries harder and running your engine generator more.

But it's an easy rule to break—most of us tend to want more stuff, and that includes more electrical loads. When I decided to buy a freezer, I was worried about whether or not our system would have the energy to run it. Most off-grid homes do not use electricity for hot water, space heating, or cooking; so refrigeration is often the largest electrical load the RE system needs to support.

You might think that I'd be worried more about operating the freezer in the summer, when it's hottest and the freezer has to work the hardest to keep our food frozen. But at that time of year, our PV system is regularly running a surplus. We have lots of sun here in the Northwest during the summer; we aren't using much energy for lights, and we're outside more and at the computers less.

I was much more worried about the winter, when it can be calm and dark for several days in a row, during which our PV arrays and wind generators aren't producing much. Enter the SunDanzer DCF225. This freezer, and the way we use it, have made my worries unnecessary.

Quick & Easy Installation

Installation of the SunDanzer was a snap. It will operate at either 12 or 24 VDC nominal, and automatically senses the system voltage. This makes for user-friendly installation, since there are no voltage-related configurations or settings to make.

Just wire the unit with the correct gauge wire and a breaker for overcurrent protection, and you're in business. Polarity is important, but the terminals are clearly labeled.

The only other thing to do is to set the thermostat—a dial on the outside of the freezer that can be adjusted between "Min." and "Max.," which correspond to a range of roughly 0 to 23°F (-18 to -5°C). For freezer operation, the normal internal operating temperature should be from 0 to 10°F (-13 to -12°C).

We opted to install our freezer outside, in an open shed on the north side of our house, to take advantage of the natural coolness on this side of the house. It also means that when we're most worried about energy use, we're giving the freezer the least work. Our normal winter temperatures in the 40s and 50s (4–15°C) don't tax the SunDanzer heavily. On a recent winter day, the freezer consumed less than 200 watt-hours of energy in a 24-hour period.

Many people aren't willing to give up the convenience of having their fridge right in their kitchen. But there's an energy price to pay. Increased ambient temperatures intensify the burden on the fridge to keep cool. It's even worse in our kitchen, which has fire burning in the wood cookstove all winter. It may be too much to ask to put your refrigerator in a shed, but it's worth considering putting a freezer there. It's not too inconvenient to run outside when we want to get a fish, a package of steaks, or some frozen blueberries out of the freezer. To keep a few frozen food essentials at hand, we use our refrigerator's small freezer compartment.

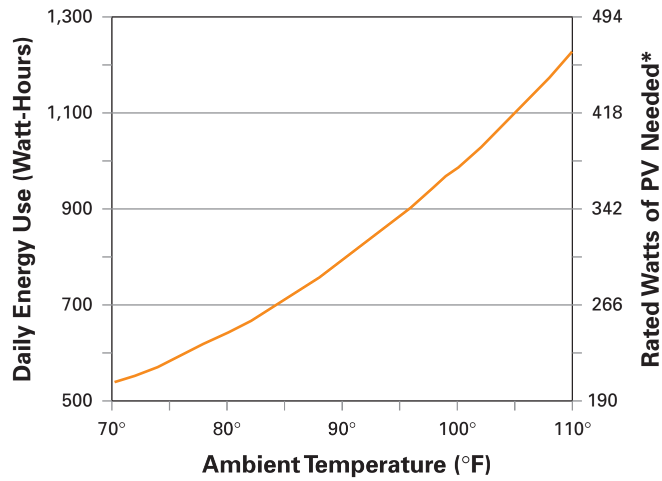
Space-Age Energy Sipper

The SunDanzer takes advantage of space-age design—literally. David Bergeron, team leader for NASA's Advanced Refrigerator Technology Team, who was designing battery-free, PV-powered air conditioning and refrigeration systems for habitats in space, developed it. Bergeron realized that there was also a need for a solar-electric powered refrigerator here on Earth. In 1999, Bergeron founded Solus Refrigeration Inc. (now SunDanzer Refrigeration Inc.) to make this technology available to consumers.

The SunDanzer has a well-insulated cabinet (produced in Hungary by Electrolux) that features 4.33 inches (11 cm) of polyurethane insulation. This, coupled with a super-efficient Danfoss compressor, gives the SunDanzer its energy edge.

A low voltage disconnect (LVD) built into the compressor electronics helps protect batteries in the event of a very deep discharge of the battery bank. If the input voltage to the

Typical SunDanzer DCF225 Energy Use



*Array size is based on 5 average daily peak sun hours

Goodies stay frozen using very little energy in the SunDanzer freezer.

Tech Specs

Power supply: Batteries wired for 12 or 24 VDC nominal (automatic voltage sensing)

Gross capacity: 8.1 cubic feet (229 liters)

Exterior dimensions (W x D x H): 46.9 x 26.2 x 34.5 inches (119 x 66.5 x 87.6 cm)

Shipping weight: 160 pounds (73 kg)

Cost: US$1,074 (MSRP)

Warranty: 1 year

An efficient Danfoss compressor and lots of insulation combine to make an energy-saving freezer.

freezer falls below 10.4 V (in 12 V mode) or 22.8 V (in 24 V mode), the compressor shuts off. When the voltage rises above 11.7 V (in 12 V mode) or 24.2 V (in 24 V mode), the compressor kicks back on. (All battery-based, off-grid RE systems should have a battery amp-hour meter installed that is regularly monitored by the homeowner. The activation of the built-in LVD feature should never be necessary, but it's nice to have this feature incorporated into the unit to protect the batteries from inattentive homeowners or system malfunctions.)

The SunDanzer's low energy use means that this model can be handled with just a few PV panels. In sunnier, arid or semi-arid climates with at least five daily sun-hours, there's even a batteryless model available for PV-direct use. This model marries a variable-speed compressor with MPPT controls to a nontoxic, low-cost, water-based phase-change material that keeps the cabinet cool overnight.

The SunDanzer is a modern appliance that gives excellent performance with minimal energy use. Besides its thick, insulated walls, a CFC-free refrigerant helps the freezer keep cool. The cabinet is comparable to any freezer on the market, with smooth, cleanable surfaces, handy baskets that hang inside the cabinet, and a tight-fitting, lockable lid. A patented low-frost system reduces frost buildup for easy maintenance. This freezer has been a great addition to our off-grid home, at a very reasonable economic and energy price.

Access

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Manufacturer: SunDanzer, 11060 Dyer D-12, El Paso, TX 79934 • 915-821-0042 • Fax: 775-201-0236 • info@sundanzer.com • www.sundanzer.com

Bypass Diodes

& Their Function in Photovoltaic Arrays

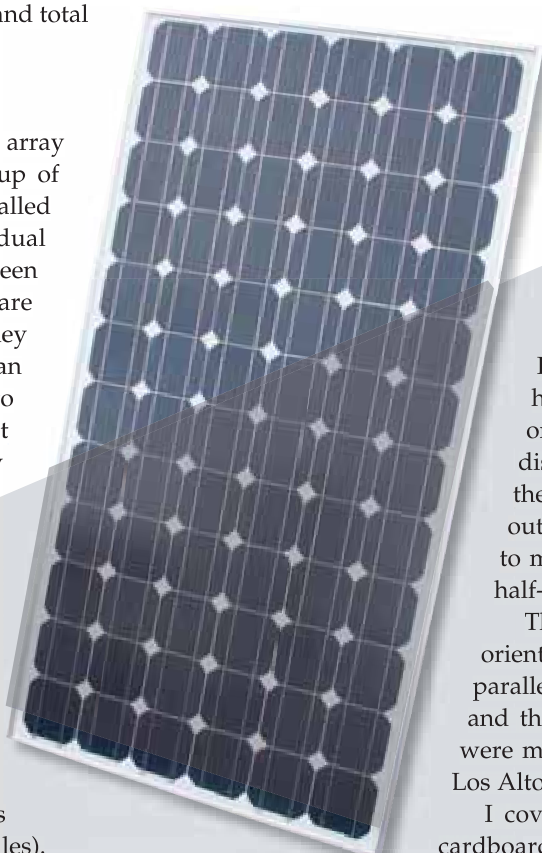
Mark Byington

We all know that solar-electric (photovoltaic; PV) systems don't like shade, even partial shade. A PV system can easily lose a significant portion of its total output with only minimal shading if the shading is in the right place—or maybe I should say "in the wrong place."

Virtually all modern PV modules include bypass diodes. Bypass diodes help a PV system continue to work properly when a module is partially or even totally shaded. I was curious to see how well these bypass diodes really work, so I made some measurements of system output under various conditions of partial and total module shading.

PV Architecture

The particular PV modules in my array are single-crystal. They are made up of crystalline cells of silicon, also called wafers. You can see the individual cells, as well as the small gaps between cells, in the photo. These cells are actually diodes themselves, and they are specially designed to produce an electrical current when exposed to light. In this case, the 72 cells that make up each module are physically arranged as 12 rows by 6 columns.



The cells are all connected in series. The modules, in turn, are connected in series to form a string going to each inverter. (Sometimes more than one string is connected in parallel to one inverter, but I will not consider that here.) In my test system of 11 modules, there are actually 792 silicon cells connected in series (72 cells per module, times 11 modules).

Diodes to the Rescue

OK, so far so good. If an individual cell is shaded, that cell becomes an open circuit or very high resistance condition. That is just the nature of a silicon photovoltaic cell. Since the cells are all in series, the shaded cell blocks the output from all other cells. This is a problem! Without bypass diodes, a small shadow from a vent pipe or even a large leaf on the module surface could actually knock out an entire PV system if the array was configured as a single series string.

This is why manufacturers put bypass diodes in virtually all PV modules. The bypass diodes allow the energy from other cells and other modules to pass around the shaded cells. In the case of the Sharp NT-S5E1U modules in my system, there are three bypass diodes per module. Each diode is connected across two of the six columns as shown in the "Bypass Diode Wiring" diagram. Let's call each of the three sets of two columns with a bypass diode across it a "section."

Measurements & Conclusions

My PV system consists of twenty-two Sharp NT-S5E1U 185-watt modules connected to two SMA Sunny Boy 2500 inverters. Each inverter is powered by eleven modules in series. For my test measurements, I only used half the system—eleven modules and one inverter. An AC disconnect, DC disconnect, and KWH meter make up the balance of the system. I used the output power display from the inverter to measure output power (watts) from the half-system.

The modules are mounted in landscape orientation (long side running horizontally, parallel to the roof eaves) on a wood shake roof, and they face due south. The measurements were made at noon on a bright, sunny day in Los Altos, California.

I covered various parts of a module with cardboard to block the sunlight, and observed the system output for each condition. Keep in mind that the output of a PV system constantly changes throughout the day as the sun's intensity (irradiance) and module temperature change. This affected the absolute accuracy of the data I collected somewhat, and the results should not be considered "scientific." But a definite pattern emerges as far as the importance of bypass

A small bypass diode from a 75-watt photovoltaic module.

diodes is concerned. My results are shown in the "Shade Test Results" table.

With eleven modules in the string and a total "shade-free" output under these conditions of 1,474 watts, I expected about 134 watts per module on average (1,474 divided by 11). Furthermore, 134 watts per module divided by 3 gives us about 45 watts of expected power per section. As you can see from Test 2, shading just one cell reduces the total system output by 54 watts. This shows that with one cell shaded, an entire section is knocked off-line. However, the bypass diode across that section is doing its job, and allowing energy to flow around the disabled section. If it weren't for the bypass diode, the whole PV array would be shut down—from just one cell being shaded.

In Tests 3 through 5, shading any number of rows in one module essentially disables the entire module, but the three bypass diodes work together to allow energy from the other modules in the string to flow around the disabled module. (Note that there is some variation in output as conditions vary.)

In Test 6, shading one column does indeed prevent one entire section from producing energy (reduced power equals 48 watts), but the bypass diode routes energy around the disabled section. And finally in Test 7, with the whole module shaded, the three bypass diodes route energy around the entire module (reduced power equals 136 watts). Conclusion: the bypass diodes do their job very well.

Implications for System Design

Most real-world PV systems experience occasional shading. The effects of this shading on the system output and total energy produced can be minimized if you understand how the bypass diodes work and lay out the system appropriately.

For example, with the Sharp 185-watt modules, you would much rather have a shadow over an entire column of cells (reducing the module's output by 33%) than have a shadow over one row (disabling the entire module). Also, if several modules will have a shading problem, you should connect those modules together in one string. This will effectively localize the shading effects to that one string, and keep other strings performing at their maximum.

What Is a Diode?

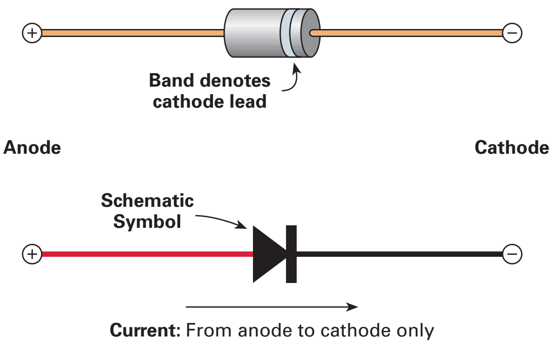
A diode is a one-way electronic valve, the simplest semiconductor device. A diode has two terminals—an anode (the positive side) and a cathode (the negative side). A diode will allow charges to flow only from the anode to the cathode.

Physically, the diode is a small, barrel-shaped device with a wire coming out of each end. The negative side of the diode (its cathode) is usually marked with a band, which encircles the diode's body. Diodes used in electronics are named and marked with a 1NXXX-type designation number.

Diodes are semiconductors and have a nonlinear resistance to electrical flow. All diodes have some forward voltage loss due to the energy barrier (effectively the variable resistance) of the diode itself—about 0.7 VDC for silicon diodes. That is, it takes at least 0.7 VDC of voltage differential from the anode to the cathode before the diode begins to conduct electricity.

When a PV module is exposed to sunlight, the energy barrier of the PV module, or a specific group of individual cells wired in series, is lower than that of the bypass diode. In this case, electricity will flow through the group of cells and eventually on to the battery or inverter. If a cell in a given series-wired group of cells is shaded, the resistance to electrical flow increases radically, and electricity moves through the bypass diode since it's now the most conductive electrical path. This creates an alternate circuit, allowing energy to bypass the shaded group of cells. The specific voltage and current ratings of the diodes used in PV modules vary depending on the operating characteristics of a given module.

A Diode & Its Schematic Symbol



Shade Test Results

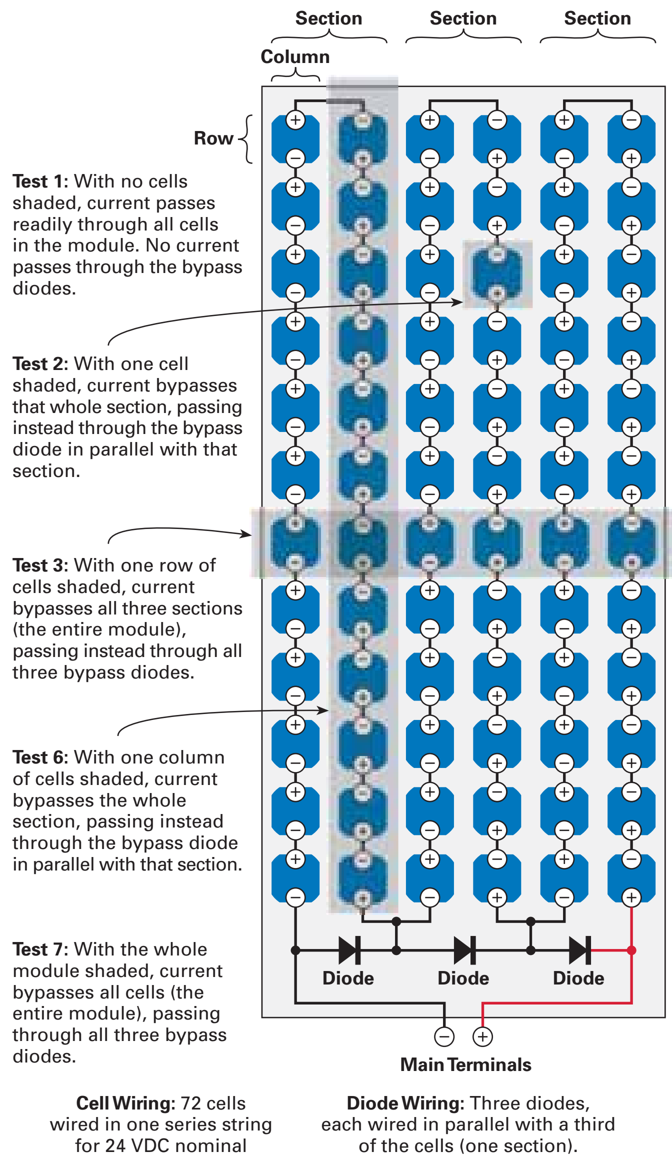
Test	Shading	Output (AC Watts)	Reduction (AC Watts)
1	None	1,474	0
2	1 Cell	1,420	54
3	1 Row of cells	1,322	152
4	2 Rows of cells	1,300	174
5	5 Rows of cells	1,325	149
6	1 Column of cells	1,426	48
7	Whole module	1,338	136

Shading also needs to be taken into account when doing string sizing for batteryless, grid-tie inverters, which means matching the number of modules to the input voltage and input current range of the inverter. In some shading cases, if you are not careful, you can actually cause the PV array's voltage to fall below the minimum MPPT (maximum power point tracking) input voltage range of the inverter. This can cause an even greater loss of output.

For example, at my location, the SMA 2500 inverter can have a minimum of eight and a maximum of twelve Sharp 185 modules in a single string. (The maximum number of modules will depend on the lowest possible ambient temperature that the array will be subject to. Make sure to account for this when determining the number of modules per string.) You would not want to design a PV system with eight of these modules per string if you were expecting frequent shading across the bottom row of cells in two of the modules. Why? Based on the tests above, we know that this would disable both modules, and the effective number of modules in the string would then be six, which could cause the inverter to fall out of MPPT range.

You can never design PV systems that are completely immune to the effects of shading. But with an understanding of how bypass diodes work, you can lay out PV systems that produce the maximum possible renewable energy in the presence of moderate, unavoidable shading.

Bypass Diode Wiring & Results of Shading



Bypass Diode Test Setup

Site

Location: Los Altos, California

Latitude: 37 degrees north

Module orientation: True south

Module tilt: 30 degrees above horizontal

System Equipment

PV modules: Sharp NT-S5E1U, 185 W STC, 36.2 Vmp, 24 VDC nominal

PV array: 11 Sharp NT-S5E1U modules in series, 398.2 Vmp total

Inverter: SMA SWR2500U-SBD (240 V) inverter, 2,500 W, 600 VDC maximum DC input, 234–550 VDC MPPT voltage window, 240 VAC output

Test Conditions

Date of measurement: March 23, 2004

Time of measurement: Noon

Temperature: 75°F (24°C)

Wind speed: 5 mph (2.2 m/s)

Irradiance: 1,006 W/m^2

Note: Modules were somewhat dirty. Power figures were taken from the inverter's LCD display.

Access

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Daystar Inc., 3240 Majestic Ridge, Las Cruces, NM 88011 • 505-522-4943 • pvvern@zianet.com • www.zianet.com/daystar • DS-05A insolation meter

Sharp Electronics, Solar Systems Division, 5901 Bolsa Ave., Huntington Beach, CA 92647 • 800-SOLAR06 or 714-903-4600 • Fax: 714-903-4858 • sharpsolar@sharpsec.com • www.sharp-usa.com/solar • PVs

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

New Inverter Models Receive UL Listing

Two new, residential-scale, batteryless, grid-tie photovoltaic (PV) inverters manufactured by Solectria Renewables recently received UL listing. For definitions of the specifications below, listings of other grid-tie inverters, and tips on selecting the right grid-tie PV inverter for your application, refer to "What's Going On—The Grid?" in *HP106*.

Solectria Renewables

The PVI 1800 (1.8 KW) and the PVI 2500 (2.5 KW) inverters are designed to fill out Solectria's inverter line, which also includes the higher power PVI 13KW (13 KW) that is geared toward large residential and small commercial systems. The newly listed inverters are manufactured with prewired AC and DC cables, and can be connected to either 208 or 240 VAC utility service. The inverters are designed to automatically detect and select the correct grid voltage. Selected specifications for the PVI 1800 are shown below. For complete specifications for both the PVI 1800 and PVI 2500, visit Solectria's Web site (see Access).

Solectria PVI 1800 (grid-tie, batteryless)
Maximum continuous output power: 1,800 W at 55°C (130°F)
Maximum recommended PV array power (STC): 2,200 Wp
Maximum DC input voltage: 400 Voc
MPPT DC voltage range: 125–350 V
Nominal AC voltage: 240/208 V (auto detect)
Warranty: 5 years (extended warranty available)
List price: US$2,193

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Solectria Renewables LLC, 360 Merrimack St. Bldg. 9, 2nd Fl., Lawrence, MA 01843 • 978-683-9700 • Fax: 978-683-9702 • inverters@solren.com • www.solren.com

What the Heck? 19

Zero Energy Home

Used In: Green building and renewable energy discussions

AKA: Total energy offset, energy-neutral home

What It Is: A home with an annual net energy input of zero

What It Ain't: A house full of couch potatoes, or fuzzy math

When your home produces at least as much energy as it uses, it's a zero energy home (ZEH).

ZEHs, like most homes, usually have external energy inputs such as utility electricity, natural gas, firewood, or propane. Then how can such a home be considered a ZEH? Simply by offsetting those external inputs with excess energy generated within a home, and netting them over the entire year. The normal method of doing this is with grid-tied home electricity production. Over a year, it's possible for a home to produce enough excess electricity during sunny or windy months to balance all of the utility electricity, gas, or other energy inputs it relies on during months of low energy production.

This home, showcased in *The New Strawbale Home* by Catherine Wanek, pairs passive solar design with well-insulated walls—two strategies toward achieving a ZEH.

Critical components of a ZEH are energy efficiency and conservation. To keep a home's energy production capacity affordable, most ZEHs also employ passive solar design, solar space or water heating, high building envelope efficiency, energy efficient appliances, and careful use and monitoring of energy by the home's occupants. But becoming a ZEH is not as simple as it sounds. Construction, design, and appliance costs will be higher than for a conventional home, and some amount of conscientious attention must be paid to keep energy use within limits. The advantages of a ZEH include high comfort, protection against fluctuating energy prices, less environmental impact, and the secure feeling of self-sufficiency.

It is very difficult for an off-grid home to be a ZEH. Despite their electric energy independence, most off-grid homes still rely on outside energy inputs like propane or wood for cooking, space heating, water heating (as a backup to solar domestic water heating), and sometimes refrigeration. But unlike grid-tied homes, off-grid homes have no method for feeding their excess energy production back onto the grid to offset the other inputs. Only a few off-grid pioneers and energy revolutionaries have achieved ZEHs by making their own burnable fuel through home-scale hydrogen or methane production to replace energy inputs.

It is important to understand what a ZEH really is. The U.S. Department of Energy has been using the term to describe an initiative that seeks to build "ZEHs" only required to perform "at least 50 percent more efficiently than those built to current minimum efficiency standards," instead of at true net-zero energy. That kind of fuzzy math just doesn't make it.

Michael Welch • michael.welch@homepower.com
(With thanks to Larry Schlussler of Sun Frost)

Cooking Under the Sun

Rose Woofenden

Next time you're in the mood for slow food—a savory casserole, or even home-baked bread—consider cooking with the sun. Almost anything that can be prepared on a conventional stove or in an oven can be cooked in a solar cooker, with delicious results. And while you're enjoying your tasty, sun-warmed meal, you can also take comfort in the fact that you've saved energy—and prevented some pollution—in the process.

Delicious and nutritious meals can be prepared in a solar oven. Here, the author uses a Sun Oven, a commercially manufactured box cooker.

Inside or Outside the Box?

Although three distinct types of solar cookers exist, they all have one thing in common—they harness the sun's energy to cook food. Parabolic solar cookers use curved or multifaceted reflectors to focus and concentrate the sun's energy onto a cook pot or food item. With a parabolic cooker, frying food is even possible. Panel cookers, the most basic type of solar cooker, use reflective panels around a black glass jar, or a cooking pot wrapped in a plastic bag or covered with a clear glass bowl. Although these cookers are simple to build, their open design compromises cooking performance and heat retention.

Solar ovens and box cookers are the most common type of cooker used. Simple box cookers and ovens use glazing materials, such as glass or clear plastic, to admit the sun's short-wavelength energy. (Glass performs better—it lets in more energy, and insulates better than plastic.) They are a little more complicated to build than panel cookers, but perform better. Reflectors, which create a larger surface area to concentrate more of the sun's energy into the box, can be paired with a box cooker or oven to boost cooking power. They can be made from a variety of materials, from foil-covered cardboard to sheet metal.

With box cookers, once the heat has been captured, it must be retained and absorbed by the food, instead of being reflected or leaked out of the box. A good seal between the box and glazing material is crucial to prevent convective heat losses. Insulation minimizes heat loss through the sides and bottom of the box.

To aid in heat absorption, the box bottom is painted black or fabricated from a dark material, and black cookware, such as cast iron or dark glassware, is also used. (Note that cast iron cookware, which has more mass than glass cookware, can add to cook time.) For cooking that requires a constant heat, thermal mass such as bricks or stones can be placed inside the cooker to help maintain a more consistent temperature in the cooking box.

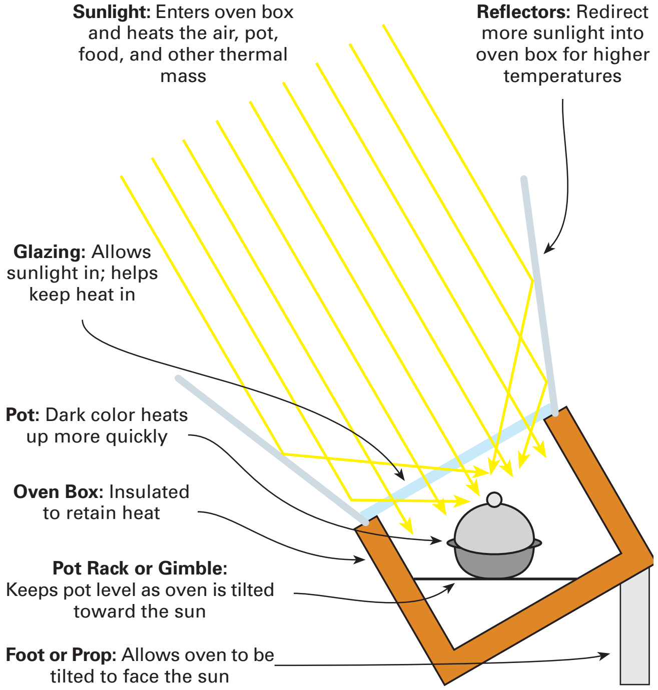
Commercially available cookers range from the rudimentary and compact (small, foldable reflectors) to the complex (parabolic cookers that require detailed manufacturing processes). Off-the-shelf cookers can range in price from US$18 for a foldable, aluminum foil-covered foam reflector to US$250 for an insulated Sun Oven, complete with a gasket-fit, tempered-glass door. With a few on-hand materials, and minimal skill and effort, you can even make your own simple solar cooker.

Energy Efficient Cooking

According to energy research scholar Richard Heede, cooking accounts for about 6.5 percent of the energy used in the average U.S. home. A standard electric range uses 750 kilowatt-hours a year. If your electricity comes from a fossil fuel-fired power plant, that means you're adding more than 500 pounds (227 kg) of carbon dioxide to the atmosphere annually, just from cooking.

Tapping into a natural, renewable resource, such as the sun, wind, or falling water, to make electricity is more environmentally friendly than using nonrenewable resources. Because solar cookers use the sun's energy directly, solar cooking is even more efficient (and less expensive) than cooking with solar electricity. Regardless of how your electricity is produced, when you use a solar cooker, less energy is used and fewer resources are consumed. With their minimal parts, solar cookers require far fewer raw materials to make or manufacture than a conventional stove—a significant savings in embodied energy.

Basic Anatomy of a Solar Box Cooker



Parabolic cookers like this Zomeworks Sunflash can actually get hot enough to fry food. Beside it, a foldable, cardboard Sunspot backpacker's cooker.

In less developed countries, it's not fossil fuels that are being burned, but wood. In Ethiopia, 500,000 acres (2,023 km^2) of forests are cut each year. The wood is used for fuel and construction, and the cleared land is used for farming. Studies conducted by the United Nations (UN) show that 50 percent of the rain forests being destroyed are used for cooking fuel.

"In some African countries, 80 to 90 percent of the total energy [for cooking] comes from firewood. The wood is rapidly disappearing," says renewable energy advocate Allan Sindelar. "Solar cooking can play a major role in easing people's lives, slowing deforestation, and reducing carbon dioxide emissions into the atmosphere."

UN studies predict that with the current trends in consumption, cooking fuel shortages will become a serious problem in the near future. Implementing solar cookers as a primary cooking application could help reduce impacts on forests. And, because no fuel is burned, carbon dioxide emissions could be drastically reduced.

"If only 1 percent of the 1.5 billion people affected by cooking fuel shortages today were to use solar cookers seven months of a year, they would save 2 million tons (1.82 million metric tons) of wood," says Joseph Radabaugh in his book, *Heaven's Flame*. "This would also prevent the release of 85,000 tons (77,350 metric tons) of pollutants, such as sulfur dioxide, carbon monoxide, nitrous oxides, ash, etc. These savings represent the equivalent of 10 million trees a year."

This homemade box cooker uses a bamboo oven box and foil-covered cardboard reflectors.

Saving Cash, Gaining Time & Health

Although using a solar cooker may not cause a dramatic change in your utility bills, you'll still save. Keep in mind that the price you pay for electricity is not its actual cost—federal taxes and subsidies pay a large part of our energy bills. According to Radabaugh, in 1989, taxpayers in every household paid US$390 toward energy costs, above and beyond their utility bills. This money is used to subsidize large energy companies.

If you are living off grid and producing your own electricity, solar cooking can help reduce your electric system costs. People living off grid often rely on propane or natural gas-fueled appliances. Using a solar cooker can minimize use of these resources, lowering your gas bill and leaving more money in your pocket.

In developing nations, using a solar cooker isn't so much a financial gain, but a valuable gain of time. In some parts of the world, people spend most of their day collecting fuelwood. As more and more wood is harvested and forests are razed, they must travel farther and farther from their homes to seek fuel.

According to Radabaugh, the costs and time spent gathering cooking fuel can exceed the costs of the food itself. "Relief agencies estimated that for a family of eight, it took 99 hours to collect the firewood to cook food for one week," he says. Eliminating the need to collect firewood frees families to work on other pursuits—more time for parents to spend with their children, or more time for farming and gathering food.

Using wood for fuel takes more than a toll on families' time. Studies done by the World Health Organization show that respiratory infections caused by smoke inhalation from cooking with biomass fuels cause two million deaths each year. Women who routinely cook with biomass fuels have a much higher risk for chronic bronchitis, asthma, and other health problems. Children who live in homes where cooking is done with biomass fuels also are at increased risks for health problems and even death.

Change, One Meal at a Time

One of the biggest obstacles to solar cooking is that it requires some lifestyle changes. Solar cookers cook food slowly—forget about getting a fast-food fix. Instead of heating up your electric range or starting a fire an hour before you intend to eat, you put food in your cooker hours before you want to eat and let it cook slowly all day.

Admittedly, solar cooking does require some planning and attention, and busy lives and schedules make it a bit more difficult. But the benefits beyond the obvious may surprise you. *Cooking with the Sun* authors Beth and Dan Halacy say that "baking is far superior to boiling as a method of cooking vegetables. The solar oven lends itself beautifully to this nutritious and tasty way of preparing vegetables, legumes, and vegetable casserole dishes."

Of course, an obvious challenge to solar cooking is the weather. When the sun is not cooperating, your solar cooker

Solar cooking pioneer Sam Erwin designed the highly efficient Solar Chef, a solar cooker that combined the features of a box cooker and a parabolic reflector cooker.

is out of commission for dishes that require high heat. But you don't have to abandon your cooker completely—even cloudy days may permit some low-temperature cooking.

Perhaps the biggest impediment to the widespread use of solar cookers is the lack of education. People are often reluctant to use a technology different from what they're used to. While the technology is very simple, it is not well known. Educating across cultures can be difficult, but it's imperative. According to Solar Cookers International, one-fourth of the world's population suffers fuel scarcities. Half of the world's population uses wood for cooking.

By replacing biomass fuels, solar cookers can improve the health of people who use them. And using the sun's energy for cooking can help curtail deforestation and curb pollution. In developing countries, solar cooking can help enhance a family's quality of life by reducing the time spent gathering fuel. For those of us in the developed world, using solar cookers means decreasing our dependence on unsustainable, nonrenewable sources of energy and asserting our energy independence, one meal at a time.

Access

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Solar Cookers International, 1919 21st St. #101, Sacramento, CA 95814 • 916-455-4499 • Fax: 916-455-4498 • info@solarcookers.org • www.solarcookers.org • Solar cooking information resource

Sun Ovens International, 39W835 Midan Dr., Elburn, IL 60119 • 630-208-7273 or 800-408-7919 • Fax: 630-208-7386 • info@sunoven.com • www.sunoven.com • Solar cookers

Zomeworks Corp., PO Box 25805, 1011A Sawmill Rd., Albuquerque, NM 87125 • 800-279-6342 or 505-242-5354 • Fax: 505-243-5187 • zomework@zomeworks.com • www.zomeworks.com • Sunflash cooker (discontinued)

Cooking with the Sun, by Beth & Dan Halacy, 1992, Paperback, 114 pages, ISBN 0962906921, US$9.95 from Morning Sun Press, PO Box 413, Lafayette, CA 94549 • Phone/Fax: 925-932-1383 • jdhowell@ix.netcom.com • www.home.ix.netcom.com/~jdhowell/

Heaven's Flame: A Guide to Solar Cookers, by Joseph M. Radabaugh, 1998, Paperback, 144 pages, ISBN 0962958824, US$15 from *Home Power*, PO Box 520, Ashland, OR 97520 • 800-707-6585 or 541-512-0201 • Fax: 541-512-0343 • subscription@homepower.com • www.homepower.com

"Solar Cooking in Kenya: Progress at the Kakma Refugee Camp," by Barbara Knudson & Mark Aalfs in *HP66*

"The Forces for Good Will Organize Around the Sun," by Allan Sindelar in *HP31*

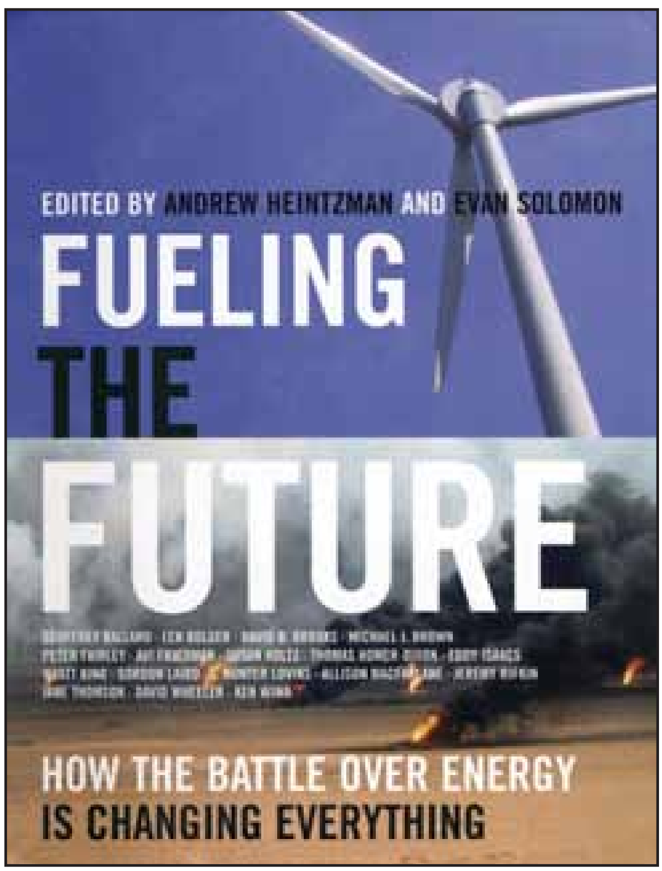
"Solar Cooking and the Livin' is Easy," by Jennifer Barker in *HP88*

Fueling the Future:

How the Battle Over Energy Is Changing Everything

Reviewed by Robin Fair

Fueling the Future arose from the Ingenuity Project, an annual effort to bring together the world's brightest minds in all endeavors to brainstorm practical, ingenious solutions to the world's most complex problems. This book, the first installation in a series, is a compilation of thirteen essays from distinguished researchers and inventors, such as fuel-cell industry leader Dr. Geoffrey Ballard, political activist and journalist Ken Wiwa, and author and energy analyst L. Hunter Lovins.



Topics range from the future of natural gas and conventional fossil fuels to in-depth examinations of energy efficiency and the potential of fuel cells. Several essays focus on the much-speculated hydrogen economy, its viability, and the hurdles still to be overcome. Here are a few highlights of the essays.

Dr. Geoffrey Ballard. Cofounder of Ballard Power Systems and a pioneer in the field of hydrogen fuel cells, Geoffrey Ballard outlines his argument for the "only technology … available [to replace the internal combustion engine] … is the proton exchange membrane (PEM) hydrogen fuel cell." His compelling writing also proposes the idea of "hydricity"—making hydrogen power and electricity almost indistinguishable from one another. Many readers may take issue with one of Ballard's more controversial positions in this essay—his labeling nuclear energy as "the only viable, clean source of large quantities of energy."

Alison MacFarlane. Georgia Institute of Technology professor Alison MacFarlane challenges Ballard's position on nuclear energy in her essay, "Is Nuclear Energy the Answer?" MacFarlane examines nuclear energy from several angles, considering old and new plant designs, greenhouse gas emissions in the production of uranium-enriched fuel, capital costs and who pays for them, subsidies, waste disposal, nuclear plants as terrorist targets, and the possible diversion of nuclear products to create weapons.

Ken Wiwa. Political activist and journalist, Ken Wiwa describes the effect of petroleum exploitation on Nigeria's Ogoni people and environment. In this country that's the sixth largest oil producer, but one of the poorest in the world (ironically, Nigeria has to import its gasoline supplies), Wiwa recounts his efforts to develop and support clean energy technologies and spur a new information economy in his homeland.

At 416 pages, this text-heavy tome could seem daunting to the casual reader. But the editors have taken care to ensure that the contributors pose their arguments in everyday language, not in academic or scientific jargon, making a potentially frustrating book an interesting and compelling read. And threaded between each chapter of the book is the history of energy, traced from 4.5 billion B.C. to present day. These energy tidbits give readers fascinating facts, and provide brief respites between the heavy-hitting, information-rich essays. *Fueling the Future* offers thoughtful discussions of the world's myriad energy issues that will provoke and stimulate your mind.

Access

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Fueling the Future: How the Battle Over Energy Is Changing Everything, edited by Andrew Heintzman and Evan Solomon, 2003, Paperback, 416 pages, ISBN 0-88784-724-2, US$18.95 from Publishers Group West, 1700 Fourth St., Berkeley, CA 94710 • 800-788-3123 or 510-528-1444 • Fax: 510-528-5511 • info@pgw.com • www.pgw.com


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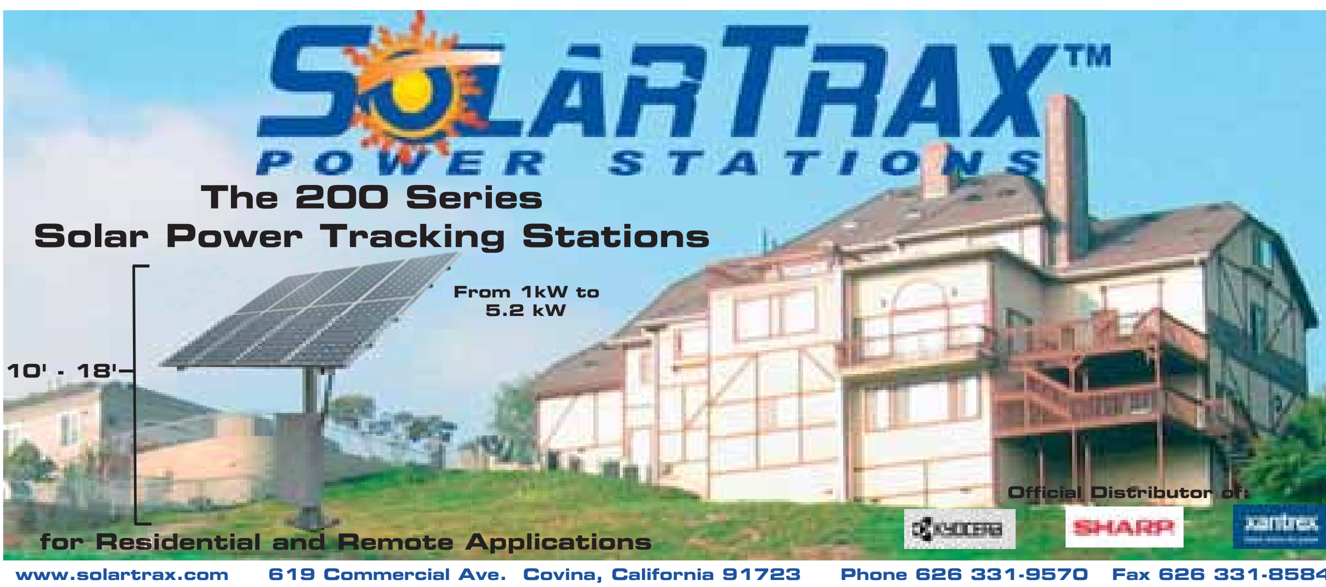
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Selecting Cables

for PV Systems

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center,
Sandia National Laboratories

Photovoltaic (PV) modules will supply energy for 40 years or more when illuminated by the sun. The cables and conductors used in PV systems need to be able to carry PV-supplied energy safely for the lifetime of the PV modules without deterioration, or hazardous conditions will arise. Numerous types of conductors, wire, and cables are widely available from a number of sources with a bewildering array of labels and prices. How do we determine that a particular cable is safe for use in a particular application, and that it will remain safe over the many years that our renewable energy systems will be producing energy?

Previous *Code Corner* columns have covered conductor type markings (USE-2, NM, RHW-2, THW, etc.) required on cables to be used in various locations in PV systems. Those columns have discussed the type markings required for environmental conditions, such as exposure to sunlight, temperature levels, and moisture. (See *HP89*, *HP91* & *HP94*.)

Unfortunately electrical cables without these type markings are available from many sources, such as auto parts stores, hardware stores, building supply stores, and welding supply shops, among others. Furthermore, many of these cables do not have any marks or labels to ensure that they have been tested and evaluated for safety. See the table for some of the commonly used conductor type markings and what they indicate.

Conductor Type Designations

Code	Temp.	Characteristics
T	–	Thermoplastic insulation (most commonly PVC)
R	–	Thermoset insulation (synthetic rubber)
W	–	Wet rated
H	75°C	High temperature
HH	90°C	Higher temperature
N	–	Nylon jacket
X	–	Cross-linked polyethylene
-2	90°C	High temperature & wet rated
Wire Type		
THHN	90°C	Dry and damp locations, flame retardant
THWN	75°C	Dry and wet locations, flame retardant
THWN-2	90°C	Dry and wet locations, flame retardant
THW	75°C	Dry and wet locations, flame retardant
RHH	90°C	Dry and damp locations, flame retardant
RHW	75°C	Dry and wet locations, flame retardant
RHW-2	90°C	Dry and wet locations, flame retardant
USE	75°C	Underground service entrance, sunlight resistant
USE-2	90°C	Underground service entrance, sunlight resistant
UF	75°C	Underground feeder
XHHW	90°C	Dry locations, flame retardant
XHHW	75°C	Wet locations, flame retardant
XHHW-2	90°C	Dry and wet locations, flame retardant
NM	60°C	Nonmetallic sheathed cable, flame retardant

To ensure the greatest probability of buying and installing safe, durable conductors that meet the requirements of the *National Electrical Code* (*NEC*), you should look for cables that have at least the following markings or labels. First, the type marking (USE-2, RHW-2, THWN-2, etc.) should be on the cable, and that type marking should be appropriate for the particular PV application, such as module interconnections or battery-to-inverter cables.

Second, the mark of a nationally recognized testing laboratory, such as Underwriters Laboratories (UL), should be present. This mark indicates that the cable has undergone extensive testing for that application and has been "listed" for compliance with the appropriate UL standard for that type of cable. The *NEC* and most inspectors require that all equipment used in electrical systems be listed.

At present, UL is the only laboratory that is recognized and accepted throughout the United States for testing and marking cables. Note that cables bearing the CSA (Canadian) and/or CE (European) marks must also have the UL mark to comply with U.S. requirements. In the near future, cables marked "CSA (U)" for U.S. standards may be acceptable, and ETL may, at some point, also list cables in the United States to standards established by UL.

UL Standards for Cables

Underwriters Laboratory has two major functions in the electrical energy industry in the United States. The first function is to write, coordinate, and publish safety standards. The second function is to test and evaluate materials and equipment against those standards.

A safety standard is a document that details all of the tests and the results of those tests that a particular type of cable must meet before it can be listed as complying with the standard. For example, UL Standard 44 for "Rubber-Insulated Wires and Cables" was first published in 1917 and has had fifteen major revisions since then. The latest edition was published in 1999 and is now entitled "Thermoset-Insulated Wires and Cables." This standard covers conductor types (such as RHW, THW, XHHW-2, and similar cables) that are acceptable for use as battery cables in PV systems. Numerous companies and other agencies that design, manufacture, sell, install, and inspect cables are involved with keeping the standard current.

This standard is more than 70 pages long, and is updated periodically and completely revised every few years as the technologies change for making, using, and testing cables. In addition to requirements for the types of rubber and synthetic rubber required to make the cable, numerous tests are included in the standard, and these tests are used to verify the quality, durability, and safety of the cables. (Note that each UL standard references other UL standards that must also be met. For cables, additional standards establish requirements for the insulation material and the copper used in the conductors. UL standards provide details on the tests, how they will be conducted, and what results are required for passing.)

Testing to the Standard

The standard is then used by nationally recognized testing laboratories to test the cable. This is UL's second function with respect to cable markings.

A nationally recognized testing laboratory goes through a lengthy evaluation process conducted by special certification agencies to ensure that the lab has personnel with the appropriate educational backgrounds and experience, and sufficient test and evaluation equipment to properly perform the required tests. Test equipment must be calibrated against calibration standards directly traceable to the National Institute of Standards and Technology (previously, the National Bureau of Standards).

A cable is submitted to UL for testing against the standard. UL tests the cable, and if it passes all of the tests in the standard, UL allows the manufacturer to use the UL mark (the letters "UL," sometimes in a circle but more often without) on the cable, indicating that it is a listed product.

UL also visits the manufacturer's facility and determines that the equipment and processes used to make the cable are of sufficient quality to ensure that uniform quantities of the cable can be produced. But the testing does not end there. Any time the cable manufacturer changes the materials used in the cable or the way the cable is made, the manufacturer must notify UL and resubmit the modified cable for evaluation and possible retesting.

Additionally, every three months, UL visits the cable manufacturer and verifies that the materials and production processes are still producing the same cable that was originally tested. UL may pull random samples of cable from the production line or the warehouse and retest them at any time.

To further establish the continuing quality of any listed cable in this highly competitive industry, cable manufacturers routinely test samples of their competitors' cables and protest to UL if the listed cables do not meet the standard in any way.

Other Cables—Usually Not Acceptable

In most major cities, many smaller towns, and certainly through the Internet, you can find a large number of widely varying cable types that are not suitable for use in PV installations. These might have type designations such as DLO (diesel locomotive cable), welding cable, battery cables, Tek cables, etc. These cables may have a very impressive set of markings, such as 600 volts, 1,000 volts, MSHA, IEEE, TVD, CE, 105°C, 200°C, and so forth. These markings have no meaning with respect to the requirements of the *NEC* and PV installations. While they may be superior cables in their intended applications, they have not been tested for use in electrical systems falling under the *NEC* and should not be used.

Best That I Can Find

Although many different cables will meet the minimum requirements of the *NEC*, when I am designing or installing a PV system that may produce potentially hazardous amounts of energy long after I am gone, I try to use the best cables that I can find. If I need exposed module interconnection cables, I use USE-2 conductors made from cross-linked polyethylene (marked XLP or XLPE).

Strictly speaking, USE-2 cables are not tested for use in conduit. Since this cable has no flame retardant, it cannot be used in buildings—even in conduit. I buy cables marked USE-2 with the additional RHW-2 marking, so that I may use them inside conduit in buildings. As far as can be determined based on actual use experiences, utility usage, and data from the manufacturers, these are the most durable cables that we can use in PV systems.

Make an Informed Decision

Yes, you can purchase unmarked or improperly marked wires and cables. They may work quite well in a PV system. But then again, they may not.

How are you to know that a piece of unmarked (no type mark, no listing mark) cable X that you bought yesterday will perform the same as a similar piece of unmarked cable that you bought at the same store a year ago? Is cable X bought in Arizona the same as cable X bought in California? Will either of these cables withstand the test of time? Did the manufacturer cut costs by making the insulation a little thinner? Did the manufacturer change insulation materials to a type that saves a few pennies, but might crack or catch fire more easily? Were costs reduced by accepting copper with more impurities, which might become brittle or have a higher resistance?

The use of properly type-marked, listed cables ensures that most of these uncertainties are eliminated. With reliable PV modules producing electricity for 40 years or more, it is prudent to buy the proper cables that have been thoroughly examined and tested by trained, experienced personnel, and periodically rechecked. Then you won't have to worry about the uncertainties of using unmarked cables.

Access

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

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

Underwriters Laboratories, 333 Pfingsten Rd., Northbrook, IL 60062 • 877-854-3577 or 847-272-8800 • Fax: 847-272-8129 • customerservice.nbk@us.ul.com • www.ul.com

Canadian Standards Association (CSA), 178 Rexdale Blvd., Toronto, ON, Canada M9W 1R3 • 800-463-6727 or 416-747-4044 • Fax: 416-747-2510 • sales@csa.ca • www.csa.ca

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Who Speaks for RE?

Don Loweburg

As a solar contractor, I read a fair number of journals and magazines, the majority of which focus on renewable energy (RE) topics. The other few I read regularly deal with general electrical contracting topics. Occasionally, even these mainstream contracting magazines run articles on my favorite subject—RE. Last January saw a veritable avalanche of RE articles in these electrical trade magazines.

Photovoltaics (PVs) and other renewable energy technologies are finally getting mainstream trade attention. In "View on Renewables," published in the January 2005 issue of *Power Engineering*, Steve Westwell, vice president of BP's Renewables and Alternatives group, says:

So what do we see as the priorities for policymakers? We do look for support that is predictable, consistent, and long-term—at both the global and local level…Our vision is of a market in which the players from the private and public sectors have a unified, strategic commitment for renewable energy, including solar, and a coherent program to implement it.

Westwell's words of support for RE are welcome, and echo the sentiments often expressed in this column and by many other pro-RE voices. Renewables *do* require both public and private sector support to accelerate their use and acceptance. But as far as establishing a "unified, strategic commitment for renewable energy," the reality is that even PV manufacturers are not yet unified. Rather, companies' "commitments" can likely be translated as, "we are committed to the products we manufacture." PV manufacturers have marketing plans and strategies focused on selling the products they manufacture. Unfortunately by its very nature, this presents a rather myopic vision for renewable energy as a whole.

The Other Solar Option

"New solar panel—50 percent efficiency! Price breakthrough—only US$1 per peak watt! No rebates required."

OK, so it's not new, but it is tried and true. What I'm describing is the typical performance of a solar water heating panel, located almost anywhere in the southern half of the United States. Most folks are surprised to discover that solar water heating is extremely cost effective—in some areas without having to take advantage of rebates.

The Department of Energy reports that, "Water heating constitutes 14 percent of the total energy consumption of residential buildings. In the lodging industry, 42 percent of energy use goes for water heating." These numbers demonstrate the great potential, mostly unrealized, of solar water heating.

According to the California Energy Commission (CEC), "A homeowner relying on electricity to heat water could save up to US$500 in the first year of operation by installing a solar water heating system." Over time, that savings grows even larger as electricity rates continue to climb. The CEC says that the cost of solar water heating systems decreased by almost one-third between 1980 and 1990. Today, consumers who install these systems can expect to recoup their investment in only four to seven years. And as demand increases and manufacturers take advantage of economies of scale, prices for solar water heating systems will continue to drop.

For many years, natural gas has been *the* cost-effective alternative to electric water heating. Today, 70 percent of the new homes and 51 percent of *all* homes in the United States are supplied with natural gas. But along with increasing demand, shortages and significant price increases have occurred. And suppliers of natural gas are currently planning to import liquefied natural gas to bolster supplies.

The historical advantage enjoyed by natural gas over electricity for water heating has evaporated. There is and will be an increasing opportunity for solar water heating—the *other* solar option and an important element in the transition to a renewable energy future.

Many Voices for RE

Some energy companies that also promote renewables are simultaneously developing their holdings of nonrenewable energy sources. According to the Energy Information Agency, "Between 1997…and 2000, BP Amoco and its consolidated affiliates increased their U.S. production of dry natural gas by 921 percent." Last year, General Electric, one of the world's largest manufacturers of nuclear reactors, purchased AstroPower, expanding its renewable holdings to include PV and wind.

Without a diligent public policy in place to support renewables and to balance the private sectors' vision, what's the possibility that corporate branding, favorably linked to the companies' renewable energy products, would be used to promote nonrenewable energy products? Here's a worst-case scenario—imagine a main-course serving of oil or nukes, with a side-dressing of "greens." Good marketing, bad policy.

Corporate press releases and marketing efforts should not be mistaken for coherent policy. We expect manufacturers to toot their own horns—that's just part of doing business. But we should not lean or rely on them to set policy standards for energy issues that have an impact on every one of us. Corporate marketing activities cannot be a substitute for sound renewable energy policy design.

A Vision for Renewables

So, who needs to speak for the solar industry, and for the state of RE? Many voices, of course.

Readers of *Home Power*, its publishers, and this author have a broad vision of a renewable energy future. We know that only with the widespread adoption of highly energy efficient buildings, efficient machines and appliances, and a full deployment of *all* available renewable energy resources—not just PV—can future generations hope to enjoy the level of comfort we enjoy today. A successful renewable energy policy would include a portfolio of renewable distributed generation technologies coupled with building and appliance efficiency.

Probably the most important voice for RE is that of everyday people. A growing number of folks are transforming their words into action, and choosing RE for themselves. This is perhaps one of the most powerful ways to support the widespread use of renewable energy technologies.

Access

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California Energy Commission information on solar water heating • www.consumerenergycenter.org/renewable/basics/solarthermal/water.html

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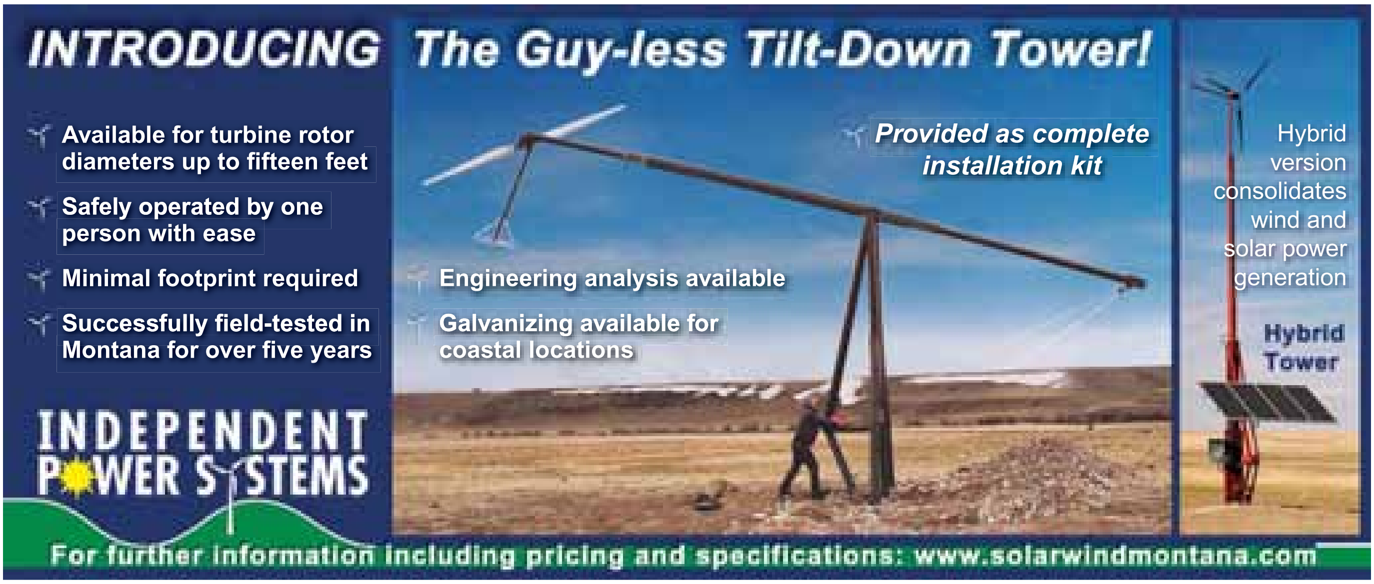
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Energy Budget for 2006

Michael Welch

This year's proposed federal energy budget looks like a gift to the nonrenewable energy industry. If passed by Congress, it will have far-reaching effects on the energy future of our nation. The budget does not recognize that the world is either on or close to the declining side of oil production. It ignores how much we could do to secure our future by increasing energy efficiency and acting as if the world's changing climate mattered.

The current administration's proposed budget for the Department of Energy (DOE) is about 2 percent less than last year's. But fossil fuel subsidies within the DOE's budget are increased by 18 percent, and nuclear subsidies are similarly increased. So what accounts for the difference? Declining subsidies for environmental, renewable energy, and energy efficiency programs, as you may have suspected. For example, a huge chunk has been removed from environmental cleanup programs at the DOE's numerous radioactively contaminated sites. About US$48 million less than last year is proposed for energy efficiency and renewable energy.

Another budget hit is the electrical transmission and distribution network subsidies. These are industry handouts for sure, but these cuts could affect many ordinary citizens if there is another major grid outage like the one in the Northeast in 2003.

Pro-Nuke Federal Budgeting

When it comes to nuclear energy, money and political power talk. The desires of the public, even when they represent a majority view, can easily be pushed to the sidelines. This is borne out by the US$511 million subsidy for the nuclear power industry in the administration's proposed budget for fiscal year 2006. An additional US$651 million (that's US$74 million more than last year) is proposed for the Yucca Mountain nuclear waste dump. The proposed Yucca Mountain budget increase is for new projects that are premature, considering that more money needs to be spent on evaluating the site's ability to contain the waste for tens of thousands of years. Instead, much of the budget funding is earmarked for building new rail lines to carry the waste, developing the site's waste handling infrastructure, and building new casks to transfer waste to the site. The cart is before the horse.

The budget proposes US$56 million (US$46 million more than was requested last year) to subsidize the Nuclear Power 2010 program, which pays half of utilities' application costs for siting and building new nuclear power plants. The stated goal of this budget item is to have a new reactor ordered by 2009, and operating by 2014.

The budget includes US$45 million (US$15 million more than last year) for the Generation IV program, which is supposed to come up with a reactor design that is "inherently safe." This sounds like a money hole to me—a perpetually funded project with an impossible task is really corporate welfare to keep the nuke industry alive and kicking.

Reprocessing of spent nuclear fuel is an idea that even the nuclear industry rejected years ago as too dirty and impractical. Yet the proposed budget includes US$70 million in research and development (R&D) dollars—still more corporate welfare. Reprocessing separates plutonium from spent nuclear fuel for bomb making, and produces fuel to be used again in nuclear reactors.

Another US$20 million is proposed for R&D on generating hydrogen by using nuclear reactors. This more than doubles last year's budget, and purportedly is for reducing future dependence on foreign oil. According to Public Citizen's Critical Mass Energy Program, "Hydrogen has a long-term potential (in 50 years or more) to help reduce the country's reliance on foreign oil, but using nuclear power or fossil fuels to produce hydrogen makes a mockery of clean energy goals."

Finally, the proposed nuke budget includes US$24 million to educate more nuclear scientists and engineers. Apparently, the anti-nuclear sentiment of the past few decades, and a floundering nuclear industry, took a toll on the number of qualified people available to the nuclear industry. The proposed subsidy is aimed at increasing the number of students pursuing careers in nuclear energy by providing grants, fellowships, and college infrastructure funding, and even developing high school curricula on nuclear engineering. How about investing that kind of money in college renewable energy and energy efficiency programs?

Less to RE, Efficiency & Climate Change

What the people, environment, and economy really need is more support for renewable energy and energy-saving programs. Even with an increased proposed budget for hydrogen studies, somehow lumped in with renewable energy, the renewables budget has decreased by nearly 6 percent compared to last year's proposed budget. Wind energy would receive a boost, leaving decreased funding levels for other RE technologies.

Proposed funding for efficiency programs took a 2.3 percent hit compared to last year. And the budget, if passed, would decrease money for important programs that get good results, like low-income weatherization, building and industrial technologies, and federal energy management programs.

At a time when fuel prices and environmental problems are expected to radically increase, we are cutting back on the very programs that could offer relief. Research on climate change is taking more than a US$100 million hit, most of which is cut from the agency that coordinates climate change among thirteen federal agencies, the Climate Change Science Program.

Arctic National Wildlife Refuge

The proposed budget includes revenues from the leasing of areas of the Arctic National Wildlife Refuge (ANWR) for oil drilling. This is a backdoor attempt to circumvent decades of success at denying oil industry access to this environmentally sensitive area. According to the Union of Concerned Scientists:

This approach is an attempt to block a full debate on the merits of drilling for oil in the pristine Arctic Refuge. In accordance with Senate rules, budget bills cannot be filibustered. Thus, the proposal could pass with a simple majority, instead of the 60 votes required to overcome a filibuster. If a budget resolution including proposed revenues from the Arctic is passed, language that will remove the Arctic Refuge's protection from drilling will be included in an overall budget reconciliation bill.

In March, language to separate the ANWR revenues from the budget proposal was defeated in the Senate. But energy activists are optimistic that they will still be able to delete the ANWR provision. This issue is controversial enough that it might keep the budget from being passed as is. Citizen action has successfully kept the oil companies out of ANWR, so please keep the pressure on your legislators.

What to Do

There is plenty of hope for turning this around, and the hope lies squarely in our hands. The public can play a critical role in our energy and environmental future. It is imperative that we let Congress know that this budget should not be supported. Contact your representatives immediately, write letters to the editors of the publications you read, and support the groups that are working so hard to protect the earth. Look for more info on these important issues from the groups listed in Access, and remember that we as individuals can make the difference when all of our voices are heard.

Access

Michael Welch, c/o Redwood Alliance, PO Box 293, Arcata, CA 95518 • 707-822-7884 • michael.welch@homepower.com • www.redwoodalliance.org

Union of Concerned Scientists, 2 Brattle Sq., Cambridge, MA 02238 • 800-666-8276 or 617-547-5552 • Fax: 617-864-9405 • ucs@ucsusa.org • www.ucsusa.org

Alaska Wilderness League, 122 C St. NW #240, Washington, DC 20001 • 202-544-5205 • Fax: 202-544-5197 • info@alaskawild.org • www.alaskawild.org

Public Citizen's Critical Mass Energy Program, 1600 20th St. NW, Washington, DC 20009 • 202-588-1000 • cmep@citizen.org • www.citizen.org/cmep

Nuclear Information Resource Service, 1424 16th St. NW #404, Washington, DC 20036 • 202-328-0002 • Fax: 202-462-2183 • nirsnet@nirs.org • www.nirs.org

Governing—Wind Generator Protection Strategy

Ian Woofenden

Derivation: From Greek kubernan, *to guide or steer.*

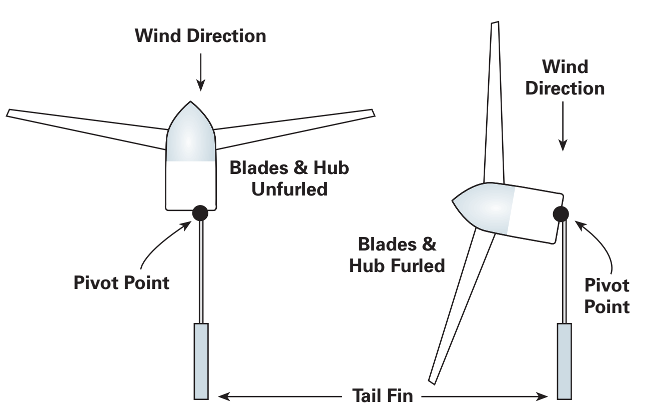
Everything has its limits, and wind generators are no exception. Though you might think you'd want to capture every scrap of energy available, any wind generator worth owning has a method of reducing its exposure to the wind and therefore its output—it's called "governing."

What is governing? It's a way to protect the wind generator from the incredibly strong forces in high winds. Wind energy increases by the cube of the wind speed, so when the wind speed doubles, the power available increases eight times. This is welcome in the winds you experience most of the time, but at high wind speeds, it means that the machines are subject to very strong—and potentially damaging—forces. Sailors know that there's such a thing as too much wind, and they furl or reef their sails to reduce the surface area in the wind's path. Governing in wind generators serves the same function.

Many wind turbines govern by reducing the swept area of the rotor (blades and hub) exposed to the wind—this is called "furling." Wind generator output and wind loading are both directly tied to how much of the rotor intercepts the wind. Moving the rotor out of the wind's path means less energy generated, and less force on your machine and tower.

Some rotors are hinged to move sideways, others tilt up, and some tip between horizontal and vertical to escape the wind. These methods all decrease the area of the rotor that catches the wind. A simple and common method is to combine a hinged tail and an offset rotor. Strong winds cause the rotor to swing sideways, exposing less of its surface to the wind.

Wind Turbine, Aerial View



Other machines reduce wind loading by changing the orientation of the individual blades. The early Jacobs machines use pitch control—a centrifugal system that swivels the blades as the machine's rpm increase. Less common methods of governing use electronics, air brakes, or other devices.

The goal of all these methods is to help the machine survive strong winds. Most of the energy on a typical wind site is in the medium-strength winds of 10 to 25 miles per hour (4.5–11 m/s). Though storm winds pack a punch, they occur only a very small percentage of the time. In off-grid systems, the battery bank is usually charged up in the first few hours of a storm, so no more energy is needed. Instead of looking to milk *all* of the energy out of these potentially damaging winds, savvy wind generator designers want their machines to survive for the next moderate winds that come along.

Governing systems should be distinguished from charge control, "braking," and manual furling and braking. Charge controllers regulate the charge going to the battery, frequently by routing excess energy to a dump load, usually a large resistor or an electric water heating element. Many wind generators with permanent magnet alternators use electrical or "dynamic" braking (shorting the three electrical phases) to stop the machines for servicing or other reasons. The user simply flips a switch, and in low to moderate winds, the rotor stops. Some machines have manual furling or braking, a user-implemented feature that uses a hand-cranked winch at the tower base to furl the machine or engage a brake.

A wind turbine's normal governing system, in contrast, must be automatic, and activated by the wind speed. The best governing systems attempt to have the machine continue to generate at a moderate level, and automatically come in and out of operation in a smooth and consistent way. This allows you to get the most out of your wind resource without risking your investment in wind energy equipment.

Access

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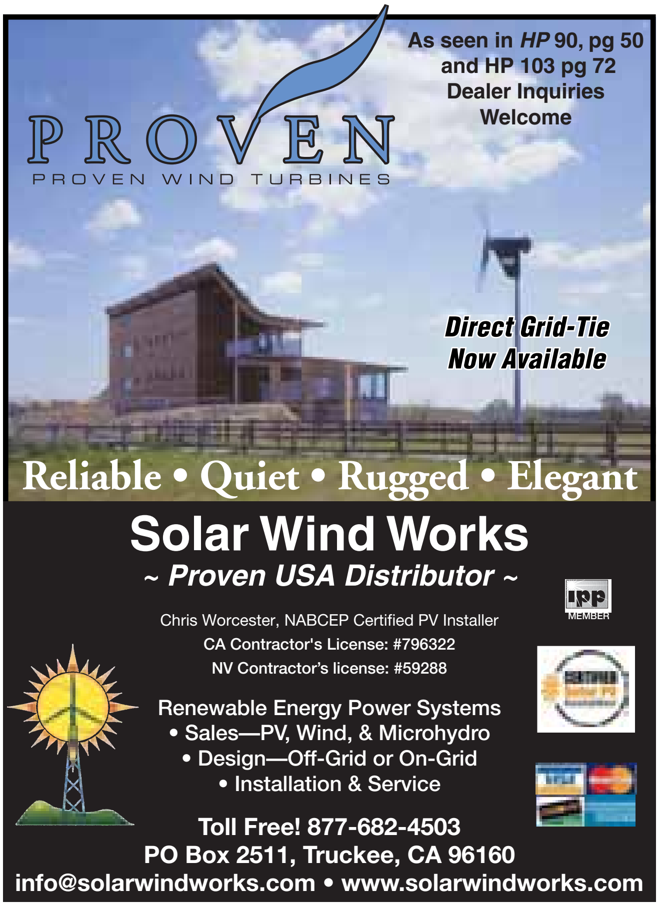
"Rotor—Wind Collector," *Word Power*, by Ian Woofenden, in *HP106*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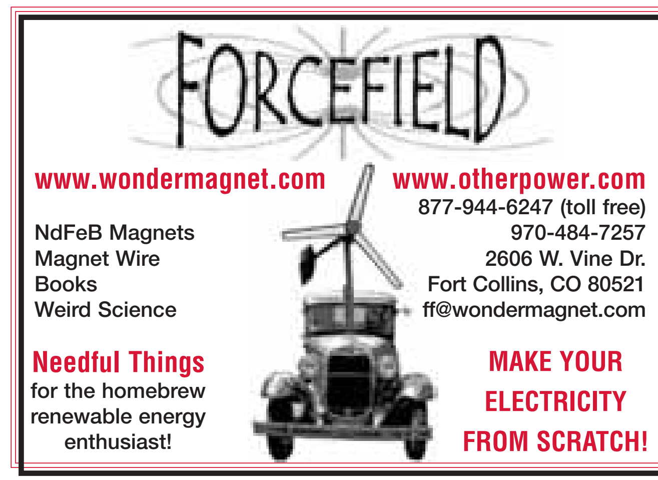
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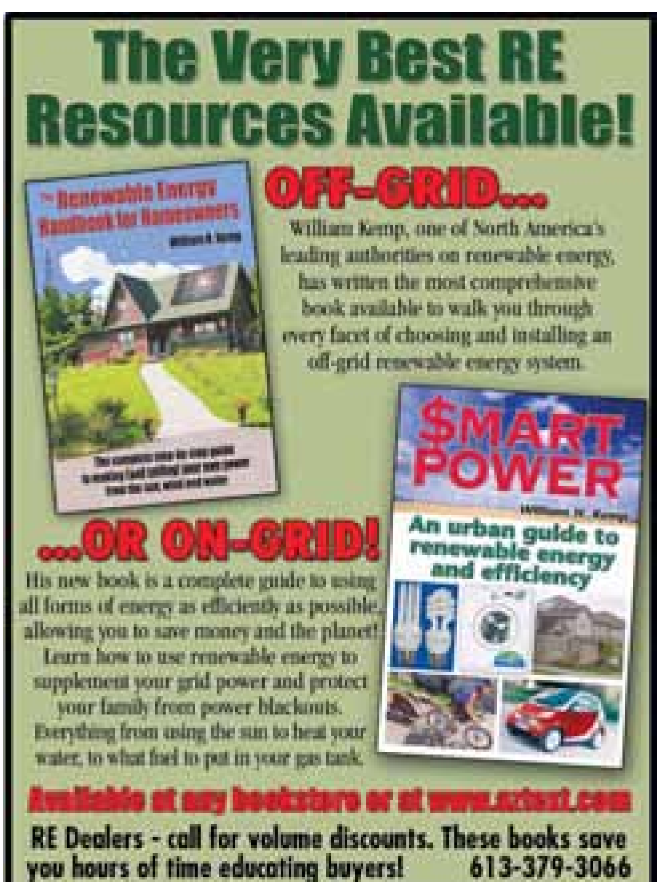
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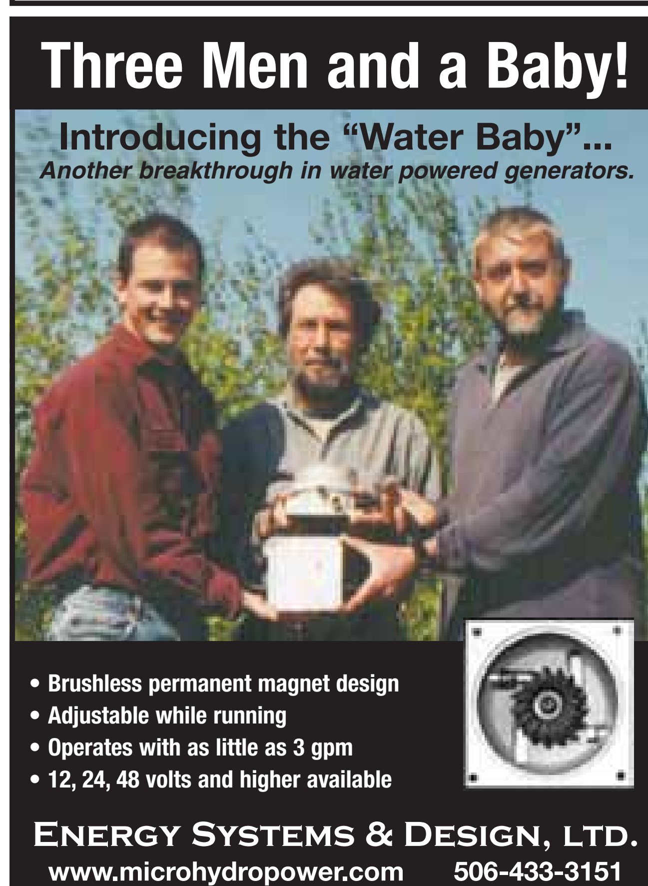
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The Skinny

on the Power Diet

Kathleen Jarschke-Schultze

The experience of most renewable energy users when visiting family and friends is the same. You find yourself lecturing about the benefits of compact fluorescents. Turning off lights in empty rooms becomes a mission. You call out through the house, "Is anyone actually watching this TV?" as you turn it off.

It is an all too easy trap to be smug about your energy conservation habits. Coming from a family who lectures, the words pop into my mouth unbidden. The reality is that my own power conservation regime is not untarnished.

When I'm Fat

In the wintertime when our creek is flowing well, our microhydro turbine is our main source of power. The sun comes up late and goes to bed early in our little canyon. The wind only blows before and during a storm, a rare event for us.

The hydro runs 24 hours a day, rain and shine, wind or no. When I go to sleep at night, I know that in the morning the battery bank will be fully charged and ready for another day of gluttonous use.

I can do as many loads of laundry as I like. I am limited only by my own ability to remember to go to the basement and start a new load washing and put the wet clothes into the gas dryer. This is also the time of year when water is plentiful for us. I have no worries there. I am frequently caught up on the household laundry. This engenders a feeling of smug accomplishment.

I'm able to run the dishwasher more often. I freely admit that the dishwasher is a luxury. I don't have to have it, but I always wanted one. I have indulged that desire. If I have the power to use it, I am not wasting our limited resources.

I leave the air cleaner on all day. Its nameplate rating is 55 watts. That's probably for the "high" setting, and when I leave it on, I use the "low" setting. Living as we do off the pavement and heating our house with a woodstove, our home gets very dusty. I feel that the air cleaner is an important wintertime appliance.

Cheating

In addition, there are guilty pleasures. Some of these I do because I can. Aw, face it. I do *all* of them because I can; I have the power.

I leave the TV on—just for background atmosphere. Coming from a large family, a quiet house makes me uncomfortable. I find that music distracts me from my tasks. But a movie talking in the background works for me. I like movie channels with no commercials. Or I'll put on one of my favorite movie DVDs or VHS tapes. Movies like *Hatari!*, *A Town Like Alice*, and *Last of the Dogmen* come to mind. I've seen these so many times I don't have to pay attention to them. It's wrong, but there it is.

I use my bread machine. I could make bread by hand, but I find the bread machine so convenient. It takes five minutes to start the loaf, and three hours later, the machine beeps and the bread is done.

Bob-O and I are really careless about leaving on phantom loads in the season of hydropower. He leaves his portable drill battery chargers plugged in 24–7. I leave my cell phone charger plugged in. I have strung some LED icicle lights around our front door on the outside. I like them because they make the house look so inviting at night. I'm guilty of not turning them off in the daytime.

In our office, we have satellite Internet access. This is such an upgrade from our old dial-up service, we deem it a necessity. But in the winter, we leave the server PC and modem on all day—not just when we check our e-mail or want to get online. We have the good sense to turn off the monitor, because the PC is just a server for our office full of Macs. The PC doesn't need the monitor on to perform its task.

Excuses

I know that all this use seems excessive, and it is. I do check the system performance meters, conveniently mounted on the dining room wall, throughout the day. That is a habit that has never left me. When the hydro is going, the batteries never get below 95 percent charge, even after doing several loads of laundry, vacuuming, and running the dishwasher. The really wonderful thing about microhydro is that if you deplete your battery charge in the daytime, by the next morning the battery is full again. This lulls you into a sense of endless power, which as the summer season dawns, proves to be an illusion.

Getting Thin Again

I guess you could say the Power Diet is a yo-yo diet—you're fat, and then you're thin, then fat, then thin, and so on. As the creek waters recede, we must tighten our belts and reign in the exuberant power spending of the winter.

The Watt Loss Diet Plan

As the water level in the creek wanes, the spring brings the sun and wind. Days are longer and less cloudy. The wind turbine has a daily input to our system. With Soda Mountain at the top of our canyon and Iron Gate Reservoir at the bottom, we get a thermal effect that creates wind in our canyon. The wind starts every day between noon and one o'clock and continues until sunset.

Our batteries are still full during the day, but I do only two loads of laundry in a day at the most. One reason is less available energy; the other reason is our water situation. Our house water is supplied by a natural spring and therefore subject to our summer droughts, the same as the creek.

By midsummer, the daily wind has lessened and we rely on the photovoltaic modules (PVs) to supply our power. Gone are the guilty pleasures. I use the solar clothes dryer (clothesline). The LEDs around the front door are turned off. We become very diligent about turning off our phantom loads. All of our wall cubes for charging appliances are unplugged if we are not using them. The TV isn't turned on during the day. This works for me, as I spend more time outside when the weather is fine.

With the higher ambient temperatures of summer, the old Sun Frost refrigerator runs its compressors a little more often and a little longer. We run our swamp cooler in the afternoons to keep the house comfortable.

Kathleen is up the creek when there's no water to run her treasured microhydro.

We take advantage of the incoming solar-generated watt-hours by doing all our high watt-usage activities during the hours that the sun actually shines on the PVs. Alas, when we wake in the morning, the batteries are diminished in charge, rather than full. We turn on the satellite server PC in the morning to check our e-mail, and then off it goes. It's kind of a hassle to turn it on again if we need to use the Internet, but who said dieting was easy?

Ultimate Power Diet Guidelines

You have the power to transform the lifestyle you've been living. When you're off grid, enjoy your energy abundance when you can—in the rich months of RE production. During the leaner times, here are a few key strategies for making the most of every energy morsel and taking your power use to an entirely new level of self-control.

Exercise. Use your ability to reach out and turn off the unnecessary power users in your life.

Trim the fat. Shorten the times you use the appliances you must have.

Give up dessert. Enjoy your treats when you can, but know that in months of low energy production, a little willpower will serve you well.

If you follow these guidelines, and don't cheat, you'll soon see pleasing numbers on your scale (meter) that will make you feel in control again.

Access

Kathleen Jarschke-Schultze is slimming down her power use at her home in northernmost California • c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 • kathleen.jarschke-schultze@homepower.com

Winter Memories

Just want to say thanks for a great magazine! This picture was taken at our home on Shelter Island, Alaska. After four months of almost no solar energy, I couldn't help myself. I cleared the snow off the array and we ended up with 1 KWH for the day from eight Shell 75-watt panels and OutBack's charge controller. Sincerely, Jay Beedle, Island Services • jayleenb@alaskawhalewatch.com

Buying Off Peak

I've been a subscriber and dabbler in renewable energy in central Wisconsin for many years now. I've watched the products get better by quantum leaps, and the proliferation of strategies for setting up your home to make and use electricity. I'm building a cabin in the woods for a retirement home, so I now have the luxury of designing in many of the features that will make best use of energy. I will be using in-floor hydronic heat with solar hot water panels, and gas as a backup, etc. We have a very small budget for the entire project, and have to be careful in our choices.

My main question is this: I have utility electricity and natural gas on my site. I also already have a 24-volt battery pack, inverter, and generator. Rather than buying solar-electric panels and a wind generator, what do you think about a strategy of buying electricity off peak at a lower rate to charge the batteries? We also have the option with our utility to specify that we want to purchase only electricity made from renewable energy. This costs a little more, but it would accomplish three objectives:

1. Support renewable energy.
2. Allow us to use renewables without having the very large upfront costs of a complete stand-alone system.
3. With our natural gas generator, we would have uninterrupted electricity.

Any thoughts? Jim LaPointe • jlapoi2010@yahoo.com

Hi Jim, That off-peak buying strategy works, kind of, and I suppose it is better than not doing anything. It can take advantage of a utility's under-used generation capacity, but you would still be using whatever energy mix the utility puts out. Commonly, off-peak generation comes from nuclear power plants because they cannot be easily slowed down and speeded up to meet demand schedules. You also have to factor in the inefficiency of the battery pack—you'll be wasting about 20 percent of the energy you use to charge it.

With your battery/inverter system already in place, you can add solar-electric panels at some future date. I recommend making sure that you build that possibility into your new home. For highest efficiency, a batteryless PV or wind-electric system is the way to go.

Buying utility green electricity is workable. But the way some states do it rubs me wrong. They allow utilities to take already existing "green" generation out of the normal rate base, and charge a premium price for it. In effect, that does not help anyone. It turns the rest of the utility ratepayers' energy more "brown" and increases utility profits if they charge a premium price for green energy. (One could argue that this may be what it will take to turn the utilities toward renewables.)

Further, some of the things that utilities are allowed to sell as green or renewable energy are not kind to the environment. For example, a utility's mix might contain trash-burning or tire-burning power plants. While considered "recycling," these plants are bad for the environment, producing extra pollution in spite of their supposed greenness. Or, a person might end up with hydropower from Quebec Hydro, a company that has flooded native lands to make energy, and has had an active campaign to discredit the Cree tribes and environmental groups in the area.

You get the point. I think a good long-term goal would be to make your own energy with wind and sun, or make sure your utility electricity comes from new renewable capacity. Do what you need to do in the short term to make your home comfortable, but keep your eyes on the prize. Michael Welch • michael.welch@homepower.com

Promoting Solar Energy

Hi Michael, I enjoyed your *Power Politics* column in *HP105.* I will bet that you are getting a lot of ideas. Here are a few more:

Market solar and wind energy by showing how it saves money in the long term, not by government or environmental necessity. Computers grew in use because they saved money and made work easier. Show how small solar-electric panels in automobiles extend the life of the battery. Show how much solar or wind energy is needed to run a radio for the rest of your life. Show how much energy is needed to run a house for its lifetime. Show the long-term savings of solar and wind electricity and not the cost of buying it all this year. Show how adding a little each year adds up to big savings (dollar cost averaging).

Get the Department of Homeland Security to advertise solar emergency backup systems for electricity to run radios, TVs, for battery charging, for refrigeration, and for lights. If the electricity goes out, you can make your own until the grid comes back. As we know, solar- and wind-electric systems can be used all of the time and not just as a backup. Diversified electrical generation is good for security and it will reduce your electric bill.

Discuss with your local utility how they can sell, install, and service solar, wind, and fuel cell equipment on houses and businesses. Electrical companies have the trucks and equipment, and people who understand electricity. Electrical companies run the electrical grid, and using the grid for gathering and distributing electricity eliminates the problems of batteries. This could lead to faster development of grid-intertie equipment. Some RE systems are cheaper to install in remote areas than running wires. In most areas, this is a market that the utility companies do not serve. Electrical utilities can sell systems and make money servicing the equipment too.

Get solar and wind generation programs on TV. Put up systems on shows such as *This Old House*, *Nova*, *Frontline*, and *Scientific American Frontiers.* Show building a solar and wind power assisted house. Teach what can be done with a 10-watt or a 100-watt panel. Teach how many lightbulbs can be powered with a 50-watt panel. Where are the science programs that discuss using solar energy to make hydrogen for fuel cell cars? Where are the programs that show how to hook up a house to the grid and what kind of maintenance is necessary to keep the systems running correctly? Where are the camping programs that show how to supply a cabin or motor home with solar electricity? Where are the technology programs that show solar panels being built?

Have energy shows just like boat shows, antique shows, and craft markets. Set up displays at flea markets, craft fairs, and local county fairs to answer questions and sell products.

Teach system use, safety, and installation to licensed, bonded, local electricians. The electrical industry will probably end up servicing these systems. Shouldn't they learn about the systems to continue with their licenses?

Get Greenpeace, the Sierra Club, Friends of the Earth, and some of the thousands of environmental groups to add solar and wind electrical systems to their catalogs. Have them sell, install, and teach others how to use and live with the environmentally correct electrical generation equipment that they recommend. Maybe they could sell the systems at cost, making it a winning situation for the environment and cheaper for the buyer of the equipment.

Make solar and wind-electric systems plug-in and modular. Make it easy to go to The Home Depot, Lowe's, Wal-Mart, Target, and other local stores to add on easily to the total system. Buy one module and add on as you can, with no experts necessary. The equipment could be made to just plug into an outside electrical socket or strip socket.

When you're listening to the radio or TV and you hear someone complaining about global warming, the high cost of electricity, or environmental correctness, call them up or send them e-mail and ask them if they have any wind or solar electricity. Find out if they are doing something besides talking about the problem. Talking about the problem hasn't yet solved the problem, but putting up more systems will.

Start solar and wind electrical generation companies that use small investors' money and put up large systems, with dividends paid by the companies as they sell electricity to the grid. At present rates, payback on the investments could be 5 to 15 percent annually, which is better than money markets, CDs, and much of the stock market.

Invent more direct-use solar-electric devices, such as direct solar-electric cooling for refrigerators, solar car ventilation, solar-driven air cleaners for houses, solar-powered doorbells, solar-powered fire alarms and CO_2 detectors, solar-powered exit signs for businesses and government buildings, solar-electric-driven air conditioners, portable power banks charged by solar-electric panels for construction workers or emergency use, solar-powered indoor lighting with rechargeable battery backup, solar-powered hydrogen generators for fuel cells, on-demand water heaters with battery backup, etc.

These are just a few ideas. Years from now we may all look back and see that working politically to make energy more available and environmentally friendly only slowed the process down. It may be up to us to use our money to replace our present system with something that is cheaper and controlled by the users of the energy. Put up a system and use the money saved to put up a bigger system. We can use all of the energy we can make. Bruce Wade • aap@gci.net

Sizing Expansion Tanks

Chuck, I'm really glad that you wrote the "What the Heck?" about expansion tanks in *HP105.* I have been wondering whether my tank was appropriately sized. You may recall this system from my article in *HP89.* You can see the article on my Web site: www.arttec.net/Solar/BarnHeat.html.

I have struggled with over-pressure issues on the floor loop side and came up with a rather creative solution to deal with it that I think you might find amusing. I put in a pressure gauge with an adjustable trip point that is wired across the floor loop thermostat. When the pressure gets too high on a sunny fall or spring day, the floor pump kicks on for a few minutes, dumping heat into my slab, which

Guy Marsden uses an adjustable trip-point pressure gauge to protect his solar heating system from over-pressure.

rapidly reduces the pressure without causing undue heating in the space. See more details about this on my Web site.

My system was designed by a local dealer and uses an 80-gallon Rheem storage tank and two, 300-foot floor loops of 1/2-inch Rehau PEX. He added in a #15 expansion tank as an afterthought. Maybe I need a bigger tank. Is there a formula to calculate what size to use? Any suggestions? Thanks, Guy Marsden • tekart@suscom-maine.net

Hi Guy, I think your expansion tank is undersized for your system. I think a #60 tank would suffice. You can size the tank requirements at www.amtrol.com/website/content.nsf. Click on Homeowner General Information, then on Product Sizing, then on Plumbing and Heating, then on Extrol, and it will bring up a sizing screen asking for volume, boiler, radiator type, and temperatures. Your system and workmanship are quite impressive, as are your unique solutions such as the gauge-actuated pressure reduction. We're looking forward to publishing an update on your system in an upcoming issue of the magazine. Cheers, Chuck Marken • chuck.marken@homepower.com

More Nukes for America?

On March 9th, President Bush stated that now is the time to start building more nuclear power plants. It takes many years to plan and build a nuke plant. Prior to that, it takes many years to get the required state and local approvals. Greater diligence will be required in the future to monitor this issue that was once thought to be dead. Perhaps President Bush sought to convince people that he could bring a nuke online at a moment's notice and thus undermine investor confidence in renewable energy projects. With projects using wind and hydrogen on the drawing boards from Patagonia and Canada, I am sure businesses in the oil patch are starting to get worried. What good is a hydrogen economy if many countries provide cheap and clean fuel for the new era? Let's keep the renewable energy projects moving ahead so there won't be any need for the extra electricity generated by a new batch of nukes. Pete Gruendeman, La Crosse, Wisconsin • gruendeman@att.net

Bike/Car Hybrid

I enjoyed the article on how far your electric car should go and how to increase your distance. I live off grid, so an electric car is hard to charge, but I increase my gas-powered car mileage by bringing my bicycle along. When I go to town for supplies, I park at the The Home Depot where I load up the heavy stuff. Then I ride the bike to the other stores and the restaurant. It's faster and easier because I get to park right at the front door. It's fun too, and I'm healthier when I get there.

On another note, a few years ago *Home Power* did an article on electric-assisted bicycles. I bought my wife a Giant La Free electric bike. She loves it, and we charge it off our solar-electric system. We are in our 50s and before getting the electric bike, it was hard to get her to ride because she would get left behind and hills were too difficult. Now I get to ride as hard as I want, and she easily keeps up and totally enjoys it.

With gas prices the way they are, maybe it's time for another article on electric bikes. There are a lot of new models out there. If I can help, let me know. kirkkd@aol.com

Hi Kirk, That's a great personal transportation system you have! And yes, we'd love to have submissions on electric bikes and other low-impact options. Best, Ian Woofenden • ian.woofenden@homepower.com

Water Pumping Dilemma

Hello and thank you very much for such a helpful magazine. I have a question for someone about water pumping. Our house is on grid, and I plan to integrate solar electricity over the next few years. Our well pump (submersible) is getting pretty old and I want to be prepared, when I have to replace it, to use the best system for our situation. I have reread the article in *HP97* about direct-feed solar pumps, and I like the idea that they are so efficient, but our geography is different, so we can't install a storage tank high enough to generate the needed pressure for house plumbing.

As author Windy Dankoff pointed out, with this situation he would recommend running a solar pump from a battery-based system and have it run on demand into a large pressure tank. Would this type of pump be running on AC from an inverter or DC? (Knowing this would help me to decide whether I need to have batteries and an inverter ready for the new pump, or not.)

Also, there was the implication that a well in this scenario should be producing more than 2.5 gallons per minute. Unfortunately for us, this is not the case. While our well is about 260 feet deep, we only get 1.5 to 2 gpm. We have thought about installing a storage tank to help with this low flow problem, but since it would not be pressurized, we would then need a second pump to generate the water pressure for the house. Do you have any suggestions for me? George Blakey • gsblakey@earthlink.net

Dear George, DC solar pumps are specifically designed to be powered from a PV array or battery bank. I would recommend batteries only if you experience frequent utility failures, not solely for the purpose of using a more efficient pump. Batteries themselves incur a 10 to 20 percent energy loss, which would offset some of the efficiency gain from a solar pump.

As you say, a solution for your low-yield well situation would be a storage tank with a second pump for pressurizing. But let's look at your whole system and consider other choices. First, avoid any use of sprinklers for your lawn or garden. That will eliminate long-running demand for flow rates that exceed your well recovery rate (leaving only 5-minute demands like filling a tub or washing machine). Now you can overcome occasional shortages simply by increasing the capacity of your pressure tank (replace it with a larger one, or have a second tank installed). For a household of four people, a 65-gallon tank is usually more than enough.

Another trick is to raise the cut-in pressure (at your pressure switch) so the pump starts sooner, before the tank is nearly empty. Your local well service company should be able to help you with these measures, and also with a control device to prevent pump damage if your well runs dry. If you tend to run short of water when you are irrigating a garden or trees, consider a storage tank elevated on a hill or even on a pile of soil, with gravity-fed *distribution. Maybe you can divert rainwater from your roof into that same tank. (See the rainwater catchment article in this issue.) Drain it for the winter if you are in a freeze zone.*

When you need to replace your well pump, ask your supplier to look at the specifications for several brands, and select the model that shows the best energy efficiency for your situation. If you decide to install a battery-based PV system, make it 48 volts and consider a new-technology, ultra-efficient solar pump. Windy Dankoff, Founder (retired), Dankoff Solar Products • windy@dankoffsolar.com

Tiny PV System

I am building a ham radio beacon transmitter that will send a Morse code message over and over, 24 hours per day. The transmitter draws about 50 mA. Between the dots, dashes, and spaces, I estimate that the unit will use about 7.2 watt-hours in a 24-hour period. I will be using a 12 V, 7 AH sealed battery for energy storage. Would a 5-watt solar-electric panel be adequate to run the unit *and* charge the battery enough each day to keep it from draining down? The unit will be mounted 200 feet up a tower with no AC supplied to it. I am in Wisconsin and estimate four hours per day, on average (year-round), of sunshine hitting the panel. I believe batteries have "internal losses" that work to drain down the battery. Is there a way to figure the value of any internal loss that would need to be overcome by the solar-electric panel as well? Thanks! Scott A. Littfin • acepilot@bloomer.net

Hello Scott, Your design work is good! The 5 W PV and a 7 AH battery should easily do the job. Be sure to include a PV regulator in the design so that you don't overcharge the battery during the summer. A lead-acid battery will self-discharge about 5 percent of its rated capacity weekly. This works out to 0.05 amp-hours per day in your case. Richard Perez, N7BCR • richard.perez@homepower.com

SIP Question

I want to thank Patrick Sughrue for his informative article on building with SIPs in *HP106.* I notice in both SIP walls and every other type of wall I can think of, everyone goes to these great lengths to maximize the wall insulating value and minimize thermal bridging. But nearly every wall building method features a top plate at the top of the wall. This top plate is typically wood, which acts as a thermal bridge (when compared to the much higher insulative value of the rest of the wall).

My question is why doesn't anyone add an insulating fascia (maybe 6 x 6 inches) either in the interior where the wall meets the ceiling or at the exterior, where the wall meets the bottom of the roof overhang. Aside from aesthetics, it would seem to me that you would need to cover the top plate with an insulating fascia to eliminate this thermal bridge. Sincerely, Mike Wood • mike@peaceumbrella.com

Thanks for your question, Mike. There are three reasons for using a top plate. One is to transfer the load of the roof evenly to the wall structure. In the case of stud construction, the plate creates a structural bridge between the studs, as well as a thermal one. Another use of the plate is an attachment point for the roof structure. And finally, it completes the frame of the wall, which when combined with the sheathing, creates a wall that resists racking. SIPs have achieved your goal by removing as much lumber as possible, but leaving it where it is needed for structural reasons. In a wall system that has thermal bridging, it can be mitigated by attaching 1/2 to 1 inch of a rigid insulating material to the outside of the wall before the siding is applied. Patrick Sughrue • patrick@structuresnw.com

Homebrew & Ads

I just renewed my subscription. I want to know what happened to the homebrew section that used to be in your magazine. I have noticed over the past few years that your magazine has more and more advertisements in it. I know that ads help pay the bills. However I started to get your magazine many years ago because it was about renewable energy. Now it's about advertisements and large power systems that a lot of us cannot afford. I do not like to pay for a magazine that is full of advertisements. If you ever start to put those index size cards that fall out when I open the magazine, I will not renew my subscription for sure. If you're going to put advertisements in your magazine, only the companies that offer the lowest prices should be allowed. I believe that a lot of the renewable energy products are still too expensive. What ever happened to US$1 a watt PVs? Nowadays it's all about making *money.* Thanks, Tim Henley • tjhenley@worldnet.att.net

Hi Tim, Thanks for your comments. As the solar energy industry matures, there is less interest in and need for homebrew, and more call for mainstream solutions. Many of us are nostalgic for the old days, but the reality is that if we want our modern society to be renewably powered, we need off-the-shelf solutions. We still welcome homebrew submissions where there is a specific need or a unique solution, and we would love to see more articles that help readers understand the function of system components.

Our advertising percentage has not changed as much as you might think over the years, and is much, much lower than most mainstream magazines. Advertising not only makes publication of the magazine possible (how many of our readers would be willing to pay many times the current cover price for an advertising-free publication?), it lets readers connect with manufacturers and suppliers of gear. How else does anyone find out about the latest equipment that's available?

I take exception to your suggestion that we should only allow low-price advertising. We want high-quality products, and you get what you pay for. We're definitely moving in the right direction—toward lower cost and higher quality—but I don't expect any dramatic shifts, just a continuation of the price declines we've seen over that last 25 years. Compare renewable energy to the nonrenewable choices for total life cycle cost and impact, and it's a bargain. Regards, Ian Woofenden • ian.woofenden@homepower.com

Stream Ecology

I liked the fact that you had a three-part series on hydropower. I did not like the fact that author Dan New repeatedly talked only of efficiency and the "bottom line," while entirely leaving out ecology. What I would like to see in future issues with hydro discussion is an inclusion of aesthetics, minimum flow, and upstream and downstream aquatic life passage where appropriate. Regulation of small-scale hydro has been minimal. We need to police ourselves. Your magazine needs to be an advocate for stream ecology. Sincerely, Ken Burchesky

Hi Ken, Efficiency merely means that for the energy developed, we've used the energy source wisely, with as little waste as possible. Nearly all developers of energy strive to reduce waste.

Water power—small hydro, large hydro, pico hydro—is not free. It is merely one of the energy sources available to us. It is renewable, as long as the sun shines and drives the water cycle, and virtually void of pollution. Use of water forces to develop the electrical energy is merely a choice. We could choose coal, oil, wind, photovoltaic, gas, geothermal, nuclear, wood, or pig manure, none of which is free. I kinda favor hydro.

I respect those who protect our water resources, and the task they've chosen. I focus my own energy on building machines that use as little of those resources as possible to develop needed energy. Best regards, Dan New, Canyon Industries • CITurbine@aol.com

Hi Ken, While we strive to provide thorough information on the topics that we cover, it is impossible for every article to completely and encyclopedically cover every aspect of each subject, and each author has particular areas of expertise and interest. We would definitely like a future hydro article to cover the ecological impacts of hydro. Thanks for bringing it up because we also think addressing stream ecology is very important. The HP *editorial crew.*

RE happenings

INTERNATIONAL

Internet courses: PV, green building & international development. Solar On-Line (SóL) • 720-489-3798 • info@solenergy.org • www.solenergy.org

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

BELIZE

Dec. 5–9, '05. Understanding PV workshop. Design & installation of PV: stand-alone, grid-tie, water pumping & more. Ecovillage Training Center • 970-527-4680 • ecovillage@thefarm.org • www.thefarm.org

CANADA

Sep. 17–18, '05. Campbellford, ON. Resource—Trent Hills RE Showcase. RE exhibits & education. Trent Hills Chamber of Commerce • 705-653-1551 • Fax: 705-653-1629 • resource@trenthillschamber.ca • www.energyresource.ca

British Columbia. BC Sustainable Energy Assoc. meetings at chapters throughout the province • www.bcsea.org/chapters

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

CZECH REPUBLIC

Sep. 7–9, '05. Prague. Green Power Central & Eastern Europe. Utility-scale RE finance & regulatory frameworks. Info: see "Green Power Conferences" under Rome, Italy.

FRANCE

Jun. 27–Jul. 1, '05. Haut Vallespir, French Pyrenees. Intro to Solar Energy. System design, wiring, instrumentation, appliances, tours & case studies. Accommodations included. Green Dragon Energy • 44-16-54-761-731 or 44-78-40-600-979 • courses@greendragonenergy.co.uk

GERMANY

Jun. 21–22, '05. Frieburg. European Solar Thermal Industry Conf. Markets, promotional policies, marketing, technology & certification. European Solar Thermal Industry Assoc. • 32-2-546-19-38 • Fax: 32-2-546-19-44 • info@estif.org • www.estif.org-solar.de

HONG KONG

Jun. 15–16, '05. RE Finance Asia. Learning & networking. Info: see "Green Power Conferences" under Rome, Italy.

ITALY

Nov. 14–16, '05. Rome. Green Power Mediterranean. Policy & networking. Green Power Conferences • info@greenpowerconferences.com • www.greenpowerconferences.com

NEPAL

Kathmandu. School of Renewable Energy Ltd. • 977-01-42-44-003 • sre@nepalmail.com • www.sre.org.np

NICARAGUA

Jul. 31–Aug. 11, '05 (again Jan. 2–13, '06). Managua. Solar Cultural Course. Lectures, field experience & ecotourism. Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

U.S.A.

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

Info on state & federal incentives for RE. North Carolina Solar Center • 919-515-5666 • www.dsireusa.org

Ask an Energy Expert—online or phone questions to specialists. Energy Efficiency & RE Info Center • 800-363-3732 • www.eere.energy.gov/informationcenter

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

ARIZONA

Aug. 4–6, '05. Flagstaff, AZ. Southwest Sustainability Expo. Workshops, exhibits, sustainability tours, teen fair & more. Center for Sustainable Environments • 928-523-0602 • Fax: 928-523-8223 • julye.evans@nau.edu • www.sustainabilityexpo.com

Scottsdale, AZ. Living with the Sun energy lectures, 3rd Thurs. each month, 7 PM, City of Scottsdale Urban Design Studio. Info: 602-952-8192 • www.azsolarcenter.org

CALIFORNIA

Aug. 20–21, '05. Hopland, CA. SolFest. RE exhibits, alternative transportation, green building, music, speakers & workshops. Info: see Solar Living Institute below.

Sep. 24, '05. Ukiah, CA. Ecopalooza 2005. RE workshops & exhibits, solar-powered music, Kids' Town & activities, green businesses, Ecotopia, veggie food, green building demos & more. Ecopalooza Green Living Expos • info@ecopalooza.com • www.ecopalooza.com

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

Hopland, CA. Ongoing workshops, incl. beginning to advanced PV, wind, hydro, alternative fuels, green building techniques & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

COLORADO

Sep. 17–18, ’05. Ft. Collins, CO. Rocky Mt. Sustainable Living Fair. Exhibits, workshops, speakers, entertainment, vehicle showcase & more. Rocky Mt. Sustainable Living Assoc. • 970-224-3247 • Fax: 970-419-1056 • kellie@poudre.com • www.sustainablelivingfair.org

Carbondale, CO. Hands-on workshops & online distance courses on PV, solar pumping, wind power, RE businesses, microhydro, solar thermal, alternative fuels, green building & women’s courses. Solar Energy International • 970-963-8855 • Fax: 970-963-8866 • sei@solarenergy.org • www.solarenergy.org

Denver, CO. Windhaven RE seminars: Solar Energy Basics, Biodiesel & Alt. Fuels, Wind Energy Basics, Alternative Building, others. Windhaven Foundation for Sustainable Living • 720-404-9971 • windhavenco@yahoo.com • www.windhavenco.org

FLORIDA

Jun. 20–23, ’05. Orlando, FL. Ecobuild America technology conf. & exhibit. Green building, construction, RE & sustainable growth • www.ecobuildamerica.com

Aug. 6–12, ’05. Orlando, FL. Solar World Congress. Symposium, workshops & exhibition for International Solar Energy Society & American Solar Energy Society • www.swc2005.org

ILLINOIS

Aug. 13–14, ’05. Oregon, IL. Illinois RE Fair. Workshops, exhibits, speakers & music. IL RE Assoc. • 815-732-7332 • sonia@essex1.com • illinoisrenew.org

IOWA

Sep. 10–11, ’05. Hiawatha, IA. I-Renew Energy Expo. Workshops, exhibits, food, entertainment. Info: see below.

Prairiewoods & Cedar Rapids, IA. Iowa RE Assoc. meets 2nd Sat. every month at 9 AM. Call for schedule changes. I-Renew • 563-432-6551 • irenew@irenew.org • www.irenew.org

KENTUCKY

Sep. 24–25, ’05. Lexington, KY. Bluegrass Energy Expo. Trade show, workshops, exhibits & demos, film festival, kids’ activities, energy consultations & more. Appalachia—Science in the Public Interest • 606-256-0077 • Fax: 606-256-2779 • aspi@a-spi.org • www.bluegrassenergyexpo.org

MICHIGAN

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

MONTANA

Jul. 9, ’05. Livingston, MT. Sustainability Fair 2005. Vendors, workshops & demos in sustainable building & RE. Sustainably produced food, educational materials & kids’ activities. Corp. for the Northern Rockies • info@northrock.org • www.northrock.org

NEW MEXICO

Oct.–Nov. & Feb.–Mar. each year. Deming, NM. Intro to Homemade Electricity. Meets 5 Thurs. eves. Mimbres Valley Learning Center • 505-546-6556 ext. 103 • www.wnmu.edu/extuniv/mimbres.htm

Albuquerque, NM. Speakers on RE. Meet 4th Tues. each month. NM Solar Energy Assoc. • 505-246-0400 • www.nmsea.org

NEW YORK

Jun. 25–Jul. 2, ’05. Bath, NY. Building With Spirit natural building colloquium. Straw bale, timber framing, cob & cordwood workshops. Demos & presentations in permaculture, RE & more • 607-776-4060 • www.peaceweavers.com

Oct. 27–28, ’05. New York, NY. Green Power North America, Green Power Conferences • info@greenpowerconferences.com • www.greenpowerconferences.com

NORTH CAROLINA

Jun. 25–26, ’05. Beech Mountain, NC. Small Scale Wind Energy. Hands-on Bergey, with installation, wiring & troubleshooting. Info: see NC Small Wind Initiative below.

Aug. 26–28, ’05. Fletcher, NC. So. Energy & Environment Expo. Workshops, presentations, exhibits, clean-air car fair & more. SEEE • 828-696-3877 • Fax: 828-696-0700 • info@seeexpo.com • www.seeexpo.com

Sep. 17–18, ’05. Beech Mountain, NC. Grid-Tie Wind Installation Workshop. SWWP installation & maintenance. NC Small Wind Initiative • 828-262-7333 • wind@appstate.edu • www.wind.appstate.edu

Pittsboro, NC. RE, biofuels, green building & other sustainable living courses at Carolina Community College. Piedmont Biofuels Coop • 919-542-6495 ext. 223 • www.cccc.edu or www.biofuels.coop

Saxapahaw, NC. How to Get Your Solar-Powered Home. Solar Village Institute • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OREGON

Jun. 18, ’05. Seneca, OR. Solar Cookery Extravaganza & Potluck. Info: see EORenew below.

Jul. 26–28, ’05. John Day, OR. Pre-SolWest Hands-On Installation Workshop. Features a backup utility-intertied PV system. Info: see EORenew below.

Jun. 27–Jul. 1, ’05. Portland, OR. SEI’s Carpentry Skills for Women. Intro to carpentry for women. Info: see SEI in Colorado listings.

Jul. 29–31, ’05. John Day, OR. SolWest RE Fair. Exhibits, workshops, family day, speakers, music, alternative transportation & Electrathon rally. EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10 weeks, 14 interns per quarter. Info: Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Sep. 23–24, '05. Kempton, PA. Penn. RE & Sustainable Living Festival. Exhibits, workshops & speakers on solar, wind, microhydro, hydrogen, green building, biofuel & organic farming. Mid-Atlantic RE Assoc. • yoder4@enter.net • www.paenergyfest.com

Oct. 14–15, '05. Spring Grove, PA. Passive Solar Greenhouse Workshop. Design, construction & year-round production. Steve & Carol Moore • 717-225-2489 • sandcmoore@juno.com

Philadelphia, PA. Penn. Solar Energy Assoc. meetings • 610-667-0412 • rose-bryant@erols.com

RHODE ISLAND

Jun. 4, '05. Coventry, RI. Sustainable Living Festival & RE Expo. Exhibits & workshops on solar, wind, biofuels, alternative vehicles & building. Music & food. Apeiron • 401-397-3430 • brad@apeiron.org • www.apeiron.org

SOUTH DAKOTA

Aug. 8–18, '05. Pine Ridge Reservation, SD. Sustainable Training for Native Americans. PV, microhydro, small wind, straw bale, ecological design & wastewater treatment. PennElys GoodShield, Sustainable Nations Development Project • 707-677-3588 • sustanablenations@hotmail.com

TEXAS

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

Houston, TX. Houston RE Group meetings. HREG • hreg04@txses.org • www.txses.org/hreg

VERMONT

Jun. 26–Jul. 1, '05. Warren, VT. Ecological Planning, Design & Construction course. Lectures, seminars & tours on RE systems & water treatment systems. Info: see Yestermorrow below.

Jul. 16–17, '05. Tinmouth, VT. SolarFest, The NE RE Festival. Workshops, RE vendors & exhibits, kids' activities & music, dance & theater on solar stages. SolarFest • 603-847-9049 • info@solarfest.org • www.solarfest.org

Jul. 23–24, '05. Warren, VT. Solar Design Workshop. Maximize solar potential. Lectures, slide shows & tours of passive solar design & PV. Yestermorrow • 802-496-5545 • www.yestermorrow.org

WASHINGTON DC

Jun. 23–24, '05. RE Finance Forum. For bankers & investors. American Council on RE • 202-429-2037 • weirich@acore.org • www.acore.org

Oct. 6–9, '05. Solar Power 2005. Business to business solar conf. Solar Electric Power Assoc. • 202-857-0898 • htaylor@solarelectripower.org • www.solarpower2005.com

WASHINGTON STATE

Aug. 5–7, '05. Vashon Island, WA. Island Earthfair. A "created community" with sustainability exhibits, incl. EV & RE workshops & speakers. Info: Island Earthfair • 206-463-1725 • earthfair@jps.net • www.earthfair.org

Oct. 8, '05. Guemes Island, WA. Intro to RE. Solar, wind & microhydro for homeowners. Info: see SEI in Colorado listings • Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Oct. 10–15, '05. Guemes Island, WA. PV Design & Install workshop. System design, components, site analysis, system sizing & a hands-on installation. Info: see above.

Oct. 17–21, '05. Guemes Island, WA. Microhydro Power workshop. Design, system sizing, site analysis, safety issues, hardware specs & a hands-on installation. Info: see above.

Oct. 24–29, '05. Guemes Island, WA. Wind Power workshop. Design, system sizing, site analysis, safety issues, hardware specs & a hands-on installation. Info: see above.

WISCONSIN

June 17–19, '05. Custer, WI. RE & Sustainable Living Fair (aka MREF). Exhibits & workshops on solar, wind, water, green building, alternative fuels, organic gardening, energy efficiency & healthy living. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: see MREA below.

Jul. 30–31, '05. Merrill, WI. Continental Cordwood Conf. Lectures, demos, tours of cordwood homes, panel Q&A, slide show, cordwood papers, presentations, test studies & silent auction. Richard Flatau • 715-536-3195 • flato@aol.com • www.daycreek.com

Custer, WI. MREA '05 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

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Energy-Efficient Computing

I live in a 100 percent solar-powered home. One of the ways that I get away with having no backup electricity source is that I am careful about what gets plugged into the wall. This brings me to my question—where can I go to find out which computers are the most energy efficient? I know that laptops are better than desktops, but how much better? Laptops are a lot more expensive—what's the tradeoff? Thanks, Thomas Bluefeather • rionada@hotmail.com

Hi Thomas, I have recently been researching this subject because I am looking for an energy-efficient server to monitor a demonstration solar-electric system and display its data.

Higher-quality laptops are designed to get as much computing time as possible out of their batteries, and some are better than others at doing so. That's the big reason energy efficiency is a concern for laptop builders. One thing I question in laptops is the consumption/efficiency of their external AC battery chargers. Charging efficiency is of little concern to manufacturers who are more concerned about length of operation while on batteries.

In essence, external chargers become the full-time power supply for many laptops when used to replace desktop computers. People often do not cycle the batteries in that situation; they just leave the power supply plugged in. It is likely true that they still use less energy than a desktop PC and its monitor power supply, but there is much room for improvement in laptop battery chargers. For example, my friend's Hewlett Packard laptop has a charger that is rated at 153 W AC input with a 65 W DC output. That is pretty poor conversion (though ratings are usually the max to be expected, and actual consumption is most often lower), and the charger operates pretty darn warm, as does the computer while under charge.

It seems that cost is the main concern for desktop computer builders, though the Energy Star specifications are better than nothing. But many laptop components, like hard drives, are adaptable to use in desktop PCs—cable adapters and mounting hardware are readily available. Many varied components, when combined together, would make a much more energy-efficient desktop PC.

We had an article submitted to us some time ago about a home-assembled desktop computer based on a Via Cyrix processor with laptop components, including hard drive, CD-ROM, and all the other basic needs. It consumed only 32 W while accessing data on the hard drive, and 24 W while just sitting there fully on. That's pretty good, and from what I have seen recently, things have gotten even better. Now there are energy-saving components for desktop machines that can be run with an internal DC power supply that will take 12 to 30 VDC, and will run off a wall cube.

Very few computer manufacturers make energy consumption figures easily available to the public. Keep in mind that LCD monitors save quite a bit of energy over CRTs—this can be the largest, single, energy-saving upgrade for a desktop computer user. And the smaller the screen, the less energy it will use. I hope that helps. Michael Welch • michael.welch@homepower.com

Old Batteries

Hey folks, I just stumbled on a homesite of a cantankerous old guy who had a PV system and batteries. He died and a contractor is bulldozing over everything. The batteries are there, and I can have them if I want. So my question is, "Do I want them?" I'm not able to find any writing on them, but they are single cells, roughly 6- by 4- by 14-inches tall, single-vent cap in the middle with a snap-top cover. The cells are put together in series in wooden crates connected electrically with metal plates over hex-head nuts with double terminals on each pole. There are 20 to 30 of them.

The catch is that the cells are voltage-dead and probably have been neglected for five to eight years. Are they worth my while to haul out? Can they be rescued or are they only scrap material? Thanks for any replies about this. Seems a shame to let the excavator jaws just crush them up and throw them into the landfill. Regards, Martin Fleming • martinf@forkidsake.net

Hello Martin, I'd pass on those cells. It is very unlikely they could be brought back to decent service. Also, these shouldn't be crushed and sent to a landfill. All batteries should be properly disposed of and preferably recycled. If they are NiCds, they must be treated as toxic waste. If they are NiFe batteries, the electrolyte is caustic and should at least be neutralized before disposal. Richard Perez • richard.perez@homepower.com

System Sizing

I just took a class on solar electricity and built a basic system. It's nothing fancy, but enough to make me want to learn more. I have 1.5 acres on a lake, with a small shed that I would like to light in the evening. It won't be used all the time, but will be used to learn about solar-electric systems. The goal is to convert my house later on.

Here's my question. I want a couple of lights in the shed, and maybe to power a small radio now and then. How do I determine the size of the panel, battery, and inverter?

I just want to start simple and learn, and then grow. My main problem is determining how long a battery will last on a charge. For example, a 40 AH battery running two to four 45 W bulbs, for a couple hours would last how many days? Thanks for the help, Richard Smith • radarman2001@yahoo.com

Hi Richard, Using your example, a 40 AH battery at 12 VDC (nominal) will give you about 488 watt-hours (40 x 12.2). Folks differ as to how deep they like to discharge their batteries, but in general I prefer to only use 25 to 30 percent of my battery capacity, which should give me long life for my batteries.

If you choose 25 percent, you have 122 watt-hours (488 x 0.25) to consume before your battery will need recharging. That means you could run two, 45-watt DC bulbs for 1.4 hours (122 ÷ 90) without any solar recharge, and stay within the battery discharge goals. (AC loads would require figuring in inverter inefficiencies of about 15 percent.) But wait! Just think what would happen if you used more efficient lighting. Replace those 45 W bulbs with

9 W compact fluorescents that will put out about the same amount of light. Then you would get 6.8 hours (122 ÷ 18)!

Size your battery based on how many sunless days you want to be able to use the electricity. If you want four days of autonomy (time without generation), you will need four times the battery. As you can see, autonomy can get expensive after awhile.

Size your PV array based on how fast you want those batteries charged up again. Most folks size their array based on the PVs meeting slightly more than the daily load, and based on the average daily sun hours they get. The problem with that is in the wintertime, it might be difficult to catch up, while in the summertime you will have more energy than you can use.

Your inverter must be sized for your peak load—the maximum wattage you will ever draw from the system. With two 45-watt bulbs and a small radio, a 150-watt inverter would cover things. But if your system will be very small and simple, with only a few lights and a radio, a DC system may be the best bet, and then you don't need an inverter at all. Michael Welch • michael.welch@homepower.com

Homebuilt Pool Heaters?

I have tried looking through your back issues for articles on how to build your own solar pool-heating panels, but have had no luck. Have you covered this before? If you have, can you please tell me the back issues so I can order them? Thanks for your help. Jim • jglover@watermarkpromo.com

Hi Jim, I've never heard of anyone building plastic solar pool panels. Buying do-it-yourself kits with manufactured panels is something people do every day. All good solar pool collectors are made of polypropylene because of its UV resistance and high temperature tolerance (200°F plus). Polypropylene products (buckets, sinks, pool panels, etc.) are extruded, molded, or thermal welded. No commonly known adhesive will stick to polypropylene, hence the thermal welding process for joining parts. Good thermal welders (a high temperature industrial hair dryer is a good description) cost from US$200 to US$1,000. In addition to having a thermal welder, it takes quite a bit of practice to do a good job. Pool collector manufacturers have equipment to automate joining the small riser tubes to the large headers.

I have heard of people using coils of black polyethylene tubing, but I would imagine it would have a limited lifetime with constant exposure to the sun. In addition, something like a 3/4-inch polyethylene tube will not have anywhere near the surface-to-volume ratio of pool panels made with 1/4-inch waterways. This will limit the efficiency of the heat transfer. Perhaps, there is information on the Web that would be helpful. Cheers and good luck, Chuck Marken • chuck.marken@homepower.com

What's It Worth?

Richard Perez

After more than twenty years of living on solar electricity, I'm still thrilled to look outside the window at all the PV modules in our front yard. This amazing collection of silicon has allowed us to live six miles beyond the utility lines, with all the creature comforts of a home in town. I often muse about what our life would have been like without all the energy these PVs have produced over the years. I wonder what they are worth to us. Was the value they gave us worth their cost?

Value & Time

What is a thing worth? I'm talking about its cost and its value, and how the cost and value of things change over time. I went to the Web and began "Googling" (searching), and was immediately immersed in the esoteric world of economics—a world where everything has a constantly changing price. I was buried in facts and figures. I was lost in a swamp of supply and demand, differing economic theories, and leading economic indicators. After five days of amassing more factoids than could be printed in an entire issue of *Home Power*, I decided to take another approach. I started to look closer to home, to analyze the cost of things we use here and how this has changed over time.

Homestead Economic Indicators

I was looking for products that many of us use—real things that most everyone can identify with. I settled on two ubiquitous products—a gallon of gasoline and a pound of hamburger. I want to compare these products to PV modules—to compare their value, their cost, and how their cost has changed over the last twenty years.

A Gallon of Gas

Just about everyone uses gasoline. We use it to power our vehicles. In the early days, before PV module prices came down to earth, we also used gasoline to run a generator, which at the time was our sole source of electricity. Twenty years ago, a gallon of gas was less than US$1 in our neighborhood. Today that same gallon of gas costs more than US$2. On a global level, the price of a barrel of oil is now more than US$50, and some energy economists predict it may reach over US$80 per barrel within three years. The cost of gas is rising as the oil shortage becomes more acute.

A Pound of Hamburger

Twenty years ago a pound of hamburger was less than US$1 at supermarkets around here. Today the same pound of hamburger is well over US$2. Hamburger shows the same price doubling over two decades as gas does. Inflation is a reality that seems to affect the price of most products we use.

A PV Module

Twenty years ago, PV modules were sold for about US$10 per rated watt. Today, a PV module sells for about US$5 per rated watt. These solar energy marvels have come down in price by half over the last two decades. In addition, the quality of the modules has improved. They are now more efficient, more powerful, easier to install, and carry manufacturers' warranties of 25 years, which is more than twice the warranty that modules had two decades ago.

Compared to twenty years ago, you get more bang for your buck buying PV than buying beef or gas.

Value

The value of a gallon of gas is questionable. Sure, the fuel still powers the majority of our transportation, but it has environmental side effects. Global warming is a reality. Our increased use of gasoline and other carbon-based fuels is warming up this planet and polluting our air. I'd have to say that the value of gasoline is decreasing as time goes on, even though its cost is rising.

Even though the beef industry has a few environmental issues of its own, a pound of hamburger still delivers its value. A good burger is as delicious and nutritious as it ever was.

The value of a PV module has increased. I personally have modules that I bought more than two decades ago. These old modules carried a ten-year warranty when I purchased them. They are still generating at close to their rated output even though their warranty expired more than a decade ago. I fully expect a modern module to produce useful electricity for more than 50 years, and quite possibly as long as 100 years. PVs are an energy source that doesn't wear out or require maintenance. The fuel, sunlight, is delivered free daily.

Some of the value of photovoltaics is less tangible than cost and service. PVs have enabled many of us to live in remote places where utility electricity is not available. They give us the freedom to live where we want to. PVs also give us economic security by freeing us from the monthly electric bill.

PVs also offer a more general value. The electricity that they make does not pollute the planet. A 1-kilowatt PV array will save putting one ton of carbon dioxide into our atmosphere each year—and it will keep on doing this for many decades. PVs use a freely and democratically offered energy source—sunlight. The use of this free fuel gives us one less reason to go to war over energy sources.

I'd have to say that when it comes to value, PVs win, hands down. No other product I can think of offers this much value to its purchaser.

The Future

PVs are made from hyper-pure silicon, the same stuff used to make transistors and integrated circuits. For years, the PV industry has been using the surplus silicon from the electronics industry. Today, the PV industry has grown to the point where it demands more silicon than can be supplied by the overflow from the electronics industry. This has created a shortage of hyper-pure silicon for PV modules.

In addition, the governments of some countries, notably Germany and Japan, have realized the value of PV, and are offering huge financial incentives to their citizens who purchase and install PVs. Now PVs are sold for higher prices in Germany and Japan than in the United States. Even at these higher prices, the Germans and Japanese are installing PV at more than twice the rate that we do in the United States.

Though PV makers are building new manufacturing facilities, the world's total output is currently not enough to keep up with demand. A combination of the hyper-pure silicon shortage and increased module demand has raised the price of a PV module for the short term. So you can expect to pay a little more for the modules you buy.

World business will undoubtedly respond to the PV module shortage. New hyper-pure silicon refineries will be constructed. New PV module manufacturing plants will be built. Eventually, the PV module will once again continue to decline in price as its supply increases. But whatever its price, the PV module offers supreme value.

In the future, other technologies may be developed that will turn sunlight into electricity—technologies that may not use silicon, technologies that are simpler and cheaper to employ than current silicon-based PV technologies. Whatever the technology, the fuel source remains the same—sunlight. The value remains the same—a nonpolluting energy source, and the fuel is free.

Access

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