
HOME POWER
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THE HANDS-ON JOURNAL OF HOME-MADE POWER

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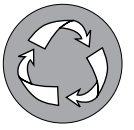

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Sunshine

Sunshine's good for lots of things. We couldn't possibly list them all. But we'll show you a couple. Above our good buddy Tree, a two year old Piñon Pine ex-Christmas tree, hangs out and flies his Earth Flag. Resting on Tree's pot is a JetSki PV module recharging our AA flashlight batteries cool in the pot's shade. Tree likes sunshine. We like it, too. Try some!

Karen & Richard

People

Bill Battagin
David Booth
Barry Brown
Jay Campbell
Reynaldo Cortez
Chris Greacen
Mark Hawes
Jim Healy
Kathleen Jarschke-Schultze
John Mills
Mark Newell
Therese Peffer
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William Raynes
Sue Robishaw
Mick Sagrillo
Steve Schmeck
Bob-O Schultze
Allan Sindelar
Alan Spivak
Laurie Stone
Michael Welch
John Wiles

" Think about it…"

In gentleness there is great strength.

Power — most of the time — can be a very quiet thing.

— Sun Bear

Above: Sue, Steve and Ditto in front of their solar-powered and earth-bermed home and business. Photo by Dan White

Some talked, we moved…

Sue Robishaw

It's been fifteen years since we quit our jobs and the city to move to the backwoods of Michigan's Upper Peninsula. We were part of the much talked of homesteading movement of the seventies. Most of our friends talked, we moved. Many who moved went back, physically or philosophically. We couldn't imagine "going back". Why would we? We weren't trying to make a statement. It was just our way of life — a comfortable, happy, satisfying and fun one.

OK, I admit, there are hard times. But they're easier when you have shelter, food, heat and electricity — all with little money needed for maintenance. It's a great sense of freedom for us to know that when things get bad we can make do quite well with very little money. To be honest, that's the way we live most of the time! And it's not bad at all.

Shelter

A person's home is all relative — hovel to one, castle to another. We started out in a four foot by eight foot plywood based, truck camper-cap-top home. It was great. It was paid for. We had an old car battery to run our car radio/tape player, and oil lamps for light. However, when the temperatures dropped into the low digits our half-built cabin/shop next door became our new castle. It didn't matter that it was barely up, let alone anywhere near being "done". It had a wood stove that could blast you out with the heat, and it kept a fire all night — heaven.

We had little building experience but we poured over the available books, especially Eccli's *Low Cost Energy-Efficient Shelter*, and drew plans. The wood and nails for our shop/temporary home were bought with $1500. The wood was green, but that was what we could afford. We built a comfortable, simple, 14 foot by 22 foot shed-roof home with south facing windows. It was a great way to learn to build. Steve wired in a simple 12 Volt system, replaced the old car battery with a new marine deep cycle unit and added some 12 Volt lighting. It was home and workplace for seven years, and has been a workshop for eight. Shelter doesn't have to cost a lot. We ended up with about $2600 total in the place, including a six foot by fourteen foot addition and a small porch. We made our own windows and latches, furniture and doors. After eight years we still miss living there, so much of ourselves went into it. But ever onward...

The Big House

We spent hours upon hours reading and drawing, building models, changing plans. Our energy efficient,

passive solar house was going to be great — slipform stone walls from the Nearings, underground design ideas from Malcolm Wells, windows and doors by Eccli, basics via Architectural Graphic Standards, and acres of south facing glass like the best of them. We were ready. We figured it'd take us two years, maybe three since we had to start a garden, cut firewood, fix roads, and build sheds and barns. Ah well. Thank goodness and any gods watching over us that we were always running out of time or money. It was many years before we finally got to the bulk of building. By then we had mellowed some, had a much closer feeling for the place and had come across Mike Oehler's *$50 and Up Underground House* book.

Two of the biggest changes were to build out of wood instead of stone, and to reduce our planned south facing glass to a size that made sense in our climate. The result was a place that fits in well with the surroundings, the local weather and us. We had no natural stone to work with and the price of cement was going up much faster than the house. We live in the woods, there are sawmills nearby. Wood just made sense for us. Oehler gave us the inspiration (if you're out there Mike, Thanks!). So our home is a timber-frame structure with 12 inch by 12 inch posts and beams, four inch by six inch intermediate posts and four inch by twelve inch rafters. The ceiling/roof and walls are two layers of one inch rough-sawn green pine. Yes, planed on the interior side would have been nicer but the budget didn't allow. The six-sided shape of our place had already been set in concrete, in the form of footings already dug and poured for the slip-form house. So we adapted our wood design to the shape which made for interesting joints and creative saw work!

We used scrap lumber to rough out a model actual size, on site, to reach our final south window and roof design. The original 12 foot high front window area came down, and down, and down farther to end up three feet high. It felt better and turned out to be a good decision. A large south window expanse would heat up the house well on sunny days, true — the status quo solar home design. But if you actually work and live in your home during winter days it's not practical or comfortable. The glare and heat from all that glass exposure on sunny days would make for very uncomfortable conditions in the south rooms. Also the large area would allow a lot of heat to escape during cold winter days. Insulating curtains are a good solution for night, but you usually don't want to block out the light and view during the day. Since we both work and live in our home year round, the three and four foot high by thirty-six foot wide south facing window design was a good compromise. Each window has its own insulating curtain so on really cold, not sunny, winter days we open only those windows needed for light. An attached greenhouse now covers a third of the window area and provides a place in the shop to work which is glare free.

Building an underground home has peculiarities of its own to take into consideration, some obvious some not. One is that it does need to be insulated — from the ground. The earth insulates you from the hotter or colder air temperatures (how well depends on the type of soil, how wet or dry it is, and how deep). In the cold areas, the ambient temperature of the earth can be 45–50 degrees — rather cool for living spaces. We used an inch of foam board on the bottom half of the walls, two inches on the top half and three inches on the roof. We have about six inches of soil on our roof. If we were to do it again, we would put another inch or two of foam on the roof and walls. But that was what we could afford then.

Never underestimate the power of the earth. It's amazing we have learned. Design well for the particular stresses of underground buildings. Then add in lots of fudge factors and overbuild from there. It's unnerving to see a six inch by twelve inch beam bow in an inch or two and it takes a lot of digging to correct. But we wanted a window there anyway....

We enjoy living this close to the earth. It fits us and the land. With clerestories and windows, it is not at all like "living in a cave" as many imagine. The buffering effect of the earth is much appreciated in temperature extremes and storms. It is also very quiet which could be a great advantage if one lived in a noisy area. For us we put in a vinyl window to let in some of the surrounding noises. Then there are the deer and rabbits stomping across the roof at night — comforting for us, a bit of unnerving for guests.

Power

"As the old story goes," we started with a car battery and car radio in our four foot by eight foot camper home, with candles and oil lamps for light. As we settled into our cabin/shop we progressed to some 12 Volt, 8 Watt RV fluorescent lights and an old marine deep cycle battery. Then in December 1982 we installed our two ARCO 16-2000 photovoltaic (PV) panels, 4.4 Amps of power, on a handmade manual tracking pole mount rack. We added another marine deep cycle battery, a blocking diode, some wiring and two inexpensive meters. Our $1500 system was complete. Heaven on earth!

There wasn't much real info about alternative energy back then. We had what had been written in the old *Mother Earth News*, and the small catalogue from the Earth Store. But Steve knew about cars, understood

the basics, and trialed and errored it from there. We added tail light bulb lamps, and took the old TrippLite 250 watt inverter out of the van to run Steve's computer. We used power when we had it, and didn't when we didn't. We had a gasoline engine mechanically coupled to our power tools and the old Maytag washer (via a line shaft arrangement), but no generator to charge the batteries. December usually found us back with oil lamps and candles for a time.

The system moved with us into the new house in '85 with few changes. It would be two years before that first exciting *Home Power* issue arrived. Those first issues showed us how much better golf cart batteries would be, and that we weren't the only ones living this way. We personally knew of no one else living on alternative energy.

Over the years a few things were added, such as a 100 watt Statpower Inverter to run the printers and small tools, a 2200 watt generator to run the larger power tools, vacuum and washer, and a home-built generator to help charge the batteries in cloudy, low sun winters. Compact fluorescents with their great light color happily replaced the old regular fluorescents as our main lighting. The old lights were moved to the shop area, and small 0.2 Amp bulbs were placed here and there where candles used to burn. Steve also finally corralled the various wires and parts of our system into a neat power center. A few hours project turned into a few days and made Ananda's Power Center look *real* nice.

Last summer at the Midwest Renewable Energy Fair we splurged and bought two used Arco 16-2000s. We were now a four panel family! As is the case for those of us who build our systems piece by piece, we were happy with the added solar power but frustrated too. We were now short of battery and inverter power! All that "extra" power coming in and often no way to utilize it — but one step at a time! A larger inverter, more batteries and some efficient Wattevr Works DC motors for the washer and power tools will be added as we can. A few more panels will be next and then the generator gets torn apart for parts. We can't wait. See the chart for an estimate of how we use the power we have. Our use reflects our livelihoods which include woodworking, computer training and programming, writing, and an alternative energy business.

Sue & Steve's Energy Use

12 Volt DC Loads	*Watts*	*Hrs/day*	*W-hrs/day*
Fluorescent lighting	11	6.4	70.7
Incandescent lighting	3	5.7	17.1
Power tools	24	0.7	17.1
Greenhouse fans	3	5.7	17.1
Laptop computer	6	2.1	12.9
TV (2 inch)	5	0.7	3.6
Radio/tape player	2	1.4	2.9
		12 Volt DC Subtotal	141.4

120 vac Loads	*Watts*	*Hrs/day*	*W-hrs/day*
PC computer	35	2.9	100.0
Power tools	150	0.1	21.4
		120 vac Subtotal	121.4
		Total in Watt-hours per day	262.9

System Batteries

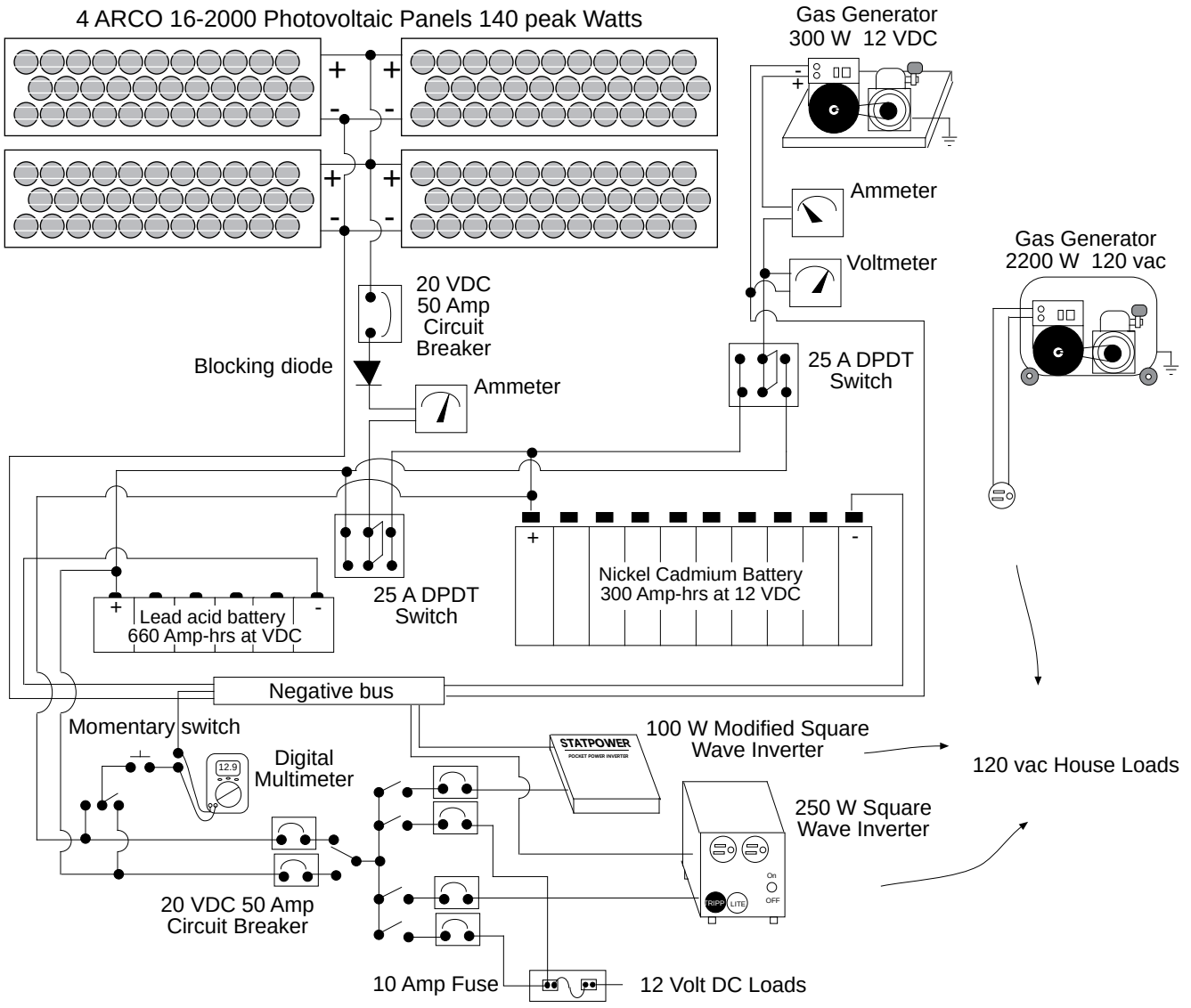
Once in a while things go OK for us simple living folks who've chosen to live with little money. We made do with one or two deep-cycle marine batteries for 10 years. They were old and way past retirement time but there just wasn't anything in the budget for new ones, even a set of golf cart batteries. Then one muddy spring day we were scrounging around the local salvage yard looking for something or other for our car when I spied a large pile of old auto batteries. We had to go look them over. There at the very bottom (of course) were some old steel case batteries in wooden crates. They turned out to be thirty-six 100 Amp-hr nicad cells made in 1963. We began learning about nicads.

In the end we replaced the electrolyte in only one set of 10 cells (the ole budget constraints again) but put the other 20 cells in service with only the addition of distilled water and oil. We tested them and found the reconditioned cells came in at 77% of rated power and the not reconditioned cells at 50%. A total of about 177 Amp-hrs of storage. Not the best, but compared to our old, tired marine batteries they are great — at a cost of only $70 for the batteries, new electrolyte and oil.

After we installed the old nicads, friends who went from generator to grid power gave us their five year old golf cart batteries, 660 Amp-hrs. We tested them out at

How much Sue & Steve spent ...

Equipment	*Cost*	*%*
4 Arco 16-2000 35W PV panels	$1,100	61%
Lighting	$170	9%
TrippLite 250 watt inverter	$160	9%
Wiring	$130	7%
Statpower 100 watt inverter	$120	7%
3 sets salvaged 100 Amp-hr nicads	$70	4%
Meters, control box	$50	3%
Total	$1,800	



Grass Valley Homestead System

65% capacity — not too good, but battery power is battery power. We weren't about to just throw them away. Since Steve was working on our new power center at that time, he built in a switch so that we can charge either battery pack, and we built a battery box for each bank. We don't have a regulator so we keep a close watch on the batteries and operate the switches manually. Then we tried the EDTA treatment to restore some of the capacity of the old golf cart batteries. We had previously used EDTA on our old sulfated marine batteries and it did appear to help. We had an interesting experience with the EDTA and the golf cart batteries though. After adding the EDTA we put the charger on the batteries and monitored the voltage. It went down instead of up — not quite what we had in mind. We dug through the old *HP*s. Nothing. We called Bob-O Schultze. The conclusion was that the EDTA was working, raising the capacity of the batteries even while we were charging, which meant the percentage of charge would go down. In the end the golf cart batteries came in at 70% capacity.

We never actually used the golf cart batteries in our system. They came in handy though as a loaner to a customer with a new system and a much delayed shipment of reconditioned nicads. Now that his nicads are installed, the golf cart batteries are in a new home with folks who live and work with a propane guzzling generator, and little cash. They have a small inverter, battery charger and hopes for a panel or two next summer. The process starts again.

Water and Waste

Our whole "alternative energy" system started when we moved here, had a well drilled and put up our 8 foot Baker "Runs in Oil" Windmill on a rebuilt power line tower. So few words but what an adventure! A 1200 gallon concrete septic tank, covered with sand, sits next to the tower to hold the water. A buried 1½ inch line down to the house (with side lines to the garden and the workshop) provide gravity fed running water. It's a great, simple system. Not without its problems, quirks and maintenance for sure but we love it. It doesn't take many winters of hauling water from town (the last half mile by sled), or pumping water by hand and hauling it from the pump, to make you really appreciate every drop coming into the house by just turning the faucet. We still use water as if we were hauling it, a habit I hope we never lose. The windmill is aesthetically pleasing, and fixable with hand tools and muscle. To us that is a big advantage over a solar pumping system.

We have an outdoor composting toilet which works great and was quite inexpensive. The view is much better than any indoor job too. It's very easy to maintain. One pit is used for a year, one pit composts for a year. At the end of the year, compost from the unused side can be spread on fruit trees. That side is then ready for use again. The generous use of wood ashes and sawdust, as well as a vent, keeps "smells" to a minimum. However, this facility was built near the workshop, not the new house. Winters being somewhat cold I admit we do use the archaic indoor toilet/septic tank arrangement on occasion. We hope to replace it with an indoor composting toilet someday. To help keep this system from being any more ridiculous than it is we use gray water to flush and a special alternative urine-commode (aka a bucket with a lid) which is carried to the compost pile. Not only does it not make any sense to use good fresh water to flush a toilet, our fresh water is often in limited supply in the winter. We can only pump water on a windy, above freezing days. We could enclose our pump in a small building so we could warm it and pump more often but this hasn't been necessary yet. Conserving water is easier.

Heat

The sun provides a lot of our heating, both space and water, as well as cooking. The south facing windows in the house (and the shop) do their job well when the sun shines. The rest of the time we heat with wood. Since we're becoming less and less happy with cutting trees to burn, we're going to install four used solar heating panels on our roof this spring. This should reduce our firewood demand, as well as be a very "interesting" retrofit to our house.

Our water heaters vary with the seasons. In the summer, we use our "¾ inch black pipe draped across the roof of the house" unit. It works great, though the grass and weeds do shade it some. It hooks into the water line at one side and has a faucet at the other, near the door. Our old standby "large dark enameled coffee pot set in the sun" system is used often since it can easily be moved to the sunniest spots. We also keep a jar and glass coffeepot full of water in our homemade solar oven for convenient hot water. During the cold months there are always kettles on the wood *heating* stove as well as a small hot water tank, fitted with a faucet at the bottom, right beside the stove. This provides warm water whenever the stove is used. Year-round whenever the wood *cook*stove is going, there are water kettles heating also. But with cooking on the heating stove in winter and the solar oven the rest of the year, the old cookstove gets very little use now. Our trees are happier.

Cooking and Refrigeration

In the winter we cook mainly on our wood heating stove. The wood cookstove is used more in the fall and spring when we want the heat it provides. We use our propane hot plate now and then for quick cooking jobs. As soon as the weather settles, we put out our homemade solar oven and use it whenever the sun cooperates. The oven is bulky and heavy so we don't move it in and out very much. The interior is an old stainless steel steamer pan we had around, painted black, with an added free swinging metal tray. We had some fiberglass duct board insulation to use, and a large cardboard mail box which was just the right size for the exterior. We painted it with some leftover epoxy resin then several coats of oil paint to try to make it weather resistant. The top is a piece of plywood cut to fit which holds the hinges for the glass door and brackets for the reflectors. The reflectors were made from aluminum which turned out to be too dull — we couldn't get the oven over 250 degrees. We still used it though! This year we glued on very reflective mylar film which we had (in the form of an emergency blanket). This is a great improvement even though we couldn't get the film on smooth. The oven easily gets up to 250 degrees on a hazy day, and into the 300s when it is sunny. The oven sits in a wooden base which is attached to a pipe in the ground so it can be tracked by hand east to west throughout the day.

Above Left: Sue and Steve at work together in their solar-powered office.
Above Right: Steve works wood on his homemade, pedal powered lathe.
Middle Left: Sue and Steve's bedroom with instruments on the wall. They make dulcimers by hand.
Bottom: Sue cuts wood with her homemade handsaw.
Photos by Dan White.

Our refrigeration is simpler. We have a root cellar and pantry in the back of our house which stays between 32–40 degrees for about seven of the colder months. This is our refrigeration, and we enjoy being able to keep leftovers for the next day. During the warmer months, the temperature climbs slowly to about 60 degrees in those rooms and we simply adjust our cooking and eating habits to reflect the lack of cold storage. We don't find artificial refrigeration to be a necessity at all. We appreciate the cold when nature provides it, and get along quite well when she doesn't.

Another kitchen appliance we use is a grinder. We have a hand operated steel bur mill for grinding oat flour, corn flour, homemade Postum and the like. For wheat, barley, millet rye and buckwheat flour, we have a hand stone mill which Steve fitted with an electric motor. This runs off the generator when we have it going for the washer and/or vacuum. Grinding our own flour works out well since whole seed stores much better and longer than ground flour.

Livelihood

We have a range of small, micro and nano businesses for our livelihood. They fit more or less smoothly with each other and blend into our lives. Steve does independent computer training and programming, usually working "out" one or two days a week throughout the year. He put together his computer to utilize the most energy efficient components at the time. This was important since his longer programming projects usually occur in the winter when our power is shortest. We are both artists, working in wood. We build stringed instruments, flutes, jewelry boxes, and do some sculpture. Most of this work is done in the winter. Since both of us work more with hand than power tools, this isn't too big of a draw on our power system. I also do some writing, usually in the winter months and usually in the evenings. We both use our computers in various ways for all of our businesses.

A few years ago we realized that more people were becoming interested in alternative energy. There are few, if any, dealers in the Upper Peninsula of Michigan to answer questions and assist those who would like some hands on help. So our business "Grass Valley Solar and Wind" began. We're in a small grassy valley so we had long ago named our place Grass Valley Homestead. Our woodworking business was Grass Valley Woodcraft. Grass Valley Solar & Wind followed without much thought. Frankly we now wish we had come up with a shorter name! We operate all our businesses out of our home with our own resources. The alternative energy business is growing slowly as education, knowledge and interest spreads. Since it is more active in the spring, summer and fall than in the winter, it fits in well with our other activities.

Costs

Our total water system cost us about $3670, the septic system $700 and the outdoor composting unit very little. We figure we have about $10,200 in the house and about $1800 in our solar electric system (not including the gasoline generator). In 1992 we spent $76 on gasoline (for chain saw, garden tiller and generators) and $8 on propane for a propane hot plate. A related cost/savings in our "alternative energy" lifestyle is gardening and food. We have a large organic raised bed garden which provides much of our food so we spend about $1000 a year on outside food, household supplies and sundries.

Of course dollar costs for any of this doesn't begin to compare to the enjoyment, satisfaction and just plain fun that we get from living and working the way we do. I hope the day will come when many others will have fun with a similar lifestyle, and it will no longer be "alternative". Not that we don't have a long way yet to go to living gently on earth. But it will be nice when most everyone around is going in the same direction. Meantime, we appreciate the support and sharing of other Home Powerers who are working toward that day.

Access

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Read your mailing label!

The mailing label on the cover of your Home Power issue tells you in plain English when your subscription expires. We don't send out renewal notices, so check each mailing label when your issue arrives. Photo by Señor Mark Newell

Above: Lu Yoder, a solar-powered businessman, juices up a few carrots. Photo by Jay Campbell.

"Give me enough sunshine, and I'll juice a brick!"

Jay Campbell

Albuquerque's incorrigible solar pioneer, Lu Yoder, has done it again. He has conceived, designed, built and put into operation a unique one-man, solar-powered business. His latest venture, aptly named "Sun Squeeze" is a mobile juice bar. Powered by a 65 Watt self-contained solar system, he produces fresh fruit and vegetable juice wherever thirsty crowds gather. Moreover, the entire rig is built onto a bicycle drawn trailer, so he can take it noiselessly & pollution free to wherever business might be.

Lu's colorful background includes a stint studying Mechanical Engineering, years building and selling bicycle trailers, lots of experimental designs of solar electric and solar thermal systems, a couple of solar refrigerators, and uncountable other small projects. He first earned the attention of HP's readers with his prize winning solar oven (HP#31). This project has combined several of his experiences into one overall winning combination.

The System

Lu's system uses two used Arco 16-2000 32.5 Watt panels to charge two 12 Volt, 30 Ampere-hour, lead-acid gel cells. Solar power output runs from the battery through a Trace 812SB inverter and into the commercial grade Champion juicer. A voltmeter mounted in the rear of the cart allows Lu to monitor the battery's state of charge as he works. Being a compact system, wire runs are miniscule. A 200 Ampere fuse protects the batteries and inverter, and a smaller fuse protects the batteries and charge controller.

The cart is divided into two major compartments. One contains the electrical equipment and a five gallon solar assisted hot water tank for hand washing. Lu uses the other compartment for food storage (in an ice chest), cups, juicer, and literature on community events — the business side of the business. Colorful painting by Santa Fe artist, Julia Coyne, adds a festive touch to the cart. The solar panels, hinge mounted to the top of the cart, allow Lu to adjust them through the day for maximum charging.

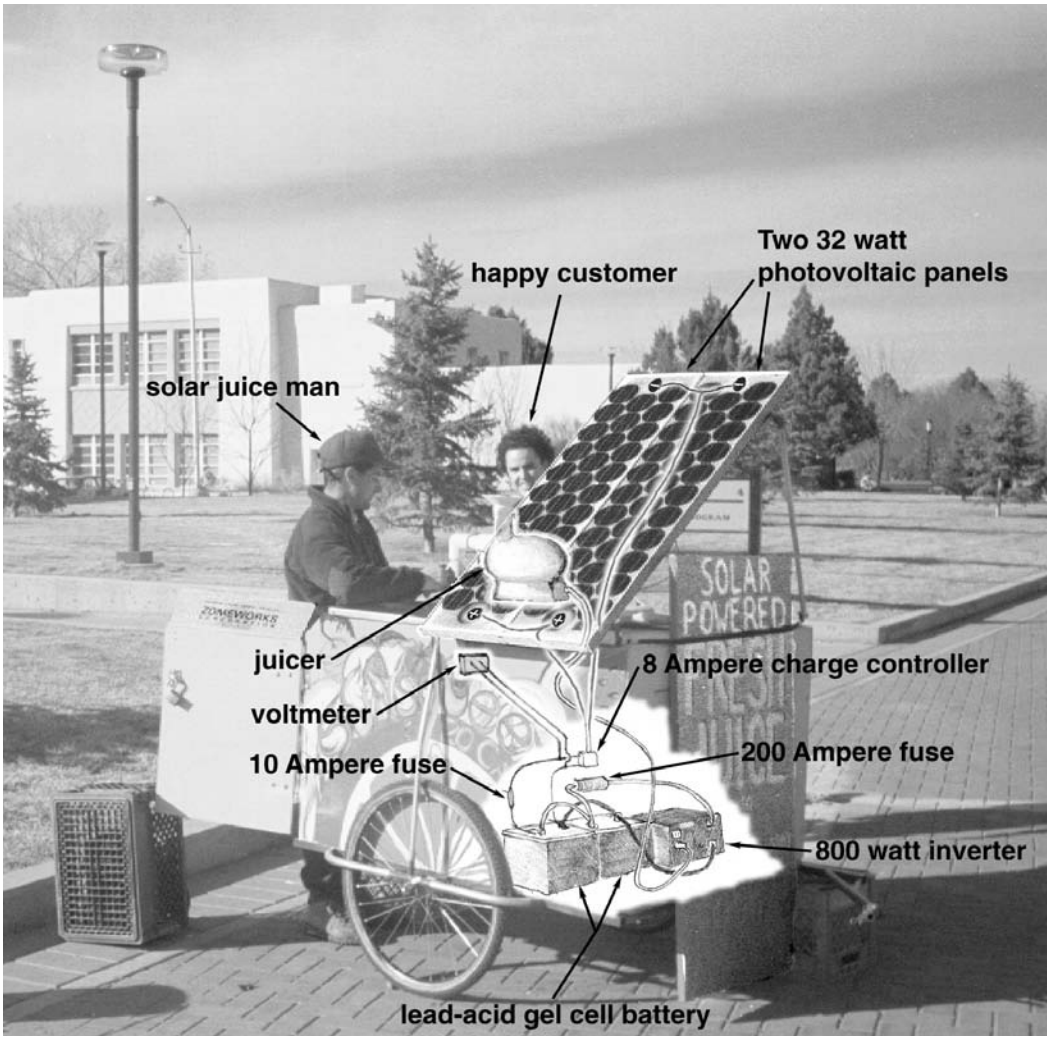
The whole rig (all 400 pounds of it) sits on a 4 foot by 4 foot steel trailer frame made from scavenged bicycle frames and electrical conduit. The panels fold down flat, and everything else fits inside. For the frame, Lu used the same basic design that he has used for years, but doubled its size, and beefed it up.

Use

When a customer orders, Lu slices up the appropriate ingredients on the stainless steel work top, flips on the juicer, and tosses everything in. The juice pours out the bottom, and all pulp is diverted to a waste bucket. After the sale, he washes his hands in the hot water and is ready to start all over. He's still waiting for the day he has to say "please wait a few minutes while the batteries charge." That will mean he has a line of people buying juice, one after another. The system has proved capable and completely reliable through the short and cloudier days of winter. Summer production will be a snap.

Lu sized the electrical capacity to meet the single load. Initially, he made the mistake of believing the rating plate on the side of the juicer, and ended up with too small an inverter. The current Trace inverter, however, works fine. The motor is rated at ⅓ hp, but a closer look at the plate shows that it is rated at 5.7 amps, and under load (carrots!) surges to 1000 watts. Also, the motor simply can't put out as much power with the modified sine wave it's being fed.

The PV panels generate 260 Watt-hours on a good four hour day. One cup of juice takes about 3.3 Watt-hours (20 seconds x 600 Watts / 3600 seconds/hour = 3.333 Watt-hours) to squeeze. This is only an approximation — tougher foods like carrots take lots more power than oranges, but with these numbers Lu can max out at 78 cups per day. Of course, by starting



Above: a diagram of how Lu's Solar Squeeze works. Art by Chris Greacen and Mark Newelll.

the week with a full charge and ending with a low one he can exceed this amount pretty handily. It takes about three minutes to recharge from each cup of juice. The four hour limit was imposed by the health department. If he cleans the juicer and gets fresh produce, he can go on for four more hours.

Lu charges the water system with hot water in the morning, and then keeps it piping hot with a simple double reflector, solar system. A foot-powered air pump provides water pressure — another clever touch in this system.

After he closes up shop, Lu pedals over to 20 Carrots (a local juice bar/produce store) to clean the equipment and stash his food. Health department regulations make this easier and more practical than subjecting his kitchen to inspection. At home Lu locks up the cart and removes the inverter to keep it dry. Albuquerque has a five month freeze season during which the inverter needs protection from frost and condensation.

Why use an inverter?

Why didn't Lu use a 12 Volt DC system and reduce his initial outlay and complexity? For several reasons tied to the educational goals and versatility of this cart, that's why. Equivalent juicers (or many other items) simply don't exist in 12 Volt DC models. He would have had to rig a 12 Volt motor with belts to a gutted 115 vac juicer, which would have looked like some crazy contraption. Lu wanted to present the image of solar power driving every day, familiar equipment. With the full system Lu can help people to "click" that it really does work here and now and explain the process for producing home power. Also, the cart can drive other electrical equipment needed for work away from the grid — construction, repair jobs, whatever. Certainly a 12 Volt only system could be made for Lu's juicer, but it wouldn't provide all the same benefits.

Money

Local business people donated or loaned parts of the system. A local juice bar, 20 Carrots, provided the juicer and a blender (not yet in use), business experience and a commissary service. Construction took place in the shop of Zomeworks, a large Albuquerque solar equipment manufacturer who also donated the batteries. Zomeworks' owner, Steve Baer, has always been known to encourage such independent thinking, and his support has been important to Sun Squeeze's success. Solo Power financed the solar system which helped keep the initial expenses low. Lu did all his own labor, and salvaged (recycled?) materials as much as possible.

With so much expense and overhead cut, it's difficult to assess what this protoype cost. It is estimated that the total cost to duplicate the system with new materials would be about $2,000. The only ongoing expenses are for fruit & veggies, cups, taxes & vendor fees. Lu charges from $1 to $1.50 for a cup of juice; sometimes this depends more on how someone talks to him than what juice they buy. With him it pays to be curious, interested and nice.

Growth

The cart passed a health inspection and Lu is licensed to operate anywhere in the state of New Mexico (should he want to pedal out into the countryside…). Tentative plans include expanding the Sun Squeeze system to cover the downtown, uptown and University areas, as well as special events.

Lu usually spends the workweek at the main campus of the University of New Mexico. On weekends he has tried some local sporting goods stores and soccer fields. Business has been growing steadily, as Lu learns how to promote his product more effectively. He does have a small loan to pay off the panels, but has been able to make ends meet at the end of the month.

Lu talks about hooking up a pedal-powered generator or juicer for customers who want to "squeeze their own." They would, of course get a discount…. Also, to support sustainable agriculture Lu plans to shift the type of produce he uses. When harvest season comes around, he will be using as much local and organic produce as possible.

Waste Management

Anyone in the food business can tell you how much trash it generates. Sun Squeeze produces a remarkably small amount. Fruit crates get recycled, pulp becomes compost and paper cups are the waste item. Some of Lu's regular customers bring their own reusable cups, so waste decreases even more. Coupled with the bicycle trailer, Lu runs a ultra low environmental impact business.

Sun Squeeze and Beyond

Lu's PV-powered juice business shows that solar systems are effective even when grid power is available. Lu has launched this venture with equal hopes of making a little money and of exposing people to the potential of solar power. As the sun climbs higher into the sky, he will add solar cooking demos and more educational literature to the operation.

One intangible advantage to this system is that Lu only has to go out on nice days. He gets to talk to a lot of people, teach about solar technology, excite some people and generally make some money doing something healthful and harmless. One day a group of elementary school kids came by on a field trip and the teacher asked Lu to explain how the system worked. Lu responded that he would not only tell, but would show, tell and taste. The kids started chanting "show,

Above: Lu Yoder gets on his bike and tows his solar-powered business home from work. Photo by Jay Campbell.

tell, taste, show, tell, taste," creating a bit of a scene. That has now become his motto for promoting Lu's unique solar driven business, and solar power in general. Just listening to the comments customers make is motivating — "This is great!," "We need more of these," "I really love what you're doing," "Carrot - kiwi is my favorite!" and on and on. Positive energy really flows around this venture.

"SHOW, TELL, TASTE!"

Access

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Sun Squeeze Cost

Qty.	*Item*	*Cost*	*%*
1	Trace 812B inverter	$600	50.0%
2	Used ARCO16-2000 PV panels	$330	27.5%
2	Interstate lead-gel 30 Ah batteries	$125	10.4%
1	M-8 Charge controller	$50	4.2%
1	FBI 200 fuse	$50	4.2%
1	Voltmeter	$20	1.7%
	Wires, connectors, etc.	$15	1.3%
1	4 Gauge inverter cables	$10	0.8%
	Total	$1,200	

Lu Yoder and Jay Campbell met through HP, when both were winners in the Indigenous Materials Solar Cooker Contest. Until then, they had been tinkering on similar projects only a few blocks apart, completely unaware of each other. This article is their first joint venture.

As the Magazine Turns

Karen Perez

As our ongoing "pulp opera" continues, our intrepid magazine is recuperating from its face lift. It has received many flowers, a few get well cards and (to date) only two "we want a divorce…" Cut to commercial… Are you asking yourself just what the heck those crazy folks at Home Power are up to? Totally confused? Tune in to issue #34, page 5, to find out why we're using coated paper and why it is not as environmentally nasty as you thought. To learn a little bit more about the mysterious world of OMGs, recycled paper, and one fine printer stay tuned.

New Printer, New Friends

Therese, Richard and I trekked to New Richmond, Wisconsin to meet the friendly folks at St. Croix Press, our new printers. We spent three days seeing and learning, and oohing and aahing. We got help learning the ins and outs of electronic pre-press. We saw the *big* presses and binding equipment in operation and met the people who will be helping us put ink to paper.

The folks at St. Croix do things right! St. Croix prints almost 200 magazines. While we were there we saw several publications being printed and bound, and racks of previously printed publications. They all looked great! St. Croix has installed scrubbers on their printing presses so that their printing plant emits no pollution. They recycle all of the preconsumer waste paper generated when magazines are trimmed. They like what they do and it shows.

What you're holding

What you're holding is 50% recycled. The cover paper is 20% recycled postconsumer, 30% preconsumer recycled paper. Unfortunately, 75% postconsumer non-chlorine paper is not available in a weight that's heavy enough to survive the mails — yet. The good news (or so the paper people tell me) is that very soon it will be available. The interior paper is also 50% recycled (10% postconsumer, 40% preconsumer). We'd love to be able to use 75% postconsumer paper on the interior paper but we can't afford it — our "green paper" won't stretch that far.

What's an OMG?

Recently the Paper Stock Institute (a division of the Scrap Recycling Industries) has given OMGs (old magazines — clay coated paper) a class of its own. OMGs are no longer the orphan of the paper recycling industry. Why? Because people are demanding more recycled paper products and less environmentally damaging manufacturing methods. So more recycled paper mills are being built and more high quality postconsumer waste paper is needed. The clay in the coating is used by the recycled paper mills in the de-inking process.

There's actually a shortage of OMGs in parts of the U.S. One Oregon paper mill is having to bring in OMGs from as far away as Texas to meet its demand. In 1991 390,000 tons of OMGs were used by 13 mills in the U.S. This year that number is up to 19 mills requiring 579,000 tons of OMGs. The projected need after 1995 are 30 paper mills that will need 1,338,000 tons of old magazines to make everything from more magazines to critter bedding. So folks, it's time for us to educate our local recyclers about the growing demand for OMGs, use as much recycled paper as we can, and recycle those old magazines.

I gleaned most of the above info from the recycling industry's "trade" pub, *Resource Recycling*. We first saw *Resource Recycling* when St. Croix Press (our new printer) sent us a copy as an example of their printing. What a find. We liked the paper that they are printed on so much that we decided to use it for our interior paper. *Resource Recycling* covers all aspects of commercial recycling from batteries to composting landfill organic waste — a great info source for recycling nerds.

Zip-a-dee-doo-da

The last few months have been exhilarating, exhausting and exciting. The deed is done, we've learned a lot and even made new friends.

Home Power might look like some megamag out of New York; it's a trick of the eye. We still live and work eight miles up a four wheel drive road — no pedestrian crosswalks, no stop lights. The traffic here are deer, mice, skunks, bobcats, squirrels, coyotes and toady frogs. The only lights we see at night are the stars and the renewable energy powered lights from our windows.

Access

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Info on recycling: *Resource Recycling*, POB 10540, Portland, OR 97210 • 503-227-1319

Apples and Oranges

Mick Sagrillo

You're about to make the big decision: should a wind generator be in your future? You've analyzed your resources, both environmental and monetary, and weighed the pros and cons of having a wind generator. The only question left is, which system should you choose?

I can't answer that question for you. However, I can give you the tools to help you make that big decision. Those tools include the detailed information, specifications, and power curves for a number of wind systems.

Background

This article will review all of the commercially available wind systems that are sold in the United States by bona fide manufacturers. An explanation is in order.

In the late '70s and early '80s, the federal and state governments offered tax rebates and incentives to folks who bought renewable energy systems, including wind generators. The objective of the program was to help a fledgling RE industry get off the ground, while weaning the United States from foreign energy supplies by growing more of our own. While the intentions of the tax incentive program were good, the results for the wind industry were nearly devastating. (Similar results occurred with the other renewables, but this article will be restricted to wind electric systems.)

Scores of companies opened shop and began building wind electric equipment. Virtually all of these companies failed. Customers, however, were left with wind generators that didn't work, plus a bad taste in their mouths for RE.

The Vantage Point

Lake Michigan Wind & Sun, of which I am owner, is in the business of rebuilding and making parts for dozens of different models of wind generators that were manufactured by now defunct companies. We do a lot of reverse engineering. That is, we try to figure out where system design flaws are so we can correct them. By making the necessary upgrades, customers can turn a poorly designed wind generator into a usable piece of equipment.

Because of the services we perform, we have a unique perspective as to where the wind energy marketplace is. We have no allegiance to any one manufacturer. We are in business primarily because all but a handful of wind generator manufacturers failed to build reliable equipment. As we found out a decade ago, anyone can make a wind generator. But making one that will work for years is another matter entirely!

So when I say "bona fide manufacturers", I am not trying to slight anyone. I do, however, want to inform readers who the successful manufacturers are. I have tried to fairly represent their products in relation to all others reviewed. They are the survivors, because they have learned how to manufacture reliable products that have withstood the test of time.

Addenda

Two more points before we start. First, this article does not include either the Survivor or Soma wind generators, both of which have received good press in *Home Power*. Neither machine is commercially available in the United States at this time.

Second, a word on failures is in order. You may know someone who has or had one of the wind generators reviewed here that has suffered a failure of some sort, maybe even a catastrophic failure. Don't prejudge all wind generators based on a few isolated instances. Sure, there have been failures, even with the best of wind systems. Paul Gipe of the American Wind Energy Association reminds us to only look as far as the automotive industry for a comparison. The auto industry is a multi-billion dollar industry spanning over nine decades. Yet they still don't always get it right, as evidenced by the numerous annual recalls.

What you should be interested in is trends, not the occasional failure. Problems with wind generators usually occur early in the system's life. All wind generator manufacturers have experienced some failures, as have all other RE equipment manufacturers. Numerous reports of problems with a particular manufacturer should raise a red flag in your mind. However, as stated earlier, those systems have not been included in this article.

I have extensive experience with all of the systems reviewed here, with the exception of the Rutland Windchargers. This machine is a newcomer to the U.S. (We recently installed a test machine at our shop. An article on our Rutland Windcharger test will appear in a later issue of *Home Power*.) However, Marlec, the manufacturer, has sold more than 20,000 of these units worldwide. They obviously have a proven design.

The Envelope, Please

The table on pages 22 and 23 summarizes all of the various features that you should seriously consider when shopping for your wind system. Explanations for the column headings follow. All of the specs have been provided by the manufacturers.

Manufacturer and Model The various models are listed in ascending (i.e., increasing) output to help with comparisons. Manufacturers (or their major distributor) addresses and phone numbers appear at the end of the article.

A note on the NEO/Windseeker: For a little over a year, the Windseeker was manufactured under licensed agreement with Wind Baron as NEO. That agreement was recently terminated, and the system is now being manufactured and supplied by the original manufacturer, Southwest Windpower, under the name "Windseeker". Southwest Windpower still holds the copyrights, trade mark, and patent on the Windseeker Technology.

All of the wind generators presented are new equipment with the exception of the remanufactured Jacobs Wind Electric generators. Even though the old Jacobs has not been made for 40 years, it is still considered by many to be state-of-the-art technology. They have been "remanufactured" (that is, rebuilt with all new components and put back onto the streets with a warranty) by various companies for at least two decades. The Jacobs wind generator is the yardstick by which many judge today's wind equipment.

Rated Output, in general, refers to the maximum power output of the system. Any wind generator may peak at a higher power output than the rated output. This is because the faster you spin a wind generator, the more it will produce, until it overproduces to the point that it burns out. Manufacturers rate their generators safely below the point of self-destruction.

Rated Wind Speed is the wind speed at which the wind generator reaches its rated output. You will notice that there is no standard rated wind speed, although most companies rate their systems somewhere around 25 to 28 mph.

With regards to rated wind speed, note that not all wind generators are created equal, even if they have comparable rated outputs. In the past, some manufacturers have abused the concept of rated output by fudging on the rated wind speed. For example, a wind generator that reaches its rated power at 50 mph is obviously not the same animal as one which hits that same rated output at 25 mph. How often do you see 50 mph winds?

Rated rpm refers to the alternator or generator rpm at which rated output occurs. Generally, the smaller the rotor, the faster the blades spin. Rpm will have an effect on the amount of noise that the wind generator produces. We'll consider noise later.

Cut in Wind Speed is the wind speed at which the wind generator begins making power. For all practical purposes, there is no usable power in the wind below 7 mph, even though the blades may be spinning. This holds true unless you greatly oversize the rotor to allow it to capture power in low wind speeds. But then you open up all sorts of worm cans when trying to control generator output at higher wind speeds.

Rotor Diameter is the "fuel collecting" part of the wind generator. The bigger the rotor diameter, the larger the collecting area and therefore, the greater the wind system's output, or the lower its rated wind speed.

Number of Blades refers to the number of blades in the rotor. This is primarily a design consideration for the manufacturer. The greater the number of blades, the more torque the rotor can produce. A certain amount of torque is necessary to get the rotor spinning from a stopped position. However, torque is inversely related to rotor conversion efficiency. When you are trying to generate electricity competitively with the power company, efficiency is of prime concern.

The fewer the number of blades in the rotor, the more efficient the rotor becomes. One blade is the ideal, but poses some dynamic balance problems. Two blade or three blade rotors are seen most often. The question arises, why use three blades if two blades are more efficient? Time for a digression!

"Yaw" is a term that refers to a wind generator pivoting on its bearings around the tower top to follow the continually changing direction of the wind. Two bladed rotors pose a problem as the wind generator yaws. A two-bladed rotor actually sets up a "chatter" as it yaws, which causes a strain on all of the mechanical components. Chattering occurs during yawing because of the continuous changing of the position of the blades in the plane of rotation. When the blades are in the vertical position (that is, in line with the tower) there is little resistance to the rotor yawing around the tower. However, when the blades rotate 90 degrees so that they are in the horizontal position (that is, at right angles to the tower, or parallel to the ground) they pose maximum resistance (or inertia) to any yawing motion. The result is a rhythmic starting and stopping of the yaw twice per revolution of the rotor. This starting and stopping of the yaw is what is seen as blade chatter.

Three-bladed rotors eliminate the chattering problem because there is never enough inertia from the one blade in the horizontal position to set up a blade chatter in the first place. The horizontal blade is more

WIND GENERATOR

Model	Furlmatic 910	Windseeker	Whisper 600	Whisper 1000
Manufacturer	Marlec Engineering	Southwest Windpower	World Power Technologies	World Power Technologies
Rated Output in Watts	150	500–12V 600–24V	600	1000
Rated Wind Speed	36 mph	30 mph	25 mph	25 mph
Rated rpm	900 rpm	2000 rpm	1100 rpm	935 rpm
Cut-in Wind Speed	4 mph	5 mph	7 mph	7 mph
Rotor Diameter	3 feet	5 feet	7 feet	9 feet
Number of Blades	6	2	2	2
Blade Material	Glass reinforced nylon	Sitka Spruce or Basswood	Basswood	Basswood
Airfoil	True	True	True	True
Lateral Thrust	100 pounds	100 pounds	150 pounds	250 pounds
Governor System	Side-facing	Tilt-up	Tilt-up	Tilt-up
Governing Wind Speed	37 mph	35 mph	27 mph	27 mph
Shut-down Mechanism	none	none	Dynamic Brake	Dynamic Brake
Tower Top Weight	38 pounds	20 pounds	40 pounds	55 pounds
Marine Option Available?	No	Yes	Available soon	Available soon
Generator Type	PM Alternator	PM Alternator	PM 3 phase Alternator	PM 3 phase Alternator
Tower Top cost	$820	$875–$925	$990	$1,500
Dollars per Watt	$5.47	$1.75–$1.55	$1.65	$1.50
Battery Systems	12V & 24V	12V to 180V	12V to 240V	12V to 240V
Utility Intertie Available?	No	No	No	Yes
Resistance Heating?	No	No	Yes	Yes
Water Pumping?	with batteries	DC	AC	AC
Est. Mo. KWH @ 10MPH	15 kWh (14%)	60 kWh (17%)	70 kWh (16%)	120 kWh (16%)
Est. Mo. KWH @ 12MPH	22 kWh (20%)	90 kWh (25%)	110 kWh (25%)	190 kWh (20%)
Warranty	1 year	1 year	2 years	2 years
Time in business	15 years	8 years	4 (15) years	4 (15) years
Routine Maintenance	None Recommended	None Recommended	Visual Inspection	Visual Inspection
Notes	US Import Duties	Built-in Regulator	Includes Rectifier Box	Includes Rectifier Box

COMPARISON TABLE






BWC 1500	Jacobs Short Case	Jacobs Long Case	Whisper 3000	BWC Excel	Jacobs 23-10
Bergey Windpower	Lake Michigan Wind & Sun	Lake Michigan Wind & Sun	World Power Technologies	Bergey Windpower	Wind Turbine Industires
1500	1800–24V 2400–32V to 48V	2400–24V 3000–32V to 48V 4000–200V UTI	3000	10,000	10,000
28 mph	18 mph	23.5 mph	25 mph	27 mph	25 mph
500 rpm	225 rpm	275 rpm	625 rpm	350 rpm	200 rpm
8 mph	6 mph	6 mph	7 mph	7 mph	8 mph
10 feet	14 feet	14 feet	14.8 feet	23 feet	23 feet
3	3	3	2	3	3
Fiberglass	Sitka Spruce	Sitka Spruce	Basswood	Fiberglass	Sitka Spruce
Single-surface	True	True	True	Single-surface	True
375 pounds	750 pounds	800 pounds	700 pounds	2000 pounds	1500 pounds
Side-facing	Blade-activated	Blade-activated	Tilt-up	Side-facing	Blade activated & Side-facing
30 mph	18 mph	23.5 mph	27 mph	33 mph	25 mph
Folding Tail & Dynamic Brake	Folding Tail	Folding Tail	Dynamic Brake	Folding Tail & Dynamic Brake	Mechanical Brake
168 pounds	450 pounds	550 pounds	130 pounds	1020 pounds	1400 pounds
Yes	Yes	Yes	Available soon	Yes	Standard
PM 3 phase Alternator	DC Generator	DC Generator	PM 3 phase Alternator	PM 3 phase Alternator	Brushless 3 ph. Alternator
$3395–$3595	$4,600	$5,200	$3,200	$15,995–$17,995	$13,100
$2.26–$2.40	$1.92	$1.73–$1.30	$1.07	$1.60–$1.80	$1.31
12V to 120V	12V to 120V	12V to 120V	12V to 240V	48V or 120V	120V
No	Yes	Yes	Yes	Yes	Yes
Possible	Yes	Yes	Yes	Possible	Yes
AC	DC	DC	AC	AC	AC
125 kWh (12%)	250 kWh (18%)	340 kWh (16%)	320 kWh (15%)	925 kWh (13%)	850 kWh (12%)
220 kWh (20%)	440 kWh (30%)	520 kWh (24%)	520 kWh (24%)	1425 kWh (20%)	1250 kWh (18%)
3 years	1 year	1 year	2 years	3 years	1 year
15 years	12 years	12 years	4 (15) years	15 years	6 years
Visual Inspection	Visual 2X & Grease	Visual 2X & Grease	Visual Inspection	Visual Inspection	Grease & Oil change
			Includes Rectifier Box		Gear box (not direct drive)

than counterbalanced by the other two blades working somewhere off on their own. Well-balanced three-bladed rotors operate very smoothly with no noticeable vibration or chatter.

World Power Technologies has come up with a unique solution to the two-blade problem on their Whisper wind generators. The blades are mounted on a spring plate. The spring plate flexes to absorb some of the yawing vibration and therefore helps mitigate the yawing chatter on the Whisper wind generators.

Blade Material refers to what the blade is constructed of. Within the last decade, blade material has fallen into one of two categories: wood or extruded fiberglass. While more expensive for materials and labor, wood is still considered by many as the material of choice for blades. Blades do a lot of flexing. That's what trees did as a side job for most of their lives.

There is no question that sitka spruce is the "primo" material for wood blades. Sitka has one of the highest strength to weight ratios of any materials ever used by blade makers, as well as airplane and boat builders. Done properly, however, extruded fiberglass also makes an excellent blade material. Bergey holds the secrets with extruded fiberglass.

Airfoil refers to the shape of the blade. Two types of airfoils are used by wind generator manufacturers: true airfoils and single-surface airfoils.

The cross section of a true airfoil blade would look much like an airplane wing, that is curved on one side and more or less flat on the opposite side. Single-surface airfoils have matching curves on both sides. They are easily formed by the extrusion process.

The differences between the airfoils occur in three areas: performance, noise, and manufacturing cost. True airfoils are quieter and perform better than single-surface airfoils. But single-surface airfoils are cheaper to manufacture than the more complex true airfoils.

Lateral Thrust at the Tower Top is mainly a design consideration for tower manufacturers. Lateral thrust, the horizontal force vector, is a function of swept area of the rotor, the resistance the tower presents to the wind, and wind speed. The greater the lateral thrust, the stronger (and therefore, more expensive) the tower must be and the larger the concrete footings must be.

Governor System refers to the manner in which the wind generator protects itself from high winds and rotor overspeeding. Governing is necessary for two reasons: to protect the generator itself from overproducing and burning out, and to protect the entire system from flying apart in high winds.

The governing devices used on all of these wind generators fall into two general categories: those that reduce the area of the rotor facing the wind and those that change the blade pitch.

Changing the swept area of the rotor is accomplished by either tilting the rotor up and out of the wind (Windseeker and Whispers) or by side facing the rotor out of the wind by moving it around the tower (Rutland and Bergeys). In either case, the rotor is offset either above or to the side of a pivot point. Wind pressure on the rotor causes it to pivot out of the wind. These governing mechanisms are almost a foolproof method of controlling rotor speed. They do come with a cost though. Once the rotor governs by tilting up or side facing, it produces little power.

Blade-activated governors work by pitching the blades out of their ideal alignment to the wind. The greater the rotor speed, the greater the degree of pitch. Having more moving parts than either the tilt-up or side-facing mechanisms, they are considerably more complicated governing devices. However, they offer much better power curves, as we will see later.

Governing Wind Speed is the wind velocity at which the governing mechanism is fully operational.

Shut-down Mechanism refers to the manner in which the rotor can be stopped and the generator shut down. This is desirable for maintenance or repairs, or whenever else you do not want the rotor to be turning.

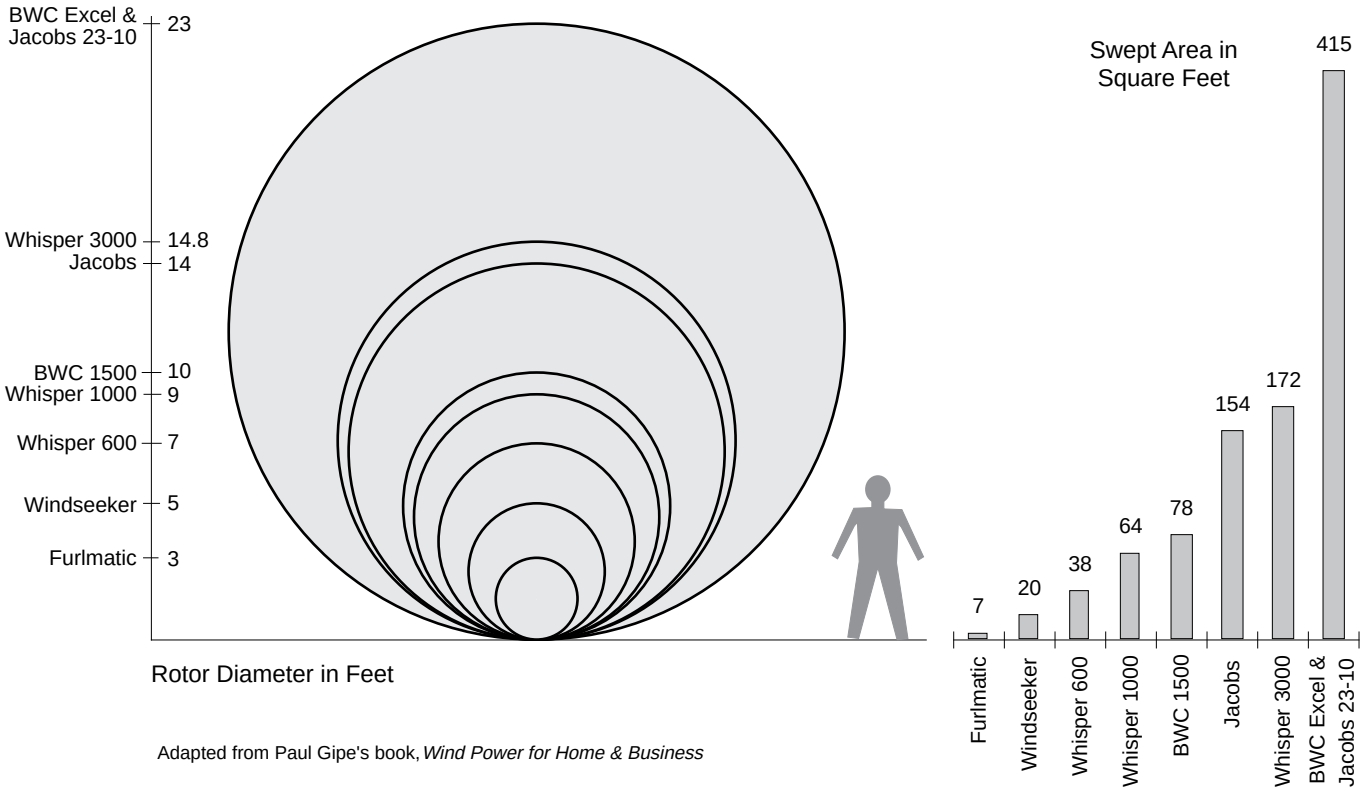
The most common system used is to fold the tail (all of these systems have tails) so that it is parallel to the blades. This takes the rotor out of the wind, and it will cease to rotate. Folding the tail involves either cranking or uncranking a cable which will furl or unfurl the tail, depending on the system. The cable winch is at the base of the tower, meaning you must go out to the tower to accomplish the shutdown. Wind Turbine Industries uses the winch to activate a mechanical brake which slows the rotor to a stop on the 10 kW Jakes.

Dynamic braking is unique to permanent magnet alternators. Dynamic braking works as follows: if you short out the three phases of a permanent magnet alternator, it will overpower the ability of the rotor to spin the alternator (i.e., stall the blades) and the rotor will come to a stop. This can be done from the comfort of your home!

Tower Top Weight refers to everything that goes on the tower: generator, governor, rotor, tail, and turntable assembly. You'll notice that there is wide variation in tower top weights. Based on my experience I side with the "school of heavy metal", manufacturers who believe that beefiness of components is directly related to the longevity of equipment life.

Marine Option indicates whether the unit is suitable for use in a marine climate (within one mile of an ocean

Relative Sizes of Small Wind Turbine Rotors



Adapted from Paul Gipe's book, *Wind Power for Home & Business*

or on an island) or if this option is available for an additional price.

Generator Type describes the electrical generator that is used in the system. Three types are used: permanent magnet alternators, DC generators, or brushless alternators. A little about the pros and cons of each is in order. But first, another digression!

Electrical generating devices work by having a wire (or series of wires) pass through a magnetic field. The movement of the wire through the magnetic field causes a current to flow through the wire. It's the flowing current that we are after for our batteries and grid intertie inverters.

Permanent magnet (PM) alternators use, as the name implies, permanent magnets for the field. PM alternators are lighter in weight than generators that use copper wire-wound fields. Alternators produce three phase "wild" ac current. "Wild ac" means that the frequency is variable with the wind speed. As rotor speed increases, so does the frequency. Wild ac cannot be used by standard 60 cycle appliances, and must be rectified to DC before it can be used in either a battery bank or a utility tie-in synchronous inverter. DC generators simply produce DC current.

Some manufacturers claim that PM alternators are better in wind systems than DC generators, primarily because there is less maintenance involved with an alternator than with a generator. DC generators have brushes, which have to be replaced periodically, maybe every six years or so. PM alternators do not have brushes. From my perspective, replacing brushes twice a decade can hardly be construed as a maintenance problem.

The real advantage of permanent magnets to a manufacturer is that the magnets are cheap. Compared to the cost of the copper wire needed in a wound field, permanent magnets are a bargain! Cheaper material means that a manufacturer can be more competitive in pricing his product.

The advantages to a system owner of PM alternators are two. First, you can take advantage of dynamic braking, described earlier. Second, three phase ac current can be transmitted through wires more efficiently than DC current, meaning that you can keep your wire costs down.

However, PM alternators have a disadvantage compared to generators with a wound field. Because the magnets in a PM alternator are permanent, the amount of magnetism they exude, or their flux density, is fixed at the magnet's maximum amount. The amount of flux density in a wire-wound field magnet, however, is proportional to the amount of current that it draws

and, somewhat, to the amount of voltage present. (I'm going to simplify this greatly, so all you electrical engineers out there, please don't drop your teeth!) In other words, the higher the voltage present in a wire-wound field, the more current the field will draw, and therefore the stronger the magnet will be. However, as the rotor speeds up, the flux density of the field increases accordingly.

The nice thing about this arrangement is that the magnets in a wire-wound field generator put very little magnetic drag on the spinning armature when little wind is blowing. But there's plenty of magnetic drag available when the wind is cranking, and the generator is peaking. The power curve of a DC wire-wound field generator nicely follows the power available in increasing wind speeds (the cube law). That's just the way you want it. PM alternators, on the other hand, always have maximum magnetic drag on the current generating stator. This means that performance is at its peak at really only one spot on the entire power curve. All other points on the power curve are a compromise, especially at the low wind speed end of the curve, the part of the curve where the wind system spends most of its life.

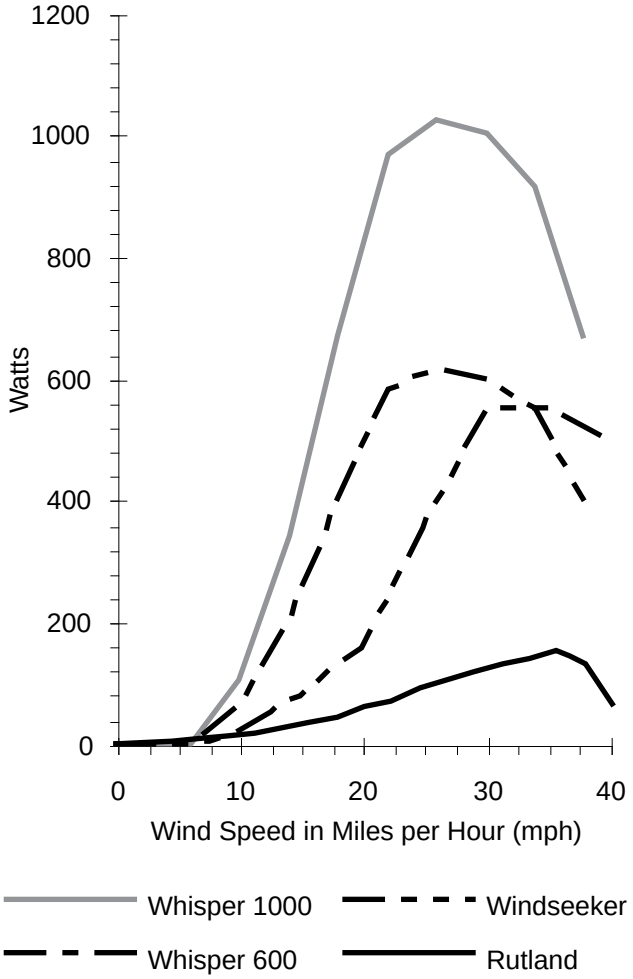
In order to overcome this problem, manufacturers using PM alternators have to design more torque into their blades just to get the rotor spinning in low winds. But remember, torque is inversely related to efficiency. So while PM alternators are simpler (no brushes) and cheaper to build than DC generators, the simplicity comes at a price. To be fair, DC generators come at a price, too. They are more expensive than PM alternators.

Brushless alternators offer the best of both worlds. The fields are wire-wound rather than permanent magnets, but there are no brushes to replace. Their power curve is similar to a DC generator. On the down side, brushless are considerably more complicated, and therefore more expensive to repair or replace than either DC generators or PM alternators.

Tower Top Cost is the cost of the complete wind generating device. In most cases, it does not include the cost of any controls, except where noted in "special notes." Different end uses require different types of controllers, and some end uses don't require any controller.

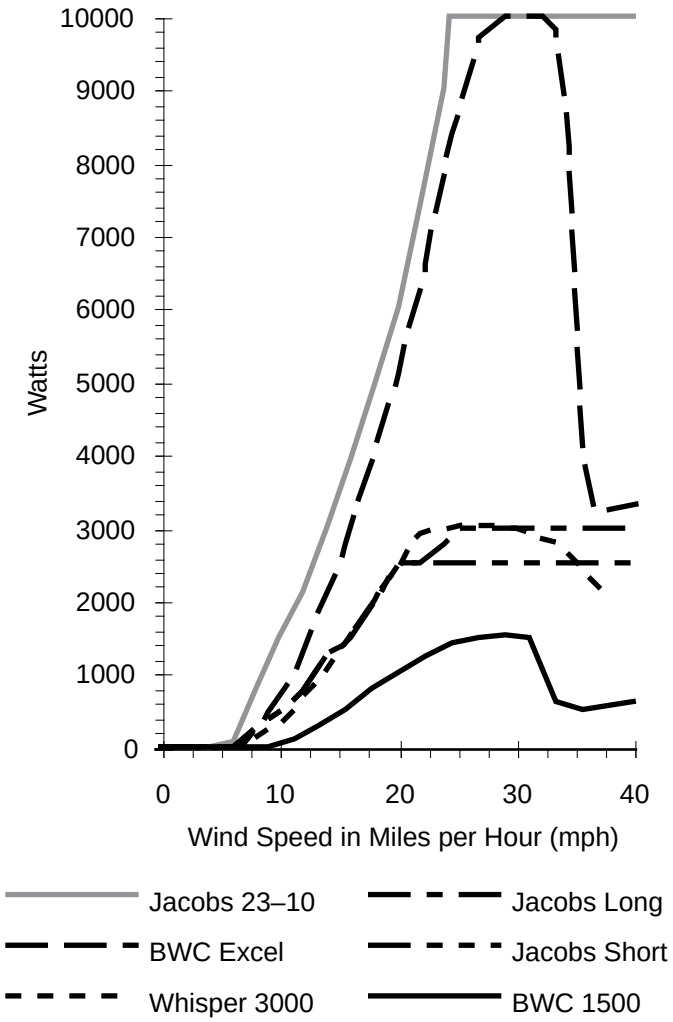
$/Watt refers to the tower top cost divided by the rated output in watts. This figure is included so that you can make direct comparisons with the cost of PV panels.

Available Systems refers to the wind generator's end use. Different end uses will utilize different control systems, which are not interchangeable. Battery Systems is self explanatory. The voltages available for the battery systems are listed. Utility intertie refers to using the utility grid as your storage. Resistance Heating means that the wind system is used for space heating. These controls are the simplest and least expensive end use option. Water Pumping means that a control package is available to pump water with an electrical pump run off the wind generator directly. No batteries! This category designates whether an ac or DC pump is used. Because of the wide variety of controllers available, prices have not been included. Contact the manufacturer with specific needs and for price quotes.



Above: Power curves for small wind generators.

Estimated Monthly Output at Sites with Average Wind Speeds of 10 mph and 12 mph is included so that you have some idea what a wind system will produce at your site. For comparisons, a very efficient home or small cabin would use 75 to 200 kiloWatt-hours (kWh) per month. The "average home in the U.S." (whatever that is) uses 600 kWh/month. An all-electric home would consume 1200–2000 kWh/month, as might a small business or farm. These are manufacturers'



Above: Power curves for large wind generators.

numbers, not mine. Be aware that "your mileage may vary"! The number in parenthesis is the calculated capacity factor for the system based on estimated monthly output.

Capacity factor refers to the amount of kilowatts that the generator produces over a given period of time compared to its potential if it were running at full output all of the time. Note that different systems boast different capacity factors. Capacity factor for wind generators is a function of the swept area of the rotor and the rated wind speed of the system. Generally, the larger the swept area and/or the lower the rated wind speed, the greater the capacity factor.

Warranty All the manufacturers warrant their products for parts and labor (that is, in house repairs) against defects in materials or workmanship. This means that you must return the defective part to the factory for evaluation and repair or replacement at the discretion of the factory. Standard practice is that you will pay shipping both ways, just as with any other consumer good. Warranties do not cover improper installation, neglect, use of unauthorized components, abuse or "acts of God" (this is why you have homeowners' insurance). Manufacturer liability is for the defective part only, and does not include incidental or consequential damages.

Time in Business is included so that you can see that these manufacturers are not fly-by-nighters. All of these folks have established businesses and have done extensive business in, as well as outside of, the U.S. Footnote: Whisper wind generators have been available for only four years. Prior to that, the company was known as Whirlwind and manufactured a different line of wind systems.

Routine Maintenance refers to what needs to be done to the wind generator to keep it in prime operating condition for a long life. How long? That's hard to say. I recently took down a Jacobs that had seen 60 years of nearly continuous duty. Properly cared for, any one of these systems could match that.

This doesn't mean that you will never have to replace parts or do some major repairs. Blades will need repainting and probably a new leading edge eventually. Bearings wear out and need replacing. Some systems, as noted, need annual greasing or oil changes. Bolts might loosen and need tightening. Adjustments might be needed here or there. It is unrealistic to expect something as complex as a wind generator operating continuously in the harsh environment that it lives in to work flawlessly with no maintenance. If that's your belief, then don't buy a wind generator.

Some manufacturers recommend only a visual inspection as their maintenance. Bergey Windpower Company, for example, suggests that after you install one of their units, once a year you need to go out to the base of the tower and look up to see if it is still running. That's it for another year! There is no question that Bergey builds the most maintenance-free wind generators available in the industry. However, I am a little more conservative than they are. Many of the catastrophic failures that I have seen over the years with various systems were due to something as seemingly inconsequential as a bolt loosening. I believe that the prudent wind generator owner should thoroughly inspect his/her system twice a year at a minimum; once on a nice fall day before winter hits and again on a warm spring day before thunderstorm season. As they say, prevention is the best cure! Preventative maintenance becomes more important as your investment in the system increases.

Most of the great strides in reduced maintenance have come not from new designs, but from new materials. The designs for today's wind generators have been

around for a long time. For example, the side-facing governing mechanism was patented in 1898 and used on waterpumpers. The tilt-up style of governing was patented in 1931. The blade-activated governor was patented in 1951, however, such things as graphite impregnated nylon used in some bushings or the aliphatic resin tapes that are used for leading edge protection were just being developed ten years ago. Continuous upgrading by incorporating modern materials in wind system components has helped greatly in the maintenance arena. The manufacturer who cuts corners by using cheap materials is the one who is courting trouble with his customers.

Power Curves

The power curves for the wind systems reviewed here have been put together so you can easily compare one system to another. The curves compare the power output of the various systems as a function of wind speed. Be aware that this is an "apples and oranges" comparison. To use the PV analogy, it is better to compare all panels of a given wattage than to put all panels made on the same chart. The problem with wind generators is that there are not that many models available to choose from. Because some equipment outputs are close, some reasonable comparisons can be made.

Noise

Questions often arise about how much noise a particular wind generator makes. For the most part, a well designed wind generator is relatively quiet. By the time the wind generator is cranking enough to cause some noise, trees are rustling and buildings are rattling as well.

Wind generator noise can come from two sources: mechanical noise and blade noise. Mechanical noise would emanate from something such as a gearbox. Most of the systems reviewed are direct drive, meaning the blade is coupled directly to the generating device. Only the 10 kW Jacobs utilizes a gearbox.

Blade noises can be caused by two things: rpm and/or the airfoil. Rpm should be obvious. The faster something spins, the more noise it is likely to make. The shape of the airfoil can also have an effect of the amount of noise the blades make. As a rule, true airfoils are quieter than single-surface airfoils.

Installation

The installation of a wind generator on a tower can be accomplished with either a gin pole or a crane. A gin pole is like a boom that is mounted on top of your tower. Using cables and rigging, either the entire wind generator or its component parts are hoisted to the top of the tower, where they are installed. This is relatively easy to do with the smaller systems. However, only an experienced crew should attempt this with something as large as a 10 kW system. These wind generators are probably better installed with the help of a crane.

An alternative is to install a tilt-up tower. Tilt-up towers tilt down to ground level, where the wind generator can be easily installed and serviced. Tilt-up towers are generally more expensive than either freestanding or guyed towers.

My Choice?

"So, Mick, what do you recommend?" is the most frequently asked question that I get. The answer: it all depends on your situation.

I can honestly say that, properly specified and installed, any one of these machines will do a fine job of producing electricity for many years. They all have their own personalities and idiosyncrasies, just like the cars we drive. And, just like the cars we drive, they come in a variety of shapes and prices. Finally, just like the cars we choose, they will all get us from point A to point B. However, not all cars, nor all wind generators, are created equal. Quality comes at a price.

I hope you now have all of the tools you need to make an educated choice. But make sure that you digest the facts and figures, as well as your needs and pocketbook, so that you may choose well.

Access

Author: Mick Sagrillo ruminates on wind generators at Lake Michigan Wind & Sun, E3971 Bluebird Rd., Forestville, WI 54213 • 414-837-2267

Wind Generator Manufacturers

The manufacturers can be contacted for prices or more information. Or you can contact your favorite wind generator dealer.

Bergey Windpower Co., 2001 Priestly Ave., Norman, OK 73069 • 405-364-4212 • FAX 405-364-2078 Manufactures the BWC 1500 and the BWC Excel.

Lake Michigan Wind & Sun, E3971 Bluebird Rd., Forestville, WI 54213 • 414-837-2267 • FAX 414-837-7523 Remanufactures the Jacobs "short case" and Jacobs "long case."

Trillium Windmills, Inc., R.R. #2, Orillia, Ontario, L3V 6H2, Canada • 705-326-6513 • FAX 705-325-9104 North American distributor for the Rutland Windchargers (which are manufactured by Marlec Engineering Co., Ltd. of England)

Southwest Windpower, 1855 Kaibab Lane #5, Flagstaff, AZ 86001 • 602-779-9463 • FAX 602-779-1485 Manufactures the Windseeker

Wind Turbine Industries, Corp., 16801 Industrial Circle SE, Prior Lake, MN 55372 • 612-447-6064 • FAX 612-447-6050 Manufactures the Jacobs 23-10

World Power Technologies, 19 Lake Ave. N, Duluth, MN 55802 • 218-722-1492 • FAX 218-722-0791 Manufactures the Whisper 600, Whisper 1000, and Whisper 3000

Halogen Revolt

Homebrew

William Raynes

For many of us who use alternative energy, the cost of low voltage lighting is a major issue. Because these products aren't mass produced, we are forced to pay the high prices the RV and marine customers have had to contend with for years. Fortunately, some ac powered halogen and fluorescent lights can be adapted to 12 Volt use, for less money than new 12 Volt lights.

If you use an inverter to run your house, your least expensive choice for efficient lighting is probably ac compact fluorescents (see Home Power #16, #20, and #30). Whereas a 13 Watt 12 Volt Osram compact fluorescent can set you back $50–$60, you can get a 120 vac fluorescent through a utility rebate program for under $20. I know of a man who gets these same quad Osram 120 volt units in Boston for $3 a piece. Talk about mark-up!

Re-volting Halogens

For those of us who use 12 Volt lighting, there is another alternative, at least in the halogen lamp market. Most of today's halogen lamps use a 12 Volt bulb and a 120 volt to 12 Volt transformer. Most of the units I have found are easily spotted by reading the box, where it will clearly point out the use of a 12 Volt bulb. If the box doesn't specify a 12 Volt bulb, a peek at the panel on the base of the display unit will tell you the output of the lamp. Many of these units, on sale, can be had for under $20. I found the one featured here for $14. When you consider the price of a 12 Volt halogen gooseneck copilot light at $30, without any base, you can easily see the savings.

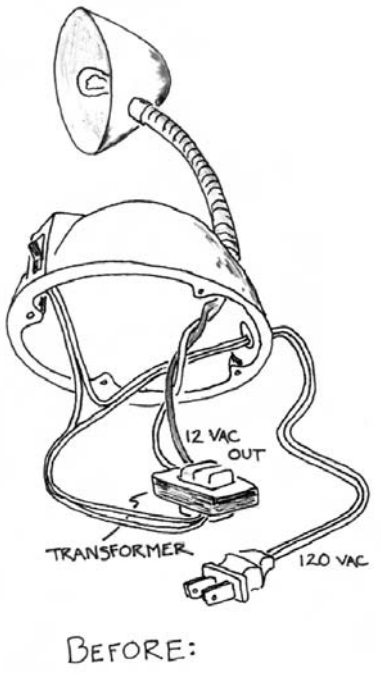
Remove the Guts

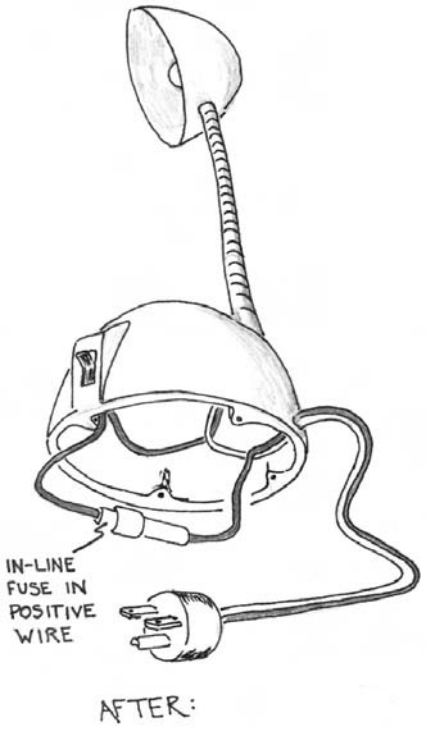
The procedure to convert the lamp to direct 12 Volt operation is really quite simple, the only tools you need are a screwdriver, a wire cutter, and a stripper tool. You'll need a new plug to plug into your 12 Volt receptacles. Many people use automotive cigarette lighter plugs. I like to use three prong 240 vac plugs that can never be plugged in backwards or mistaken for 120 vac plugs. You'll also need an inline fuse holder and a fuse. The amperage draw of the bulb is the wattage divided by 12 Volts. Choose a slow-blow fuse with an amperage slightly higher than the bulb's draw. This is usually less than five amperes.

First, remove the base of the lamp. Inside you will find a large heavy transformer — that's the part you don't need. You will notice that the incoming wire from the plug enters the transformer on one side and exits it on the other. Simply cut the incoming wires from the new plug and the out-going wires from the transformer and put the transformer aside for now.

Rewiring

Strip the ends of all the wires still in the lamp. Connect the wire that goes out from the switch to one of the wires that goes to the bulb. Now take the wire that goes into the switch, and one of the wires coming from the new plug, and connect the fuse and fuse holder between the two wires. The fuse protects the switch, which is meant for ac use and is not usually rated for DC. Even though our house is protected by DC rated circuit breakers, I like the extra insurance of the second fuse. This line is now the positive lead, and should be





attached to the positive side of your new 12 Volt plug. The other incoming line is connected to the second lead that goes to the bulb. This is the negative line and should be attached to the corresponding side of the new plug.

Finishing Touches

All lamps are different, but most use the weight of the transformer as a kind of ballast to hold the lamp upright. If the unit is stable without this extra weight you can just leave it out and replace the bottom and you are done. If, on the other hand, you find you need the extra weight you have a few other options. I find some of the transformers useful in other projects so I like to replace them with a chunk of lead, although a heavy object of appropriate size and weight can be substituted. If you don't have another use for the transformer, you can simply replace it in the unit and there you have it — a 12 Volt halogen lamp at less than half the cost of one from a catalog.

Options

You may feel it necessary to replace the switch on one of these conversions with an appropriate DC rated switch. This may be appropriate, but I have not had a problem with any I have done so far, although that may just be luck. Many styles of low voltage switches are on the market and any auto parts store or Radio Shack type store will have many to choose from.

I hope this article will inspire everyone living off the grid to take another look at what can be adapted around you, and ease the squeeze on your wallets.

Access

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Gettin' Into Wood-heated Water

Bill Battagin

Hot water — most of our minds can conjure up a variety of images. We've all been in it in one way, shape, or form. But today, let's look at water heated by a woodstove for residential use. The thermosiphon system discussed here uses no controls, sensors, switches, or pumps. Safety, simplicity, and function are the primary elements in this system's design.

Principles

Life is full of 'em! In this case we're discussing thermosiphoning. We find forms of thermosiphoning all around us. From boiling our tea water to the thermals we ride in our daily hang-glider flight, rising and falling currents "drive" convection cycles.

In a wood-fired hot water system with no fire in the woodstove, there are no forces to drive the water in the coil, tank, and connecting pipe. Though the system *is* under pressure, the pressure supplied by the domestic water supply to the tank is exerted equally throughout the system.

Add some excitement to your life. On a molecular level this means heat. If you heat molecules of a gas or liquid, they become excited and thus move faster. In this excited state these molecules require more space — the volume of gas or liquid expands and becomes less dense. The heated gas or liquid is lighter and rises within the total volume. Those hot excited little buggers rise above their surrounding cooler, more dense cousins. We're movin' now!

With boiling tea water, the water in the center of your teapot rises to the top; cooler water on the sides sinks to replace it. We hang glide in thermals generated by hot air lifting off solar heated areas on the ground. Water heated in the coil in your stove becomes less dense and lighter; it rises to your hot water storage tank, which is elevated with respect to the coil. The cooler water in the tank is relatively heavier and thus sinks back to the coil to replace the heated water. As long as you supply heat to the coil, the water will rise (convect) to the tank. You are a thermosiphoning dude!

Not just any stove...

Most stoves can have a hot water coil installed in them. Generally though, the warranty on a new stove will be voided. The new "EPA-approved" stoves present a variety of challenges to the installation of a coil. Woodstoves are no longer cast iron or steel boxes with little thought devoted to combustion and heat transfer efficiency. Today's controlled combustion woodstoves now employ new high temperature secondary and tertiary burn processes and/or catalytic combustion.

If you're in the market for a new stove, beware of the woodstove that costs less than about $700 and is listed as an "EPA-exempt" woodstove. These stoves use older technology, are inefficient (produce less heat for the same amount of wood), are not airtight, and are guaranteed to last a lifetime (of a mosquito). They are exempt from the EPA emissions regulations because they are not airtight. So much air is allowed into the firebox that the fire will burn relatively clean. Because of these lower emissions, the EPA does not require certification of these stoves.

In my opinion, installing a coil in the new EPA-approved "High Temp" non-catalytic woodstoves can jeopardize the somewhat critical thermal environment found in these stoves. Combustion efficiencies can be dramatically reduced when you place a perpetual "ice cube" in what is designed to be a highly infrared-reflective, high temperature firebox. Lower combustion efficiencies mean more emissions, especially at lower burn rates. Stoves using high temperature combustion techniques may have smaller fireboxes, thus less space available for a coil.

On the other hand, a catalytic stove makes a fine home for a hot water coil. Catalytic stoves are much less affected by the cooling effect of the coil. The efficiency of a catalytic stove is highest during a slow rate of combustion. During normal operating temperatures, a decrease in wood smoke temperature entering the combustor will have little effect on its combustion efficiency.

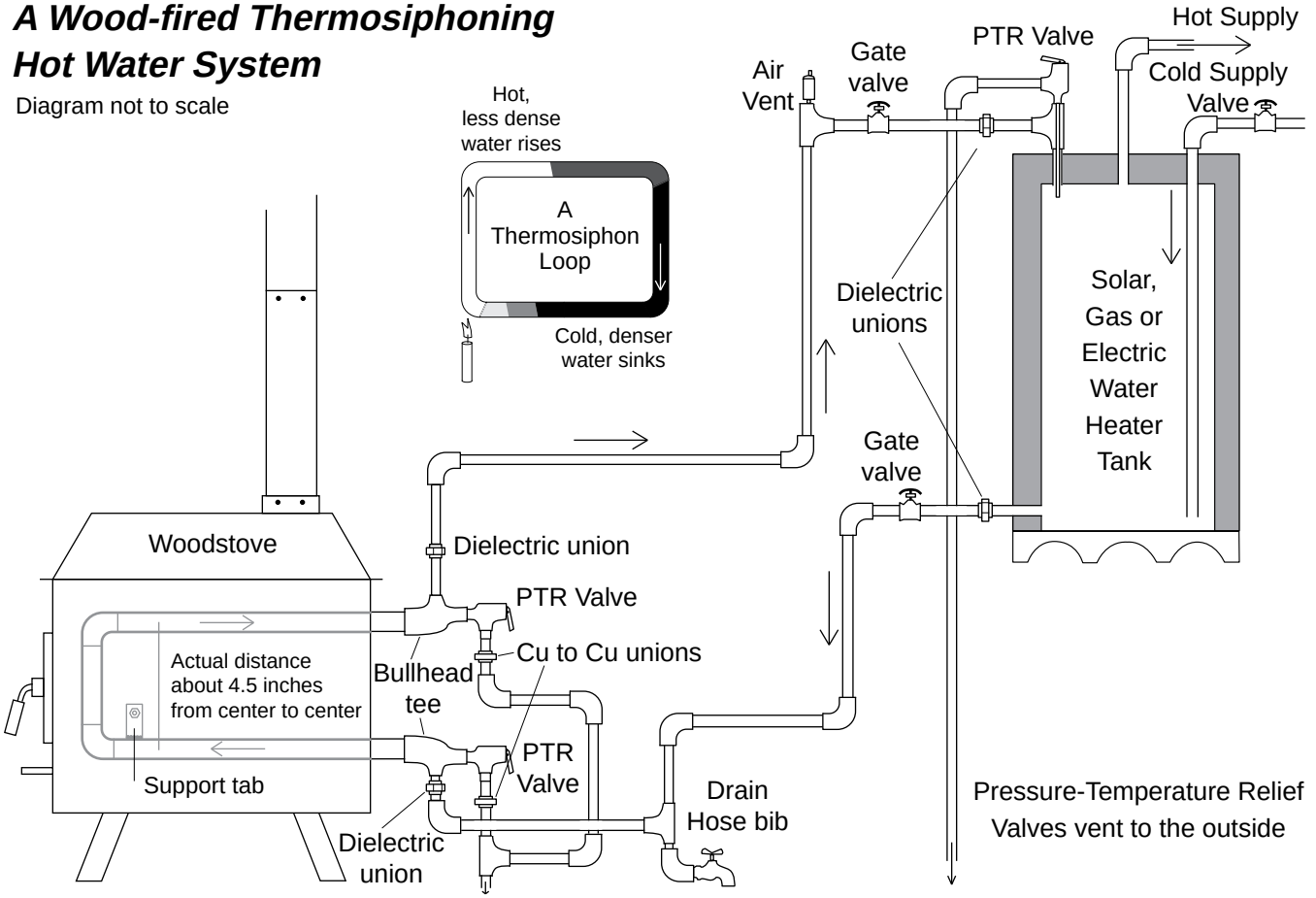
Stoves more than approximately seven years old are all pretty much in the same design boat — not High Temp nor catalytic. The efficiencies of these stoves will be little affected by the addition of a coil, so go ahead and attack these stoves with your coil installation.

The Coil

An important consideration for the hot water coil is the material. Use either Schedule 80 steel galvanized pipe (home grown) or stainless steel tubing, pipe, or tank-type premanufactured units. If you use Schedule 80

A Wood-fired Thermosiphoning Hot Water System

Diagram not to scale



steel galvanized pipe, I recommend 1¼ inch or 1½ inch diameter, rather than ¾ inch pipe. These larger diameters allow enough surface area in your coil to be able to install a simple "U" (two lengths of pipe) instead of a "W" (four lengths of smaller diameter pipe) in your stove. Copper pipe and copper tubing are not good choices for woodstove coils. Too many variables exist to address the coil size issue here. Ask your local plumber who is experienced with these systems or the author so all the variables can be discussed.

If possible, remove firebrick or interior side heat shields and install the coil in its place to save firebox space. You will have to be the judge of the costs and benefits of sacrificing firebox space to generating hot water. The coil will act to protect the side of the stove where the firebrick or heat shield used to live.

Position the coil as close as possible to the most heat. This means about 4 inches off the bottom of the stove, either along one side or the back of the firebox.

The hot water coil you install in your woodstove should have pressure-temperature relief valves (PTR valve) connected to it immediately after the coil penetrates the wall of your stove. If not, then your coil can be referred to as a bomb. A safe installation will have a PTR valve inserted in the inlet *and* outlet of your coil within a foot of the stove (see illustration). In any water heating system, whether electric, gas, oil, nuclear, solar, or wood fired, this type of valve is installed to prevent explosion in the event of malfunction. Malfunctions may be caused by: mineral build-up on the inside of your coil to the point of complete blockage, accidental closure of one or both of the gate (isolation) valves while the stove is hot, or loss of water pressure to the cold supply side of your storage tank.

Installing the coil in the firebox means cutting two holes (usually with a hole saw) in the side or back of your stove. Carefully plan the location of these holes to minimize the space lost in your firebox. Cut these holes about ⅛ inch larger in diameter than your pipe size. Be sure the center-to-center distance between these holes is the same as that of your coil. Fill the gap between the coil and the hole with furnace cement.

In most cases, an extra support should be added to the part of coil furthest from the exit holes. Use a muffler clamp around the coil to hold it against the stove wall. Or weld a tab of steel to the coil so a bolt can be passed through this tab and the wall of your stove.

Plumbing

Refer to the illustration for some help here. Your coil, either galvanized or stainless steel, should be plumbed to the hot water storage tank with copper pipe. Copper, though not safe material for your coil, is preferred to connect the coil from the stove to the tank. Copper pipe has less resistance to the flow of water. Sometimes the lower resistance allows you to downsize your pipe diameter. When the storage tank is within 15 feet horizontally and at least 2½ feet above the elevation of the coil, ½ inch copper pipe can be used to connect the tank to the coil. Use ¾ inch copper pipe for tanks that are more than 15 horizontal feet away, or less than 2½ feet above the coil.

Go with the Flow

So, let's be a molecule of water just heated in the coil and head off to the tank, visiting components en route. The first thing we see is the PTR valve. This valve's exhaust port is plumbed to a visible location outside. The inside of your house is a lousy place for wild steam and scalding water. You may need to use a reducer to connect the coil to the plumbing. In my systems I use a "bullhead" tee to make this size change and offer a connection for the PTR valve. Next fitting is a dielectric connector. At this steel/copper connection, use a dielectric union to prevent electrolysis between these two dissimilar metals. This will also act as a place to disconnect your plumbing in the future for changes/maintenance.

Now we are in the land of copper and float off through pipe and elbows to the storage tank. As we near the tank, we say hi to an air vent, pass through a gate (isolation) valve, and do a dielectric back to galvanized pipe, before diving into the tank. The gate valve offers a way to isolate the tank from the coil to perform maintenance or repairs. This valve should never be closed while the stove is hot. This would stop the flow of water in the coil, allowing it to get too hot and activate the PTR valve.

Most storage tanks used are the existing hot water heaters, so the pipe will have to connect to the top of the tank. This means our pipe will have to go slightly above the tank and then drop down into the tank. We must now discuss air pockets. Places in your plumbing where air could rise and become trapped should be avoided at all costs. If this happens, the flow of water will stop in your system and the water will come to a boil, activating the PTR valve. Out goes wasted hot water. So as you plumb your system, be sure "horizontal" runs of pipe have at least ¼ inch of rise per foot of run. Install an air vent when a high spot is unavoidable. An air vent will allow air to escape, maintaining water saturation throughout the system.

The flow goes on. Let's ignore the tank for a minute, and head back to the coil. As we leave the tank we pass through a dielectric, then another gate (isolation) valve and we're off, falling back to the coil. As before, we need to be aware of high spots and potential air pockets. As we approach the coil, a dip in the pipe of at least 5 inches will prevent the water from reverse thermosiphoning when a new fire is started. This dip precludes the need for a check valve. The last components in our system are a drain hose bib, dielectric connector, bullhead tee ala PTR valve and we're back in the coil. Again, the exhaust port of this PTR valve is connected to the output of the PTR valve above it, and is vented to the outside.

Storage Tanks

Many different types of tanks can be used; the most typical is the basic residential hot water heater tank already used in most homes. Whatever you use, figure on 30–40 gallons for 1–2 people, 40 gallons for 2–3 people, and 50 gallons for 3–6 people. Your tank should be insulated to at least R-15 — the more the merrier. Remember to also insulate the pipes that connect your coil to the tank. Heat loss in transporting hot water becomes significant the more pipe you use. My recommendation is to use any of the closed-cell foam type pipe insulation with a wall thickness of at least ¾ inch.

I mentioned raising the tank above the coil in the stove. There is no concrete law regarding tank elevation with respect to the coil. If the tank and coil are separated horizontally by five feet or less, there need not be any height difference between the coil and the *bottom* of the tank. For every additional foot of horizontal separation, I recommend adding two inches to the vertical difference.

If you do not have gas or electric back-up for your wood-heated water and need to purchase a tank, a conventional water heater works well. You can often buy these on sale for less than $175. New water heaters do not leak and are already insulated. If you are willing to gamble, a recycled, but not leaky, water heater tank can be used. These are usually free but run the risk of early replacement.

If you need to build a stand for your tank be sure it's strong. A 50 gallon tank full of water weighs about 450 pounds. A strap to secure the tank to the wall is appropriate in some installations.

Materials

Most components in this system are readily accessible from a well-supplied hardware/building supply store. You may have to get some parts from a plumbing supplier.

Buy high quality gate valves and dielectric connectors. Cheap valves and dielectrics are not worth the

headaches they will cause later (and they will). Also PTR valves must be rated 100,000 BTUs or higher, and release at 150 psi or 210°F.

My preference on the air vent is Watts model no. FV4, though other air vents are fine. You will need to purchase a ¼ inch x ¾ inch brass bushing to install this (and most) air vent(s). Start looking early for your bullhead tees from your plumbing supplier. They may not have these in stock and will have to order them. If these are difficult to find, use bushings or bell reducers after the tee for the PTR valve.

Pressure Test and Light 'er Off

With all your plumbing connected, joints soldered, dielectrics tight and hose bib closed, open your cold supply valve to the tank. Check for leaks, then open both the gate valves and check for leaks again. Are we happy? Good, put the heat to your coil with a fire in your stove. Within 5–10 minutes you should be able to feel a temperature difference of 20–50°F between the two pipes coming out of your stove. Within another 2 hours you should be able to get into some hot water....

Access

Bill Battagin, Feather River Stove Works, 5575 Genesee Rd., Taylorsville, CA 95983 • 916-284-7849 Questions? If you write, please send a SASE, or call between 6–7 AM or 8–9:30 PM.

Understanding Fuel Cells

David Booth

Fuel cells are likely to replace internal combustion engines in the next century. Internal combustion (IC) engines and fuel cells are both energy converters which transform chemical energy into a more usable form of energy. Fuel cells are electrochemical devices which efficiently convert chemical energy into DC electricity and some heat (thermal energy). IC engines transform chemical energy into mechanical energy and a substantial amount of heat.

Energy Converters

Coupling a fuel cell to an electric motor produces mechanical energy. Similarly, an IC engine produces electrical energy if we couple it to an alternator or dynamo. Fuel cells offer an incredible efficiency advantage over IC engines, especially gasoline engines in stop-and-go service. Atmospheric pollution could be greatly reduced with the use of fuel cells. These clear advantages may ultimately cause the bell to toll for the internal, infernal combustion engine.

All Fuel Cells are not the Same

Typically, fuel cells are categorized according to the kind of electrolyte which is utilized within these devices. The electrolyte may consist of a liquid solution or a solid membrane material. In any case the electrolyte serves the vital function of ionic transfer of electrical charge. Some of the technologies are relatively advanced while others are still in their infancy. There are basically five fuel cell versions:

- Phosphoric acid fuel cells (PAFC)
- Alkaline fuel cells (AFC)
- Molten carbonate fuel cells (MCFC)
- Solid oxide fuel cells (SOFC)
- Proton exchange membrane fuel cells (PEMFC)

The proton exchange membrane fuel cell is a promising candidate for stand-alone home power generation.

PAFCs: The Most Mature Approach

Phosphoric acid fuel cells (PAFCs) probably represent the most mature fuel cell technology. Westinghouse, International Fuel Cells, and at least a trio of Japanese manufacturers have been refining the design of mid-sized PAFC cogeneration plants. They are intended to fill the niche for stand-alone power generation for utility substations, factories, restaurants, hotels, and hospitals.

The fuel choice for PAFCs is not restricted to pure hydrogen. Typically, these near-term plants will use natural gas, methanol, or light distillates derived from fossil fuel sources. These cells operate at moderate temperatures (less than 200°C) with auxiliary reformers. Reformers convert the hydrocarbons to a mixture of hydrogen and carbon dioxide gases for the cells. The requirement for the initial reformation step sacrifices some efficiency, but the advantage of PAFCs is that they are tolerant of CO_2 and other reformate impurities. The overall efficiency improves above the 40–50% range if the installations are used as cogeneration plants, and the waste heat is used to make hot water and/or steam.

AFCs: Extraterrestrial & Terrestrial Applications

Another fuel cell technology which has been with us since the 1960s is the *alkaline fuel cell* (AFC) system. AFCs were first developed for spaceflight applications as part of the Gemini program to produce reliable on-board power and fresh water for the astronauts. International Fuel Cells and Siemens are currently major players in this field.

AFCs operate at relatively low temperatures, and don't require noble metal catalysts, strong advantages in their favor. Highly purified hydrogen, such as electrolytic hydrogen, is required as the fuel source. Unfortunately, AFCs also require pure oxygen as the oxidant, not air. AFCs are intolerant of even meager amounts of CO_2 which effectively poisons them. If air is to be used as the oxidant, expensive CO_2 scrubbers would have to be used to prevent a degradation of AFC performance.

The use of AFCs in transportation applications is doubtful; it is generally assumed that oxygen will not be stored on-board light vehicles. In home systems with solar hydrogen production, oxygen will also be produced in most cases, so this may not be a problem.

MCFCs: The New Hot Shots on the Block

Little will be said here about *molten-carbonate fuel cells* (MCFCs) and *solid-oxide fuel cells* (SOFCs). These second generation fuel cell strategies require

very high temperatures for operation, (600–1200°C). This allows for the internal reformation of fuels such as natural gas, methanol, petroleum, and coal. These devices tolerate CO_2 without requiring any further treatment and are possible substitutes for large to mid-sized thermal power plants, substations, or as cogenerators for factories. MCFCs and SOFCs are less likely to be utilized for remote home power generation by you or me, even in the distant future.

PEMFCs: Promise for Home Power Generation

One remaining fuel cell design approach has been saved for last. It is the solid polymer fuel cell, perhaps more commonly referred to as the *proton exchange membrane fuel cell* (PEMFC). This technology deserves the most careful scrutiny by advocates of decentralized renewable energy and alternative transportation.

Proton exchange membrane fuel cells (PEMFCs) appear to be the "new kids on the block". In reality they represent a technology that was virtually "forgotten" for about a decade. This was an area of fuel cell research that languished in relative obscurity, and which received minimal R&D funding until only recently.

General Electric pioneered the early work. The interest really revived in the last few years when Ballard Power Systems of Vancouver B.C., Canada went public with their results. Other private organizations which have gotten into the act in recent years include: H-Power, Ergenics, Energy Partners, Lynntech, Siemens, and Billings (International Academy of Science). United States educational and public institutions which have on-going laboratory research in this field include the Schatz Fuel Cell Project at California State University at Humboldt, the Center for Electrochemical and Hydrogen Research at Texas A&M, and Los Alamos National Laboratory. New players are entering and exiting this field so frequently that this lineup may already be out of date.

Elegant Simplicity

One can hardly examine PEMFCs without being impressed with their elegantly simple design concept. Yet, closer study reveals their complexities and potential pitfalls in operation. Although PEMFCs are currently available commercially from a few vendors on special order, don't rush for your checkbooks unless you have deep pockets and a strong heart. PEMFCs are currently in the prototype development stage, although laboratory research continues as well.

So most of us must exercise a little patience for the vast promise of these devices to be fulfilled. Unless, that is, you're an impatient do-it-yourselfer, and choose to follow in the footsteps of others like Walt Pyle, Reynaldo Cortez, Alan Spivak, and Jim Healy who have built an operational single cell PEMFC. A detailed description of their procedures can be found on page 42 of this issue.

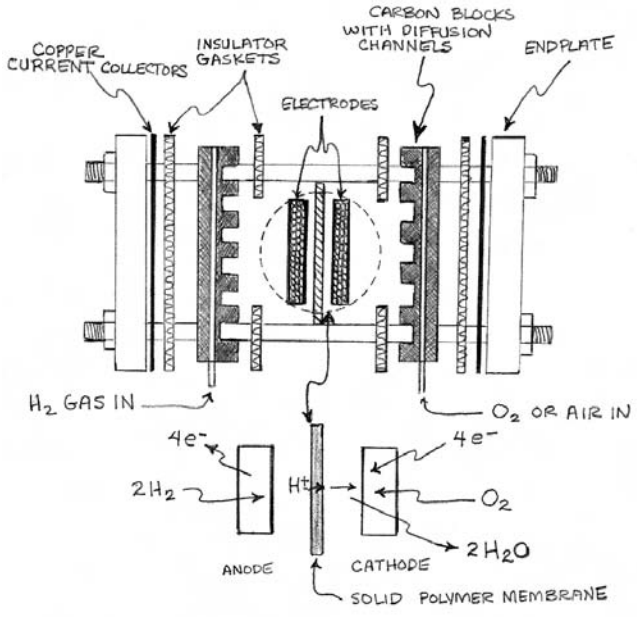
A Look Inside PEMFCs

The similarity between fuel cells and electrolyzers may be apparent from the illustration below. As Rob Wills pointed out in *HP* #23, fuel cells are essentially electrolyzers operating in reverse. Both of these electrochemical cells share certain internal elements along with batteries. They all have negatively charged electrodes, positively charged electrodes, and an electrolyte that conducts charged ions between the electrodes.

Hydrogen is introduced into a PEMFC through a porous conductive electrode, which is frequently composed of graphite (carbon). The porous conductors may consist of special carbon paper. They may be graphite blocks milled with many gas delivery channels. The porous conductors may even be formed by pressing a carbon powder with a binder into a die with sufficient heat and pressure. The particular type of porous conductor construction is determined by the size and complexity of the cell or cell stack.

Gas Separator and Ion Conductor

The solid polymer electrolyte membrane makes the PEMFC unique. Most current prototypes of PEMFCs use either a Nafion membrane from DuPont or one that is simply referred to as the "Dow membrane". Each is a perfluoronated sulfonic acid polymer, but the Dow membrane is said to have more sulfonate side chains. There are even other versions by Asahi Chemical and



EXPANDED SCHEMATIC VIEW OF SINGLE CELL SOLID POLYMER ELECTROLYTE FUEL CELL

Chloride Engineers, Inc. The simple beauty of this design is that the membrane acts both as a conductor of hydrogen protons, and as a separator to keep the reacting gases from mixing and combusting. This feature allows for compact, lightweight cells, because the membranes themselves are very thin (0.007–0.015 inches).

A sheet of Nafion 117 doesn't look much different than a thick sheet of polyethylene or Saran Wrap. Onto this Nafion substrate is deposited a dispersed coating of platinum, a noble metal catalyst. This facilitates the chemical reactions, so they proceed at lower temperatures. Approaches which have been used with success for depositing the platinum include: thin film vacuum processes, brushing or precipitating a dilute solution of chloroplatinic acid, and hot pressing powders (carbon, platinum, and teflon). Significant reductions in the amount of expensive platinum have apparently been achieved, from 20 mg/cm^2 to 0.4 mg/cm^2, without sacrificing performance.

Seen from a Molecules Point-of-View

Okay, now we're ready to travel the inner journey traversed by individual hydrogen and oxygen molecules on the path to their new union (see figure). If we introduce pure hydrogen through the porous conductive hydrogen electrode, it arrives as a diatomic gas, H_2. Each molecule is dissociated into two hydrogen atoms and stripped of two electrons as it interacts with the catalytic surface of the membrane. Devoid of their electrons they exist as two H^+, hydrogen protons. The membrane itself will not conduct electrons. However, the electrons will flow readily via the conductive hydrogen electrode through the external circuit to the opposite oxygen electrode. Along this path, the current may flow through an external load accomplishing work.

Meanwhile, the protons are moving their way through the solid polymer electrolyte on their way to meet oxygen ions. Simultaneously, diatomic oxygen molecules, O_2, are diffusing through the oxygen electrode where they contact the platinized surface on the opposite side of the membrane. Here we would find that oxygen molecules separate into oxygen atoms which are held momentarily in a "receptive" state on the active platinum. Once electrons coming from the load meet the two protons arriving at this site, they combine with the oxygen atom in a spontaneous union. Voila! This results in the formation of one molecule of water, H_2O.

Only one half as much oxygen is needed in this process as is needed of hydrogen. A chemist might write a synopsis of the entire process as shown below.

The reaction at the hydrogen electrode of a PEMFC:

$$2H_2 \longrightarrow 4H \longrightarrow 4 \text{ electrons} + 4H^+$$

The reaction at the oxygen electrode of a PEMFC:

$$O_2 \longrightarrow 2O$$

then,

$$4 \text{ electrons} + 4H^+ + 2O \longrightarrow 2H_2O$$

The overall reaction within a PEMFC is simply

$$2H_2 + O_2 \longrightarrow 2H_2O.$$

What's the Rub?

Well this works very well in theory, but there is a little more to the story. In actual practice there are some additional complications involved in PEMFC operation. First, the hydrogen which is introduced into the cell must be saturated with H_2O vapor or else the membrane will dry out on the hydrogen side hindering performance markedly. Second, on the opposite side of the membrane a delicate balance must be struck with humidification also. Water is continually forming on the oxygen side which aids hydration of the membrane. But if droplets of water condense on the active surfaces, the reaction rate can slow to a halt as the cell literally drowns in its end product. Some waste heat is also building up simultaneously, even though the process is usually between 55–80% efficient. It is primarily the need for moisture and thermal management of both sides which has plagued a number of the PEMFC designs. Leakage of gases around gaskets or O-rings is another difficulty. As series cell stacks are built up of adjacent cells in a bipolar configuration to produce useful output voltages, these problems may magnify several fold.

So What is the Prognosis?

There is every reason to believe that the operational difficulties encountered in PEMFCs will be solved in the near future. The progress needed to make these fuel cells viable should not require any major "technological breakthroughs". PEMFCs hold great promise for automotive and other transportation applications, because they should prove to be both light and compact as well as extremely efficient compared to internal combustion engines.

When transportation energy analysts compare various drive train systems for future automobile designs, they frequently speak of criteria such as energy density and power density. Energy density is commonly expressed in units such as kWhr/kg, whereas power density pertains to the ability of a system to deliver performance quickly, and is expressed as kW/kg. Since fuel cells themselves do not produce torque, they would need to be coupled with highly efficient electrical motors. The coupling of hydrogen stored on-board an automobile as a liquid, hydride, or compressed gas with PEMFCs would seem to have superior energy density as an integral system than any battery electric vehicle

configuration on the horizon. However, in order for these fuel cell vehicles to come close to matching the power of today's internal combustion engine vehicles, perhaps the best configuration would be a hybrid one. These hybrids would likely use a "base load" fuel cell for cruising with a quick discharging battery for the higher instantaneous demands of acceleration. This is exactly the conclusion arrived at by three independent research analysts, and published in two scientific papers which have recently been published (see references).

The Pregnant Promise of Fuel Cells

We can only hope that fuel cell research coupled with engineering refinements continues at an accelerated pace. The inefficiency of the internal combustion engine cannot be tolerated much longer. Atmospheric pollution, global warming resulting from greenhouse gas emissions, and the steadily declining reserves of petroleum are all part of the legacy left us by dependence on fossil fueled IC engines. Many scientists and energy analysts believe that a solar based hydrogen energy system is the answer to these problems. The timely maturity of hydrogen fuel cell technologies will be of critical significance, if the world is going to successfully wean itself from fossil fuels. An appropriate analogy might be made between the development of integrated circuits and fuel cells. The first integrated circuits were a landmark advance that ushered in the electronic and information age. As fuel cells replace IC engines, I believe a Solar Hydrogen Age will blossom from the dust of the passing fossil fuel era.

Access

Author: David Booth, Alternative Energy Engineering • 707-923-4336

Further reading

Hydrogen Fuel-Cell Vehicles, Mark DeLuchi, Institute of Transportation Studies, University of California, Davis, CA 95616

The International Journal of Hydrogen Energy, Permagon Press. Contact P.O. Box 248266, Coral Gables, FL 33124

Hydrogen-Fueled Vehicles Technology Assessment Report for California Energy Commission, Dr. David Swan and Debbi L. Smith, Technology Transition Corporation and Center for Electrochemical Systems and Hydrogen Research, Texas A&M University, 238 Wisenbaker ERC, College Station, TX 77843

Making Electricity with Hydrogen

Walt Pyle, Alan Spivak, Reynaldo Cortez, and Jim Healy

A gas fed battery that never needs recharging! This article describes a process for building a fuel cell using tools and techniques any skilled hobbyist with a well-equipped shop can duplicate. The fuel cell that we built can produce direct current electricity from stored hydrogen and oxygen. We obtained the hydrogen for this fuel cell commercially but plan to produce hydrogen and oxygen from a renewable energy system based on solar photovoltaics and water electrolyzers.

Cookbook Approach to Building a Fuel Cell

In this article we reveal the process we used to make a proton exchange membrane (PEM) fuel cell.

First, we describe what the PEM material is, and where to get it. Then we cover the steps necessary for preparing the membrane to use it in a fuel cell.

Next, we describe the catalyst and binders used on both sides of the PEM and the method of "hot-pressing" them all together to form the single fuel cell catalyst-PEM-catalyst "sandwich".

Finally, the holder for the catalyzed PEM fuel cell with its gas supply piping, insulators, and wiring studs is shown.

Some PEM fuel cell performance data were obtained using an electrical resistor to provide a variable load. Two digital multimeters and a shunt resistor were used to measure the voltage and current, so we could calculate the power produced.

Although the fuel cell described produces a relatively low voltage, several fuel cells of this kind can be wired in series to produce higher voltages and do useful work.

The PEM Material

The PEM (proton exchange membrane) material is a perfluorosulfonic acid polymer film. Several manufacturers make PEMs in one form or another. We used one made by du Pont called Nafion 117. Nafion 117 is a transparent polymer film about 175 microns (0.007 inches) thick. Dow Chemical Co., Asahi Chemical Co., and Chloride Engineers Ltd. make something similar. A patent describing how one PEM manufacturer's film is processed is listed in the references section at the end of this article.

The basic structural unit formula for Nafion 117 is shown below:

$$CF_2 = CFOCF_2CFOCF_2CF_2SO_3H$$
$$\backslash CF_3$$

Nafion 117 contains fluorine, carbon, oxygen, sulfur, and hydrogen arranged in repeating polymer molecules. The hydrogen atom on the SO_3 part of the molecule can detach from one SO_3 site. The free H+ proton can hop from SO_3 site to SO_3 site through the material, to emerge on the other side of the membrane. This is the reason it is called a proton exchange membrane. It can be thought of as solid sulfuric acid, an electrolyte.

The PEM is relatively expensive at this point in time. We paid about $100 for a 30.5 centimeter by 30.5 centimeter (12 inch by 12 inch) piece of Nafion 117 from a chemical supply house. Some manufacturers want your first born child in exchange for a sample. However, du Pont really is in the PEM business, and they will sell it to you with no strings attached from their pilot plant production. The price comes down to about $65 for the same size piece when you buy four times as much PEM direct from du Pont. The piece we bought was large enough to make about six of our round fuel cells ($10–$16/cell).

Punching the PEM Disk from a Sheet of Nafion 117

We set the sheet of Nafion 117 on a piece of clean acrylic plastic using clean cotton gloves to avoid contaminating the sheet with fingerprints. Then we punched out some round PEM disks using a 4.76 centimeter (1⅞ inch) arch punch and a mechanics hammer filled with lead powder. After one or two tries, we found that several strikes with the hammer at different angles was best for cutting the disk free from the sheet. Striking the punch too hard shattered the acrylic sheet.

Above: Punching PEM from sheet with arch punch.
Photo by Reynaldo Cortez

Handle the PEM with tweezers or forceps to prevent contamination. We used a pair of stainless steel tweezers which were ground flat and polished on the grasping faces to eliminate burrs and prevent puncturing or denting the soft PEM. Grasp the PEM disks only on the outer peripheral edge, never on the inner active area.

Preparing the PEM for Catalyst Application

We prepared the film for catalyst application by dipping it in six different heated solutions in glass beakers. The solutions were all held at 80°C (176°F) by immersing the beakers in a heated pan of water on top of two gas stove burners as shown above right.

Each beaker held the PEM film for one hour in sequence. Use safety glasses and gloves while working with the solutions. The sequence of beakers used to dip the PEM was set up as follows:

Beaker 1 = 100 milliliters of distilled water [hydrate the membrane and dissolve surface contaminants].

Beaker 2 = 100 milliliters of 3% hydrogen peroxide solution (USP) [remove organic contaminants from PEM surface].

Beaker 3 = 100 milliliters of sulfuric acid (new battery electrolyte) [remove metal ion contaminants from PEM surface, and sulfonate the PEM surface].

Above: Solutions in beakers on top of stove.
Photo by Reynaldo Cortez

Beaker 4 = 100 milliliters distilled water [rinse sulfuric acid from surface and hydrate PEM].

Beaker 5 = 100 milliliters distilled water [repeat rinse].

Beaker 6 = 100 milliliters distilled water [repeat rinse].

While the PEM disk is in a beaker, there may be a tendency for the film to curl and lift on the steam bubbles, rising to the surface. It should be kept submerged so the top side doesn't get exposed to air. Use a clean inert polyethylene plastic or glass probe to keep it down in the dipping solution.

We used a Taylor candy thermometer for controlling the beaker bath temperature, and adjusted the gas stove burner controls as needed. From time to time, more water had to be added to the bath surrounding the beakers, due to evaporation.

After the PEM disk was dipped in each of the six hot solution beakers for an hour, it was then wiped with a piece of lint-free lens cleaning tissue, and air-dried in a clean place.

The Catalyst Layer Material

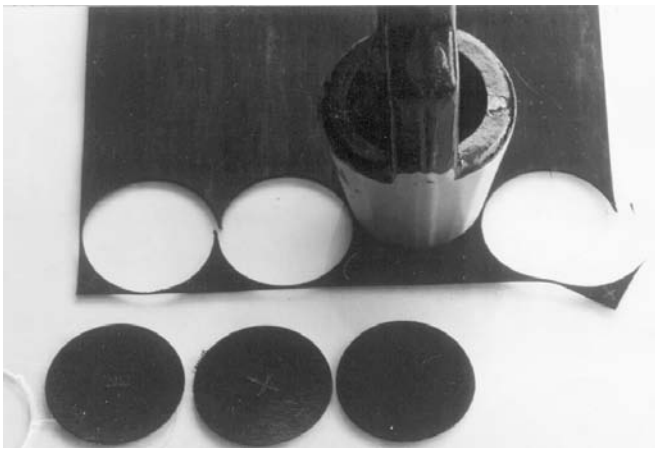
The catalyst layer is the most expensive part of this fuel cell. It is made from a mixture of platinum, carbon powder, and PEM powder, bonded to a conductive carbon fiber cloth. We obtained ours from E-Tek Inc. The cost for an order of their ELAT catalyst cloth sheet includes a setup charge. So get together with others for a larger order if you want to keep costs down. We paid $360 for a piece of ELAT 15.2 centimeters by 15.2 centimeters [6 inches by 6 inches] including the $150 setup charge. This piece provides enough for about twelve disks. Each fuel cell requires two disks of ELAT and one larger disk of PEM to make the sandwich, so you can make six cells from this size

piece of ELAT ($60/cell). The cost may have come down by now due to increased production at E-Tek.

In the future it may be possible to reduce the cost by putting the catalyst coating directly on the PEM with a platinum-carbon ink, as practiced by Los Alamos National Laboratory.

Preparing the ELAT Catalyst/Binder Layers

Two catalyst layer disks were punched from an E-Tek ELAT sheet. The sheet was placed on clean acrylic plastic and the disks were punched with a 3.8 centimeter (1.5 inch) arch punch and the mechanics hammer.



Above: Cutting ELAT catalyst disks.
Photo by Reynaldo Cortez

Be careful to keep track of which side is the active side of the catalyst impregnated carbon cloth. The active side has more of the carbon-platinum binder powder and is smoother.

Hot-Pressing the Sandwich Together

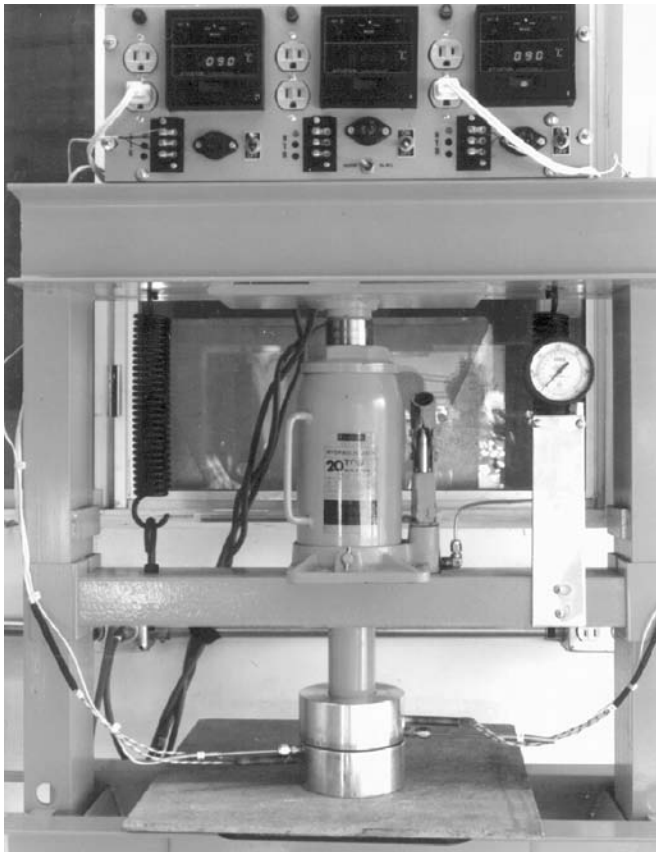
A hot press was made using a hydraulic 20 ton shop press, and two homemade aluminum heating plates. Each heating plate was drilled to accept an electric cartridge heater and a thermocouple. A temperature controller was connected to the heater and thermocouple on each heating plate.

The bottle jack on the hydraulic press was drilled and tapped to accept a ¼ inch NPT pipe to connect to a pressure gauge.

Procedure for Hot Pressing

First, two ELAT catalyst disks were coated with liquid Nafion 117. The coating only went on the active side that was to be bonded to the PEM. We used a cosmetic brush to put on a single coat (thick enough to give a wet appearance) then let it air dry at room temperature in a clean place for one hour. The liquid Nafion 117 has a strong alcohol odor, so do this coating process in a well-ventilated area.

Next, we coated the heating plates with graphite from a number two pencil and smoothed it out with a Q-tip to make a release and contamination shield layer. The three layers (catalyst-PEM-catalyst) of the sandwich were then set on top of the lower heating plate. After carefully aligning the layers, so that the smaller catalyst disks were centered above and below the larger PEM disk, the upper heating plate was placed on top of the sandwich. At this time the heaters were off and the plates were at room temperature.



Above: Hot press and heating plates.
Photo by Reynaldo Cortez

Next, the two temperature controllers were activated and the sandwich was taken up to 90°C (194°F) for one hour to evaporate the solvents from the liquid Nafion 117 catalyst coating. The temperature was then raised to 130°C (266°F) over the next 30 minutes. This is the PEM glass transition temperature.

Once the heating plates and the sandwich reached 130°C, pressure was applied using the hydraulic jack, up to 2.16 MPa (300 psig). Shortly thereafter, the pressure fell off as the PEM was squeezed by the heated plates and the sandwich became thinner.

After two minutes at temperature and pressure, the temperature controllers were turned off and the plates and sandwich cooled to room temperature.

Fuel Cell Membrane Test Fixture

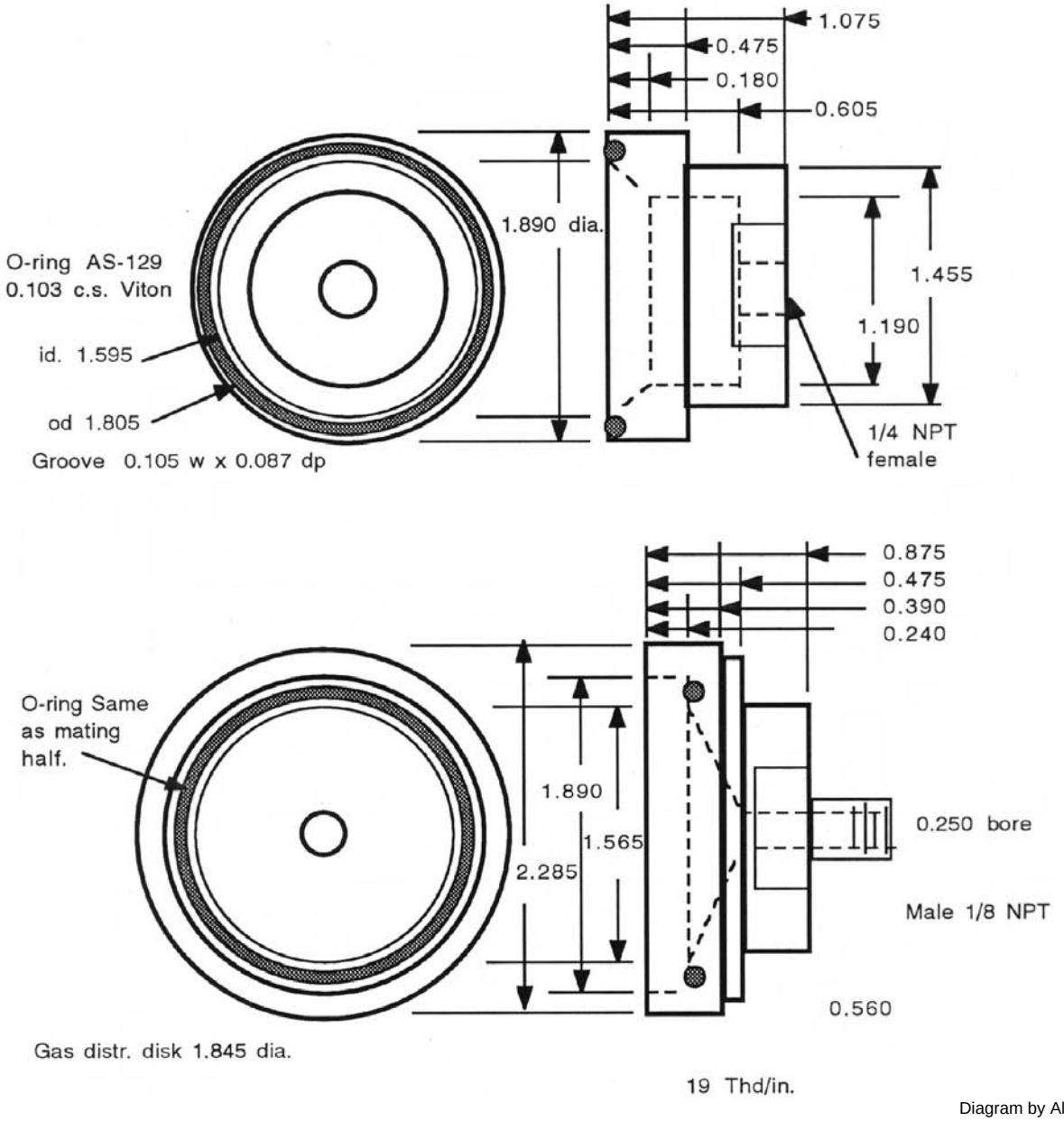


Diagram by Alan Spivak

The heater plates were opened, and the finished fuel cell sandwich was removed using the special tweezers. We noted that the PEM disk was no longer round, but instead somewhat elliptical. This may be due to alignment of the film molecules in one preferential direction. The fuel cell sandwich did not stick to the aluminum heater plates, so the graphite release coating appeared to be effective.

Fuel Cell Test Fixture

Our fuel cell test fixture was made from a commercially available membrane filter holder. We spot-welded electrode studs to the two halves of the fixture case, one for the hydrogen side and one for the oxygen (air) side.

A groove for an “O” ring was machined into each half of the case, to provide a seal to prevent the gases from leaking around the edges of the gas distribution plates.

Kapton tape was applied to the inside diameter of one case to insulate it from the other. Kapton tape was also applied to the outer diameter of the mating case to insulate the retaining ring and prevent the two cases from shorting together. An ohm-meter was used to assure that the two cases were well-insulated from one another.

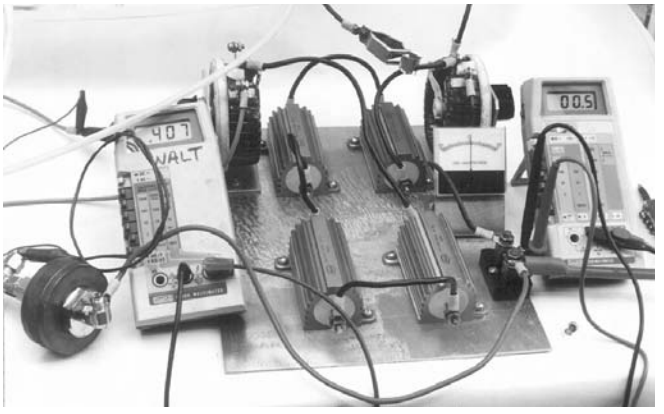
The PEM sandwich was trimmed with a pair of scissors until it was round again, and placed between the filter

Above: Fuel cell disassembled, showing a gas distribution plate on the left. Photo by Reynaldo Cortez

holder's two stainless steel gas distribution plates to make a five layered sandwich. The five-layered sandwich was then dropped into the Kapton lined case and the other case (with the Kapton on the outside) was applied on top and attached by the threaded retainer ring.

Fuel Cell Load Test System

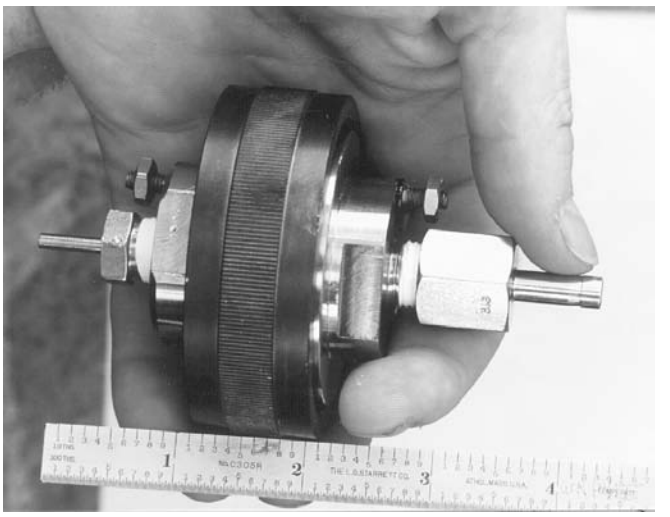
An electrical testing load system was prepared as shown below using two variable resistance potentiometers rated at 0 to 1.0 ohm at 25 watts, a current measuring shunt, and two digital multimeters.



Above: Electrical test system. The four fixed resistors were not used. Photo by Reynaldo Cortez

Hydrogen Humidification Bubbler

A hydrogen humidification bubbler was made to prevent the fuel cell PEM from dehydrating under load. Moisture management in the PEM is an engineering challenge, due to ohmic heating when high currents flow, and osmotic drag of moisture towards the oxygen side of the sandwich. The osmotic drag is caused by the migration of protons through the PEM.



Above: Fuel cell assembled.
Photo by Reynaldo Cortez

Above: H_2 humidification bubbler.
Photo by Walt Pyle

We made the bubbler out of a 30.5 centimeter (12 inch) length of 5.08 centimeter (2 inch) outside diameter, ¼ inch wall, acrylic tubing, and two 5.08 centimeter (2 inch) lengths of 7.6 centimeter (3 inch) diameter acrylic round bar stock. The round bar stock pieces were then machined to accept the length of tubing and glued together, using acrylic cement.

Holes were tapped in the center of each piece of bar stock to accept ¼ inch NPT pipe, and a Kordon Mist Air aquarium bubbler was glued into a smaller hole on the bottom inside of the bubbler.

First Test Results

Our first test was made on our fuel cell at the Schatz Fuel Cell Laboratory at Humboldt State University during January 1993. Leak testing was done by setting the fuel cell test fixture in a container of water. We applied atmospheric air pressure and hydrogen pressure (approximately 100 KPa (14.5 psig)) and found significant leakage of hydrogen around the edges of the sandwich. The open circuit voltage of the fuel cell was almost zero, because the hydrogen was leaking into the air side. With the help of the Humboldt State wizards, however, a piece of tubing was inserted into the air fitting. Blowing air into the tubing flushed out the leaking hydrogen through the annulus and provided oxygen. This gave an open circuit voltage of 0.68 Volts, showing us that we had a functional but very leaky cell.

If At First You Don't Succeed....

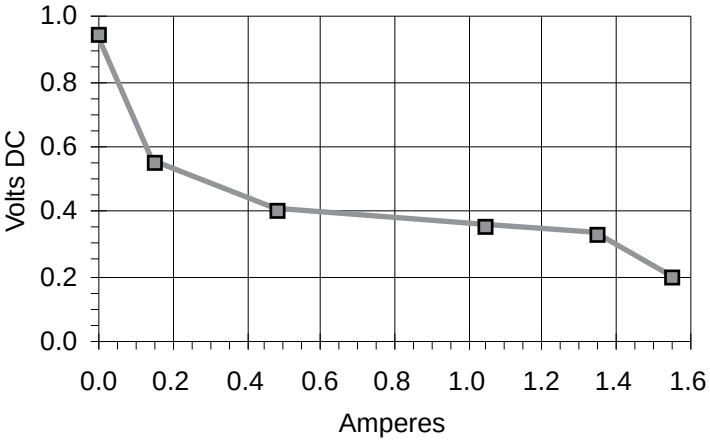
Following our visit to the Schatz Lab, we went back to the drawing board and added the "O" ring seals to the case. In March 1993, the cases were machined to accept the "O" rings and we were ready to try again. Another dip in the water container with 200 KPa (30 psig) hydrogen pressure showed that the leaks in the fuel cell test fixture had been stopped.

Another series of tests were run on our shop resistance load tester. This time, the open circuit voltage reached 0.95 Volts. Using the Humboldt tubing and annulus flushing technique on the air side, we were able to prevent the nitrogen gas from concentrating inside the cell (as the oxygen was consumed from the air). We obtained a short circuit current of over 1.5 Amperes for short periods of time (minutes). And then, by varying the load resistance we obtained data at different operating voltages and currents for the cell. Sustained power output was limited, we think, by poor moisture control on the cathode (too dry) or anode (too wet). A graph of the current-voltage response of the cell is shown above.

Future Direction

This saga has only just begun, and we are learning some valuable lessons as we go. Water management

PEM Fuel Cell Test Results



H_2 pressure = 10 psig; Air pressure = atmospheric

on both sides of the cell is a major challenge. On the hydrogen side, the PEM must be kept damp so it won't crack, and short or leak. On the oxygen side, water is produced which must be removed so the ELAT catalyst won't "drown" and get starved for oxygen.

We plan to try some experiments with oxygen instead of air on the anode side. Wick-like materials will be tried for passively absorbing and transporting water to the PEM and transporting water from the ELAT anode catalyst.

Ultimately, we'd like to have a 12 Volt or 24 Volt fuel cell that could be used in the home to power a 2 kW inverter for supplying 120 Volts, 50/60 Hz alternating current. Batteries would be eliminated, and solar energy would be stored as hydrogen and oxygen in tanks until it was needed. Others are dreaming of PEMFC cars, and locomotives. As we go to press, Ballard Battery Co. in Vancouver B.C. is driving a fuel cell powered bus around the parking lot!

Please let us hear from you if you have any suggestions for improvements or new experience to share. We don't want to squirrel this technology away; we'd rather set it free!

Hydrogen Safety Considerations

For a more thorough discussion of the safety consciousness one should develop when working with hydrogen, see our article on "Heatin' with Hydrogen" (Home Power #34). The bottom line is:

Work with hydrogen out of doors or in a well-ventilated area.

Store only pure hydrogen or oxygen, never mixtures of gases.

Remember the explosive mixture limits are wide and different from other fuels: even very rich hydrogen-air or hydrogen-oxygen mixtures can burn violently.

Access

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References

U.S. Patent No. 4,661,411, "Method For Depositing A Fluorocarbonsulfonic Acid Polymer From A Solution" April 28, 1987; Inventors: C.W. Martin, B.R. Ezzell, J.D. Weaver; Assigned to Dow Chemical Co., Midland, MI

Acknowledgements for Articles and Discussions

Supramaniam Srinivasan, A.C. Ferreira, Imran J. Kakwan, David Swan; Texas A&M University, College Station, TX

Roger Billings, Maria Sanchez; International Academy of Science, Independence, MO

Peter Fowler, E-Tek Inc., Framingham, MA

Peter Lehman, Tom Herron, Ron Reid; CA State University at Humboldt, Schatz Fuel Cell Laboratory, Arcata, CA

David Booth, Alternative Energy Engineering, Redway, CA

PEM Materials

Nafion 117 PEM (du Pont) 0.007 inch thickness: Aldrich Chemical Co., Catalog No 29,256-7

Nafion 117 solution (Nafion perfluorinated ion-exchange powder 5% mixture of lower aliphatic alcohols and 10% water d 0.874): Aldrich Chemical Co., Catalog No. 27,470-4 • 800-558-9160

Nafion 117 PEM (orders greater than 0.61 m by 0.61 m [24 inches by 24 inches] or larger): I.E. du Pont de Nemours & Co., Customer Service Dept. • 302-695-5249

Catalyst/Binder Materials

ELAT Solid Polymer Electrolyte Electrode 20% Pt/C with 0.4 mg/cm^2 Pt loading: E-Tek, Inc., 1 Mountain Rd, Framingham Industrial Park, Framingham, MA 01701 • 508-879-0733

Test Fixture

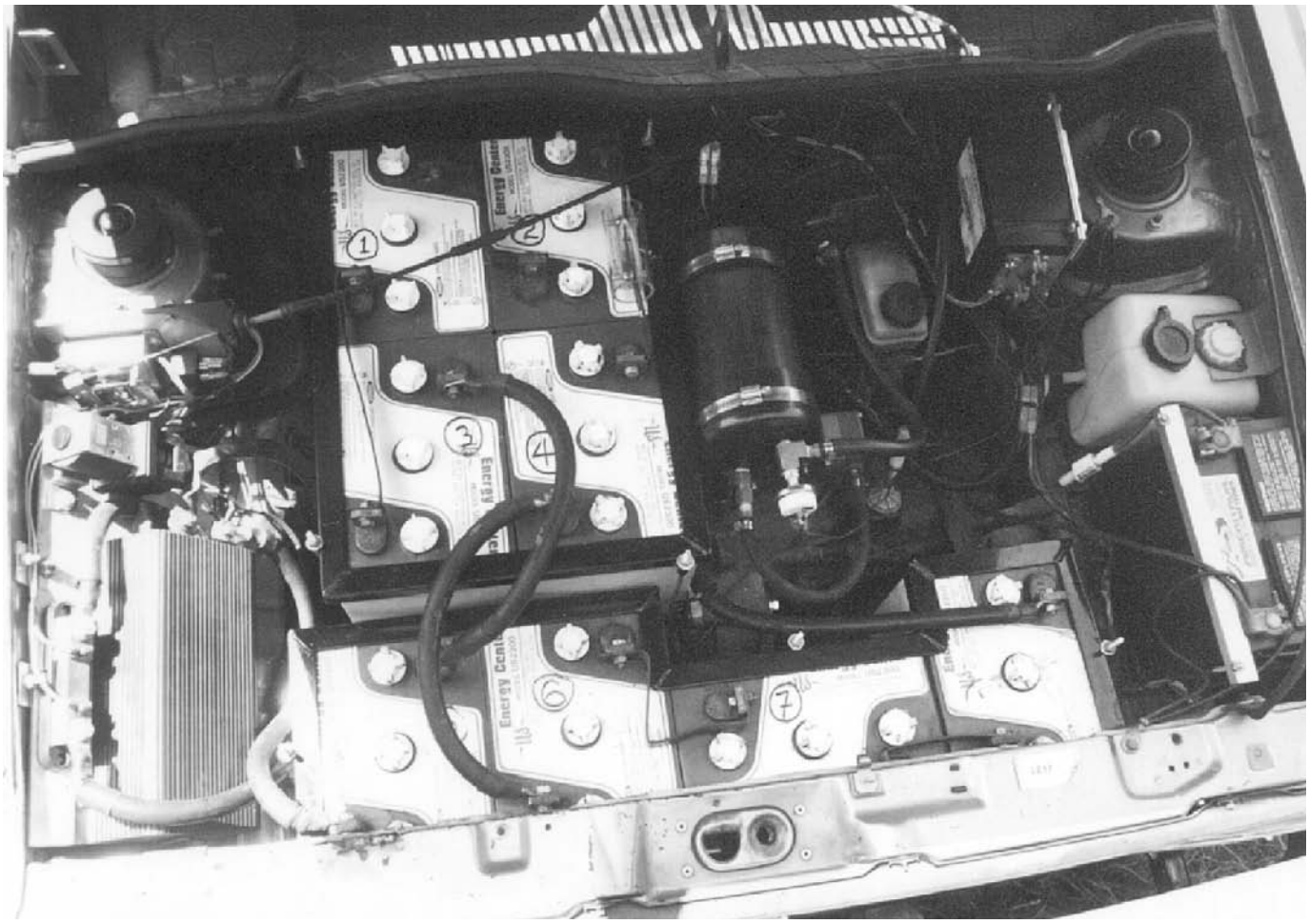
Stainless Steel In-line Filter Holder: Catalog No. L-02929-20 (47 mm), Cole-Parmer Instrument Co., 7425 N. Oak Park Ave., Chicago, IL 60648 • 800-323-4340

Hot Press Components

20 Ton Hydraulic Press: Post Tool Co. 800 E. 8th Street Oakland, CA • 510-272-0331

Temperature Controllers, Thermocouples, Cartridge Heaters

Omega Engineering Inc., 1 Omega Dr., Stamford CT 06907-0047 • 203-359-1660



Above: The front end of a Voltsrabbit (a VW Rabbit converted from gasoline to electric power). There are eight 6 Volt lead acid golf car batteries, and an accessory 12 Volt battery under the hood. Photo by Shari Prange

Electric Car Batteries

Shari Prange

The battery pack is one of the electric car's biggest components, in many senses of the word "big". It is the bulkiest and heaviest component. It is one of the most expensive. And it is one of the most important to performance.

Which kind of battery?

Designing the battery pack involves a series of decisions. The first decision is which kind of battery to use. If you study the literature about EV batteries, you may feel overwhelmed by myriad possibilities. In reality, though the realistic choices are not that many.

Miracle batteries?

The "miracle" batteries that receive so much attention — sodium sulphur, lithium polymer, nickel iron — are simply not commercially available to individuals. They may be planned for production for manufacturers only, or available only as laboratory test prototypes, or they may be nothing more than vaporware. The same is true of fuel cells, such as hydrogen or zinc air. Therefore, the first question to ask about any type of battery is, "Where can I buy one?" The answer for most of the exotics will be, "Nowhere — they aren't available yet."

How much will it cost?
The second question to ask is, "How much will it cost?" Some batteries are available — like nickel cadmium, or silver zinc — but only at costs equaling or exceeding the entire rest of the car's conversion to electric power. Unless you have special contracts, or a lot of money, the answers to these first two questions will probably narrow the field to conventional lead acid batteries.

Battery performance characteristics
The third, and most complicated, question to ask is, "Are the performance characteristics of the battery well matched to the needs of an electric vehicle (EV)?" Lead acid batteries a constructed for a variety of uses. The shape, number, and spacing of cell's plates, composition and thickness of lead paste used in the plates, and the ratio of electrolyte are all critical items that vary depending on the intended use of the battery.

For example, the normal battery used in a gas car is a starting battery. It is intended to supply high amperage for a very short time — just long enough to start the engine. It is discharged by a small percentage (about 1%), then immediately recharged by the alternator. Starting batteries are not intended to be deeply discharged, ever, and especially not repeatedly. As many of us have found out, a starting battery that is run "dead" too often, perhaps by leaving the lights on accidentally, will soon refuse to store power.

An EV needs a deep cycle battery. This means it can have 80% of its capacity discharged and charged repeatedly. Conventional starting batteries and other non-deep cycle batteries such as gel cells can provide high short-term performance for a race car, but not continuous daily use.

Traction batteries
Not all deep cycle batteries are appropriate. Marine batteries or standby power batteries are not intended to handle the occasional brief high amperage draws a car requires. They will not provide as much range or cycle life as a true "traction" battery.

A "traction" battery is designed for both high current draws and repeated deep discharges needed to move an electric vehicle down the road. The type of battery most commonly used in EVs is a golf cart battery. This is a 6 Volt deep cycle battery, typically rated at 220 to 240 Ampere-hours. This type of battery uses three series connected cells assembled into a single battery case. This is an excellent choice because it is well developed, easily available, and affordable.

There is also now a true "traction" 12 Volt battery (six series cells) available from U.S. Battery. This is the model 1450, and can be ordered through U.S. Battery or Interstate dealers. While the battery is too new to have full life-cycle testimonials from EV owners, it was

Above: The eight of the remaining Voltsrabbit's sixteen batteries reside in the trunk. Photo by Shari Prange

developed by a company with an excellent record of producing quality batteries suited to EVs. This battery would be highly recommended for very small cars where space is limited, and may well eventually take over the market for larger conversions as well.

Ni-Cads

Nickel cadmium batteries are probably the second most common in EVs, far behind lead acid. There are several drawbacks to ni-cads. One is high cost, even for reconditioned batteries. Another is low power density. It is necessary to have several strings of ni-cads in parallel to have sufficient amperage capacity for acceleration. This means a lot of space filled by batteries. A third problem is that ni-cads come in 1.2 Volt cells, which requires many more cell interconnects — potential failure points — as golf car batteries.

For most people, the conventional 6 Volt lead acid deep cycle golf car battery is the optimum choice today. If a better battery becomes available next year, you can always upgrade.

How many?

Once you know what kind of battery to use, the next decision is how many batteries the EV needs. In very simple terms, Amps equals torque and voltage equals speed. In the electric motors used in EVs, torque is governed by the battery ability to deliver high current and speed is limited by the battery's voltage.

The better the battery's ability to deliver current, the more torque power it will be able to supply to the EV's electric motor. More torque results in faster acceleration and hill climbing. The battery must be able to deliver the sustained high currents (over 200 Amperes) required by a hard-working EV motor.

Higher battery voltage gives the resulting EV a higher top-end speed. However, you can't simply add as many batteries as you want. Each one is the size of a toaster and weighs close to 70 pounds (32 kilograms). Both space and weight are limited and carefully planned for in a successful electric vehicle.

A question of voltage

Early EVs often ran 48 Volt systems. The EV industry is still trying to live down their poor performance. A 72 Volt system is the bare minimum for a road-going passenger car. This will give performance comparable to the original gasoline-powered 1200 cc VW Bugs. It will only be adequate for a very lightweight car that is never intended for sustained highway speeds.

Most electric cars now have a 96 Volt system, which means sixteen 6 Volt batteries. This seems to be an optimum weight/power balance. A typical steel-bodied conversion will have a range of 60 to 80 miles (96 to 129 kilometers) in average commute conditions: mostly flat roads, some freeway time, some stop-and-go in-town traffic. It will have a top speed of about 60 mph (95 kph). Some of the more aerodynamic cars will do better. A lighter weight fiberglass car will have a range of 80 to 100 miles (129 to 161 kilometers), and a top speed of about 85 mph (137 kph).

If there is room for the batteries, the system can go as high as 120 Volts. In fact, this is recommended for pickup trucks, where some payload capacity is desirable. Beyond 120 Volts, there is a lack of controllers and chargers. It is debatable whether the extra voltage offsets the handicap of the extra weight of the additional series cells necessary to raise the battery's voltage.

Since most EVs use a single series string of batteries, the actual number of batteries making up the battery pack is determined by the voltage of the EV system. A 96 Volt EV will use sixteen 6 Volt golf car batteries weighing 1120 pounds (509 kilograms). A 120 Volt EV will employ twenty 6 Volt golf car batteries weighing 1400 pounds (636 kilograms).

When To Buy Batteries

Although you have chosen the batteries you will use, and decided how many you want, don't buy them until you are ready to install them. Get precise dimensions and use cardboard or foamcore mock-ups for designing your car. That way the batteries won't be getting stale sitting on your garage floor for weeks or months — and you won't be tripping over them.

Next time we'll talk about battery placement, boxes, racks, and hold-downs.

Access

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Battery Technology Comparisons

Richard Perez

Electric vehicles and home power systems have batteries in common. Whether it's going down the road, or lights at night, the battery is where the energy is stored. It would be nice to recommend the ideal battery, but there isn't one. What we have instead is a confusing array of dissimilar choices. Here's a quick graphical look at how today's battery technologies stack up.

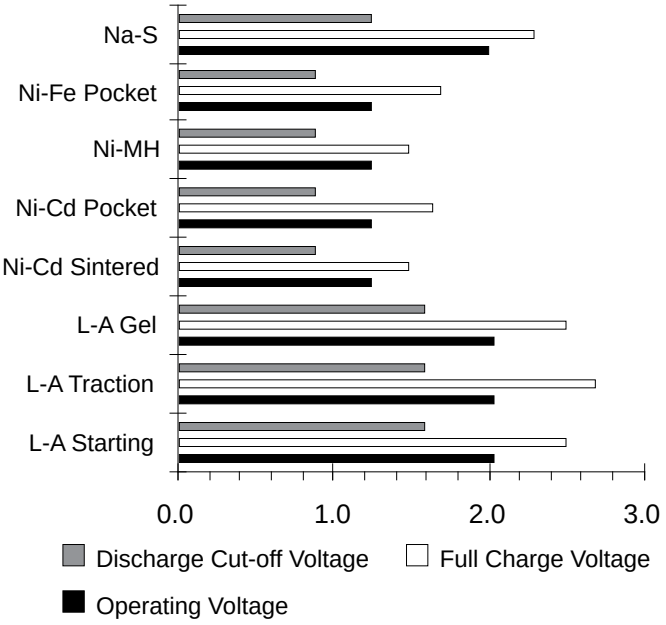
The Players

There are over twenty battery technologies that could be used in an electric vehicle. I narrowed the field down to eight current players. Three lead acid (L-A) technologies, L-A starting, L-A traction, and L-A gel are represented. Four alkaline technologies, nickel cadmium or nicad (Ni-Cd) sintered plate, nicad (Ni-Cd) pocket plate, nickel metal hydride (Ni-MH) sintered plate, and nickel iron (Ni-Fe) pocket plate, are represented. And one technology on the horizon, the sodium sulfur (Na-S) battery is also charted.

Not every cell is equal

The electrochemical couples employed in batteries are made from different pairs of compounds. Different battery technologies have different immutable cell voltage limits. For example, the lead acid reaction takes place at about 2 Volts. The nicad reaction takes place at about 1.2 Volts. And that's that. No nicad cell will ever develop the voltage potential of a lead aicd cell. Cell voltage is naturally determined by the specific materials used in making the cell's active anode and cathode. While small variations do exist due to fine tuning cell design, the basic cell voltages haven't changed since the days of Allesandro Volta's first electrochemical cells.

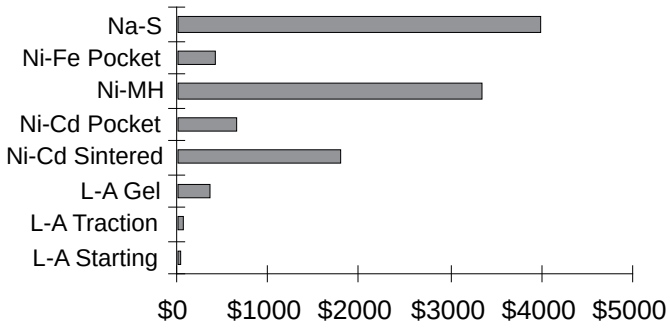
Cell Operational Voltages in VDC



Paying for a new battery

If you go shopping for batteries based on price, then you will buy an automotive starting battery. Lead-acid starting batteries are cheapest because they are mass produced and designed for very light duty service. This battery has only one mission in life — starting a car. When you consider that the average EV will store over 20 kiloWatt-hours of power, then you understand why battery buyers are cost conscious. A 20 kWh L-A starting battery will cost about $1,400. The same battery composed of traction cells will cost about $2,000. The same battery using nicads will cost over $10,000. Or you could spend a whopping $80,000 for sodium sulfur cells. The chart below shows how the different batteries compare as to initial purchase price. The cost is given in dollars per kiloWatt-hour ($/kWh) of power stored. All prices used here are for new batteries.

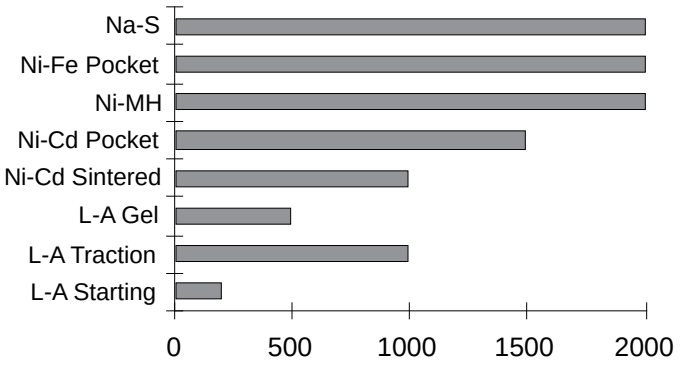
Initial Battery Cost in $/kWh



Cycle life

Both electric vehicle and home power service are brutal deep cycle punishment for batteries. Some batteries technologies survive thousands of daily deep discharge and recharge cycles. Other batteries only last a few hundred deep cycles before failing. The chart below shows how the different battery technologies accept deep cycling (discharge to 20% state of charge (SOC)). Car starting batteries fail after less than several hundred deep cycles, while other technologies go on for several thousand cycles.

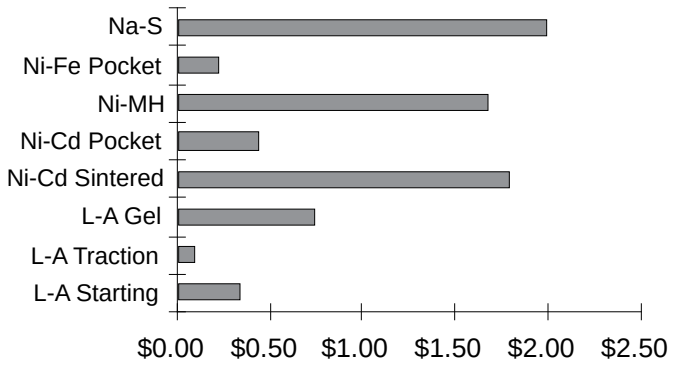
Cycle Life (discharge to 20% SOC)



The real costs

Cheap batteries are false economy if they don't last very long. The chart below shows the cost of a battery in dollars per kiloWatt-hour per deep cycle ($/kWh/cycle). While the car starting battery was cheap to buy, we see that it is expensive to operate because it dies so quickly in both EV and home power service. In fact a lead acid starting battery is over three times more expensive to use in deep cycle service than a lead acid traction battery.

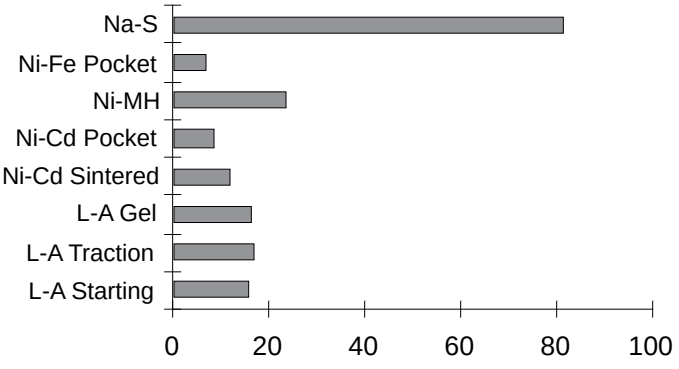
Cost in $/kWh/Cycle in EV Service



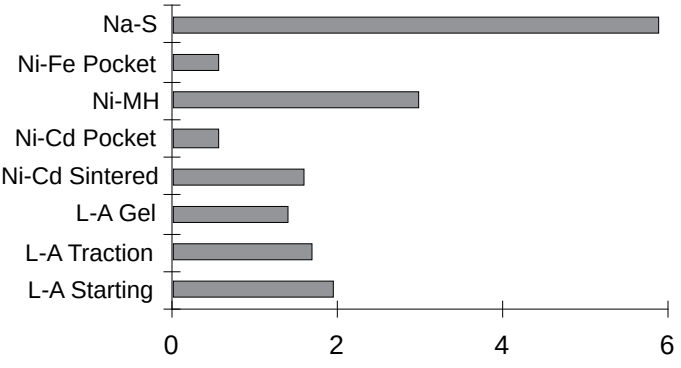
Energy density

While home power folks don't really care how much their battery weighs, the subject is of intense interest to EV drivers. Battery size and weight must be kept to a minimum if an EV is to accelerate quickly and have a long range. The two charts below show how much power can be packed into a battery by weight and volume.

Energy Density by Weight (Wh/lb.)



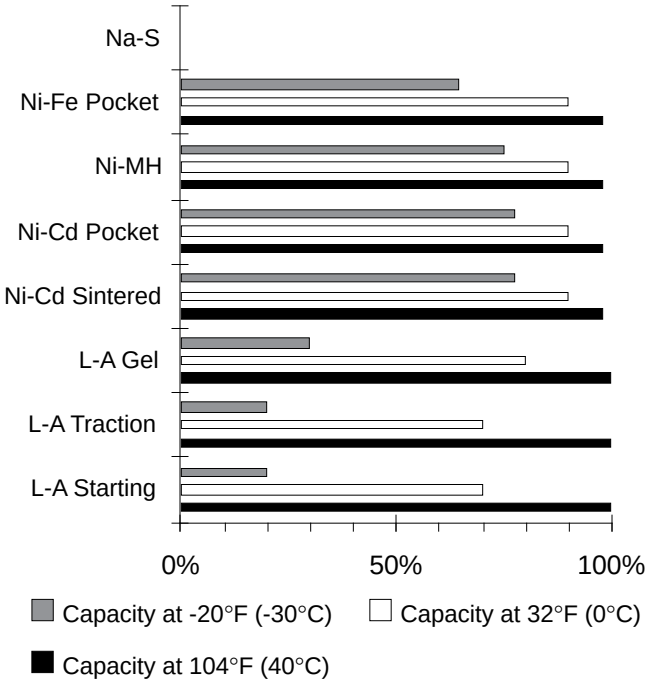
Energy Density by Volume (Wh/cu. inch)



Batteries and temperature

Home power systems and EV drivers share a common interest in battery performance at low temperatures. Home power systems often keep their batteries in unconditioned spaces. EVs are parked in a variety of cold places during the winter. The same battery that powered everything just fine last summer, suddenly seems smaller due to the winter's cold. Almost every battery technology exhibits some apparent decrease in stored capacity when it gets cold. The only battery not charted here is the sodium sulfur which must be kept at 300°F or more all the time, which is one reason (aside from astronomical price) for its limited popularity.

Cell Capacity at a Variety of Temperatures



Bottom line time

After a through study of these charts you will probably reach the same conclusions as Shari Prange did in her article on page 48 of this issue. Lead-acid traction batteries are currently the best deal for electric vehicles. They are inexpensive, long lasting, and have the necessary high power density required in EV service.

In home power systems, the freedom from weight and space restraints give the user more selections in a battery technology. While the nickel cadmium and nickel iron technologies are still initially more expensive, they offer greater longevity and better low temperature performance.

Buying batteries is like getting married, both are not to be rushed into lightly…

Access

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El Sol Simpático

Laurie Stone

Working in El Salvador opened my eyes up to a whole new world of renewable energy applications. Not only did we install solar lighting systems and teach workshops on solar ovens, but we actually saw the results of our work, and the changes that solar technology made in people's lives.

Julia Whelan, Ben Scott Luna and I went to El Salvador to transfer some of our solar energy knowledge. With the help of STI, solar companies who donated equipment, and friends who donated money, we headed south.

Photovoltaics

We installed the first lighting system in El Sitio, a rural community in Cuscatlán, north of San Salvador. This 250 member community had fled the country due to the 12 year civil war and have recently returned to rebuild their community. Needless to say, they had no electricity, and desperately wanted lights. Three young men from the community became our apprentices, and quickly learned the principles of solar energy and how to install the system.

The solar system was simple, consisting of one Siemens M53 photovoltaic module, one SCI charge controller, one lead-acid (unfortunately shallow cycle) battery, and two 20 Watt DC fluorescent lights. There are no deep cycle batteries made in El Salvador, and we decided it would be better to stay with local batteries that they can easily replace, than to import a deep cycle battery from the United States.

We spent a week visiting numerous hardware stores in San Salvador and made several phone calls to STI for technical advice. Then, after one full day of work, the system was installed. We put it on the building which acts as the health clinic, the school, and the community center of El Sitio. After the installation we gave a talk about system maintenance to the three *responsables* of the system. We also gave them a solar still to provide distilled water for the battery. Obtaining distilled water in the Salvadoran countryside is quite difficult.

Lights for Literacy

People were amazed when the lights actually turned on. I, however, was more amazed with what people did with the lights. The very next night adult literacy classes began. The illiteracy rate in El Sitio had been 95%. Many adults had wanted to learn to read for years, but working all day and not having lights at night made it nearly impossible. Now people from neighboring communities all around were travelling to El Sitio to study at night. It was amazing to see, and made us feel good to think that we had made a difference in people's lives. However, I realized that what I was doing was not that incredible. Anybody who knows how to install a simple PV system could have done what we did. The incredible thing was what the people were doing with the electricity. Although Ben, Julia and I brought the technical knowledge, the people of El Sitio brought the ambition and determination.

We had another successful experience in the second community we worked in, Nueva Esperanza. Nueva Esperanza is also a community of repatriated refugees. However, this 400 member community is located in Usulután, in the south of El Salvador. We installed a similar lighting system. We used a 150 Amp-hour nickel-iron battery which was donated by Utility Free, two solar electric panels and four 20 Watt lights to light up the community center. After monitoring the system for two months we realized that they had a lot more accessible power than they were using. We set up a 400 Watt inverter, donated by PowerStar, so they can use some of their ac appliances which they usually ran on the generator. Now they can listen to music without going through endless amounts of D cell batteries, which is a major expense in the community.

The third community in which we worked was La Mora. We installed a lighting system on the schoolhouse. La Mora is one of the central communities in Cuscatlán, and the schoolhouse is quite large since it serves over 300 children from many neighboring communities. We ended up installing two Siemens M53 photovoltaic panels, two 220 Amp-hour lead-acid batteries, and six different light fixtures consuming approximately 80 watts total. The head school teacher told us how important the lights were because many children have to work in the fields with their parents during the day. Now both children and parents will be able to attend night classes.

Technology Transfer

The three men from El Sitio helped us install the Nueva Esperanza system and the La Mora system. They learned quickly. By the third system they had the panels mounted, all the connections soldered, the lights wired, and the system working after one very long day. The people in La Mora were ecstatic. We left feeling very confident knowing that the El Sitio crew could fix any problem that occurred and install more systems if the opportunity arose.

Solar Ovens

We also gave a workshop on solar ovens in Nueva Esperanza. El Salvador is highly deforested, and many people spend hours every day searching for firewood. By cooking with solar ovens, people are not only saving time, but also alleviating many respiratory and eye problems caused by the conventional wood fire cooking methods. For two months (while battling swarms of mosquitoes and absurd heat) we taught eight women how to build and use solar ovens.

The design of the oven is from PROCESO, the Central American Solar Energy Project, directed by Bill Lankford. Bill has been introducing solar ovens into communities in Central America for years. His model is easy to construct, relies on easy to find materials, and

Above: Women in Nueva Esperanza finish their solar ovens.

Photo by Laurie Stone

Below: Rudecinda and her children are ready to use their solar oven!

Photo by Laurie Stone

is simple to use. He has had so much success in other countries of Central America that we thought we would introduce his model to El Salvador. He gave us his workbooks to use, which give detailed steps in Spanish on how to construct the oven. The materials, such as plywood and cardboard, are all readily available in El Salvador. For insulation we used corn husks which are in abundance in Nueva Esperanza.

Oven Workshops

We had class three hours every afternoon. Although the women were busy attending to the great amount of daily work, they usually managed to spare three hours. They felt solar cooking was important to learn. Since the majority of the women knew nothing about carpentry, we started with the basics. We went over all of the tools that we were going to use, and explained some carpentry fundamentals.

Then we started building. First we divided into groups, and built three ovens. When those ovens were done we built three more. These went much faster than the first three. The greatest pleasure came in building the last two ovens. Each woman in the workshop had built two ovens already, and were practically experts in the solar oven field. The three of us hardly lifted a finger, and before we knew it the last two ovens were built.

Then came the fun part. We asked each woman what colors they preferred, and we showed up the next week with six gallons of paint. We had a big painting party. Each participant painted her own oven, and brought it home to finally use.

Solar Oven Success

We left Nueva Esperanza excited that the workshops went so well, but slightly apprehensive, wondering if the ovens would really get used. Using solar ovens does require a slight change of customary cooking habits. We had heard horror stories of ovens being used to store clothes and as tables. We also encountered many skeptical internationalists who told us the ovens would never replace people's normal cooking traditions. We were ecstatic to prove them wrong!

A week later we showed up at Nueva Esperanza to do a follow up check on the ovens. The visit was definitely encouraging and inspiring. Not only were the women using their ovens every day, but the ovens cooked with great success, reaching temperatures of 300° F.

Solar Cooked Iguana?

We first visited Conchita, who had just taken perfectly cooked rice out of her oven. She told us how she cooked beans, potatoes and plantains, and was using her oven every day. Next we visited María Juana, who had also just taken her rice out of the oven, after only one hour of cooking. She gave us some solar cooked bread she had made the day before. We visited each woman, and heard stories of how they cooked beans, bread, tea, chicken, pig and even iguana in their solar ovens. Morena, who was cooking beans as we talked with her, said that she now had much more time. She could put beans in the oven in the morning and leave. When she came back at the end of the day, they were cooked. She could go to school, and do things which she never had time for before. The solar ovens were a success.

Spreading the Word

Travelling to different communities and talking with people about their needs, we saw how solar energy can play a critical role in El Salvador. Besides lighting and cooking, solar energy can help with water pumping, grain drying, battery recharging, vaccine refrigeration, and drinking water. Once other communities saw the success that Nueva Esperanza, El Sitio, and La Mora had, everybody wanted to utilize the power of the sun. Now that the technical knowledge is there, we hope it will spread.

Access

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Above: Linda and Justin Cooke and Mark Hawes in front of their solar powered straw bale home. Photo by Ralph Towl

Straw and Solar: A Perfect Renewable Match

Mark Hawes

It is late October and an early winter storm is blowing through the Sangre De Cristo Mountains of Northern New Mexico. Outside wind gusts of 30 to 50 mph are blowing around any bit of construction material that is not covered or tied down. Trees are leaning with the wind. Inside, where I am working — running ceilings on top of my vigas (log joists) — I am unaware of the storm until my friend, Ralph Towl, comes in the front door. Only then do I come down my ladder and stare outside at nature's bluster. I am surprised and happily amazed — because the inside of my straw bale house is so quiet and calm.

I decided to build a straw bale house after reading about one built near me in Tesuque, New Mexico last summer. I was going to build adobe, but this article made so much sense environmentally, I knew I had to try straw. Millions of tons of straw/crop refuse are burned yearly in the fields across America — 200 million tons nationwide! Since straw can be grown many places (an acre can produce one to two tons), and the existing supply is inexpensive, straw seems a natural alternative to milled lumber. I could see saving millions of trees annually and reducing the burning of crop refuse — cleaner air on both ends. And a new source is grown every year. Talk about renewable and earth friendly! I just finished my straw house with my partner Linda Cooke, and couldn't be more pleased.

But that's only half the story...

The same summer, I visited a friend's machine shop — complete with band saw, grinders, drills, and so on. All of this operates on solar power high atop a mesa overlooking the Rio Grande. I was impressed, and walked away with a subscription form to *Home Power*. Ah, what a gift! Like so many others, I too was suddenly obsessed with the idea of living off the grid.

Starting with Solar

The idea of independent power really captured me,

and Home Power helped me see what others had already done. But, I took a leap of faith early on. I bought a used solar system out of the Santa Fe paper (before I really knew what an inverter did). For $1200, I bought a Trace 2012 inverter, a Heliotrope charge controller, eight Trojan T-105 batteries, an ARCO 100 Watt TriLam photovoltaic (PV) module, and fifteen 11 Watt amorphous PV panels.

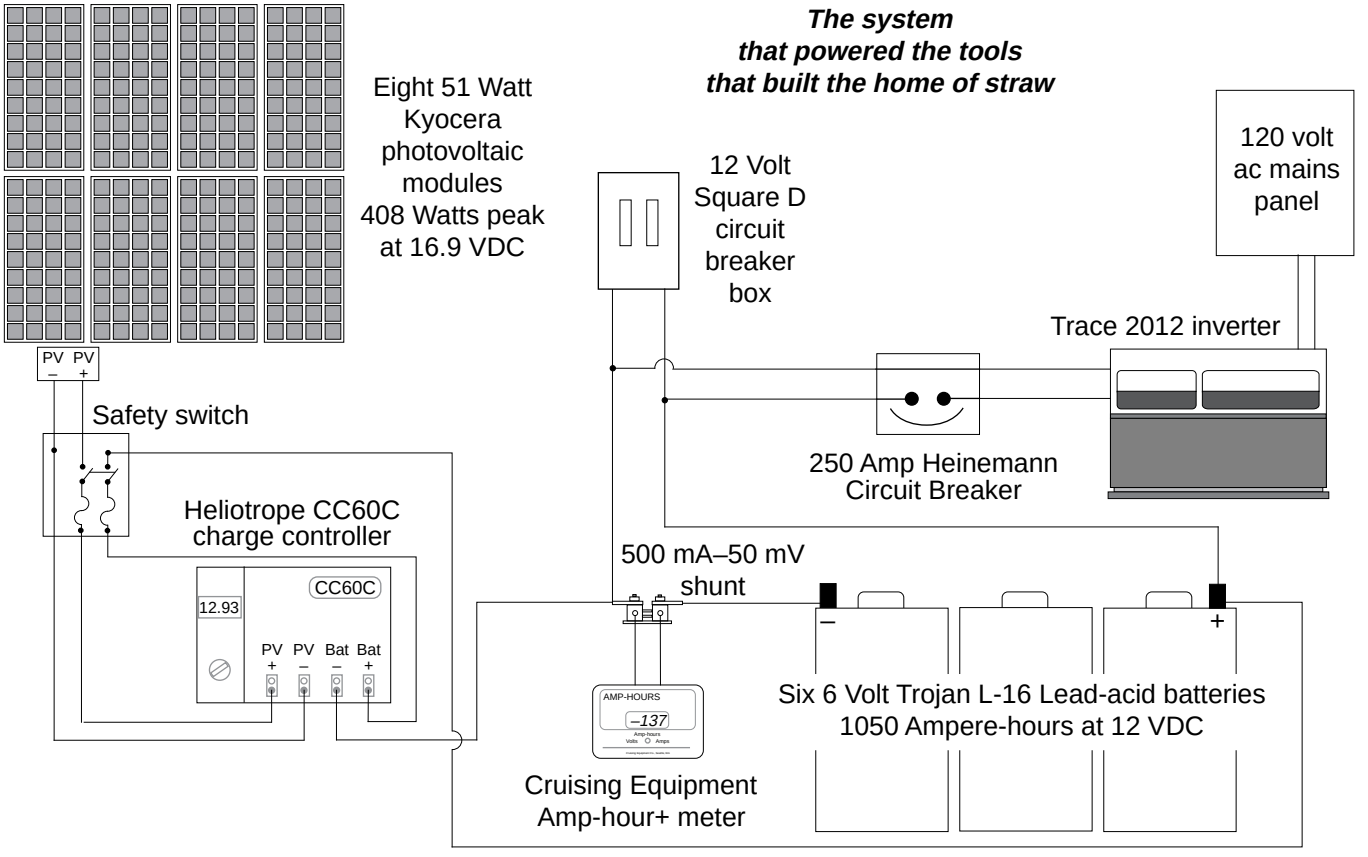
I bought an old travel trailer frame, chopped it down and welded a smaller frame together. Then, I built a housing box on top of this. I bought eight 51 Watt Kyocera panels — 408 Watts peak power from the sun — and 16 Trojan L-16 lead acid batteries to store the power (1050 Amp-hours). I used the Trace inverter and Heliotrope charge controller that I had bought second hand. The power trailer was installed with all breakers and fuses as per STI's diagram in issue #26. Brad Rose and Michael Maddex of ¡Solar Works! in Espanola, New Mexico, did all wiring/configuration on all the solar systems. This power trailer solar system not only produced all the power to build my house, but it also housed all my tools during building. This system will be installed in my house permanently next spring.

In addition to the power trailer, we have a solar well system and another system powering the small travel trailer we lived in during building. For the well system, ten of the used amorphous PVs fill four Trojan T-105 batteries. We use a 1300 watt PowerStar inverter to convert the DC electricity from the batteries to ac electricity to power a Goulds ac pump. The 1/3 hp pump delivers 7–11 gallons per minute from a 60 foot depth. The small travel trailer is powered by the used ARCO trilam PV panel, two Trojan T-105 batteries, and a 200 watt PowerStar inverter. Both systems use Sun Amp charge controllers.

After six months of working and living with solar energy, I cannot stress enough the great performance of today's solar technology. The power trailer ran everything we asked it to — power saws, table saws, drills, often multiple tools and the ever-present radio all at once. It even ran an airless paint sprayer! The other systems performed just as reliably. The well system functioned flawlessly and the travel trailer system ran lights, radio, and a TV/VCR combo without a hitch. All throughout the summer I couldn't begin to draw my batteries down. (By the way, the 200 watt PowerStar is amazing in its ability to supply your basic electric needs.) 'Nuff said.

On to the Straw Bales

The first straw bale homes were built before the turn of the century, and research is still conducted on straw bale construction. Matts Myhrman (Out on Bale, Unlimited) and Ralph Towl, independently went to the Nebraska Sandhills to view and study existing straw



Mark Hawes' Solar System Cost

Power Trailer Equipment	*Cost*	*%*
Eight 51 Watt Kyocera PV panels	$2,400	40%
Six Trojan L-16 batteries (1050 Ah)	$900	15%
Misc. breakers, fuses, wires	$300	5%
Cruising Equipment Amp-hr meter	$150	2%
Two load distribution boxes (ac & DC)	$120	2%
Trace 2012 inverter	used*	
Heliotrope CC60C charge controller	used*	

Well System Equipment	*Cost*	*%*
1300 Watt PowerStar inverter	$750	12%
Sun Amp charge controller	$40	1%
Ten 11 Watt Amorphous PV panels	used*	
Four Trojan T-105 batteries (440 Ah)	used*	

Travel Trailer Equipment	*Cost*	*%*
200 Watt PowerStar inverter	$150	2%
Sun Amp charge controller	$40	1%
100 Watt ARCO Trilam panel	used*	
Two Trojan T-105 batteries (220 Ah)	used*	
*Used equipment package	$1,200	20%
Total	$6,050	

bale homes. Some houses were over 80 years old and many are still inhabited. Interior wall removal has revealed bales that look like they were installed yesterday instead of decades ago.

All Nebraska houses have straw load bearing walls with usually a hipped roof attached to only stacked bales for support. This is called “Nebraska Style” in the vernacular. Most areas with building codes take a dim view of Nebraska Style despite standing evidence to its ability to withstand wind and weather. Storms across Nebraska can be as fierce as anywhere — but modern municipalities need stronger and more documented evidence to allow Nebraska Style building. Research is currently underway at the University of Arizona to substantiate code allowance of Nebraska Style.

Presently, building codes in New Mexico and most of Arizona require post and beam construction, with straw bales used only as “fill” for the walls. They also require an engineer to stamp structural details and plans. If you are lucky enough to live in an unincorporated/non coded area (like Cochise County, Arizona), “Nebraska Style” is the way to go. I was required (as one of the ten straw bale permits granted in New Mexico last year) to build post and beam and incorporate other structural safety measures. But my costs were in line if not below the industrial mean. My house was built with resale in mind, so RE builders without resale in mind can do it considerably cheaper. Regardless, the bonus is you’ve got a tremendously efficient house.

The Straw Bales

The main concern with straw bales is keeping them dry. Hay and straw are both baled, but are entirely different animals. Hay will decompose and is an attractive meal to many creatures. Straw, on the other hand, is tough, fibrous grain stalk. Straw resists rotting and is no temptation as food. However, straw will rot with repeated or prolonged exposure to water. Micro fungi and mites can live in wet straw, so buying dry bales is important. Bales on the bottom of a field stack may have fungi, but most stacked straw weathers well and is resistant to moisture absorption. It rained hard several times on bales I used as weights to hold plastic down over the main stack and after one or two days of sunshine the moisture meter showed them almost identical to the covered bales.

Straw can be stalks of wheat, barley, oats, rye, flax, or rice, (or even tumbleweed) and are baled at different times around the country. As a rule you can “reserve” a specific number of bales with a modest holding deposit. In fact, as straw’s popularity grows, I would encourage people to network and reserve. Supplies in certain areas can be depleted, and from a cost viewpoint, the closer the supply, the better.

Straw is baled with two-wire or three-wire balers. Two-wire bales generally measure around 18 inches wide, 14 inches tall, and 44 to 48 inches in length. The weight can range from 40 to 65 pounds depending upon the pressure setting on the baler. Three-wire bales are about 24 inches wide, 18 inches tall, and 44 to 50 inches in length. Weight can approach 100 pounds, but generally stays between 70 to 90 pounds.

Straw baled with too much compression can lose its R value. Bales should be firm and stiff but not solid or rock-like. R values for straw bale walls range between 32 to 45 as a rule. I used two-wire barley bales at about 50–55 pounds weight each, firm but not too compressed — perfect for high R value walls.

My Straw Home

The foundation is a continuous concrete pour with an eight inch stem wall brought to grade. The pitch roof was built with recycled 2x10 inch lumber and insulated with R-30 fiberglass.

Straw bale homes require slight changes for plumbing and wiring. All plumbing is buried below frost line — it can reach –35°F in New Mexico — and comes up through the floor. Electrical wiring runs below the floor and above the ceiling. The code for New Mexico allows wires 1¼ inches (or deeper) into walls without conduit.

My exterior walls were “stacked” in about 1½ weeks by basically two people, Ralph Towl and myself. But stacking can be done in as little as two days with several people (or perhaps a weekend workshop). The bales are “pinned” — the first layer is stuck in dowels coming from the floor joists and we used rebar to pin higher layers. My stack was unusual as I chose to custom fit and notch the final row of bales around the vigas and furred down ceilings. (Vigas are peeled tree trucks, about 8–12 inches round, that are commonly used as joists in adobe construction down here in Arizona and New Mexico.)

Above: The bales are stacked and ready for stucco.

The forgiving nature of this wonderful organic building resource is one of its greatest assets. Ralph and I used a hand hay saw and a sun powered Sawzall respectively, to modify and notch our bales as needed; other people like electric chain saws. Once stacked, bales can be kicked, shovel thumped, and trimmed up as needed. Windows are simple. Bales are modified and rewired to fit around a dimension lumber buck frame. Holes are drilled inside the frame and ¾ inch dowels are driven into the stacked straw bales supporting the bucks. We mounted the windows 2–3 inches in from the outside and beveled the inside corners of the bales to let in more light.

Above: Stacking the bales.
Below: The vigas and sculpted interior walls are reminiscent of an adobe home.

Once the bales of straw are stacked, the 18 inch walls are stucco meshed. Mesh is run on both sides of the straw wall and sewn/wired together, then stuccoed exactly like adobe or stick/plywood walls. But unlike adobe walls, straw walls go up very rapidly. Unlike log or stick framing, very little lumber is required — and no insulation is needed. Other siding options are viable, but they require furring strips.

Finished plastered walls look almost exactly like the double adobe walls found in older New Mexico homes, or can be sheetrocked or paneled to look like any standard room. I started my house with efficiency and environmental concerns as well as aesthetics and wants. The graceful curves of my sculpted straw walls fit alongside any hand-built adobe of days past.

Geographical distribution of straw bale houses is fairly widespread — there are straw bale structures throughout the United States. It seems that straw bale buildings manage quite well even in wet

humid climates. There is an eight year old hay bale building in Alabama with no problems

Straw has been widely used across the country and grows well in many places. The time-weathered examples of its durability still stand in Nebraska (and are lived in). I think that straw bale building could revolutionize the building status quo. With its wonderful insulation properties, straw gives people a home that can be heated and cooled with very little use of resources. In fact, active heat is scarcely used in some solar-oriented dwellings. And it's quiet!

The age of sun and straw has arrived. Photovoltaics and straw bales combined with passive solar orientation give one the perfect cost-effective, low-impact house for the future.

Access

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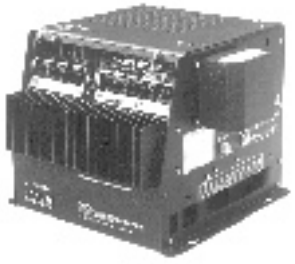

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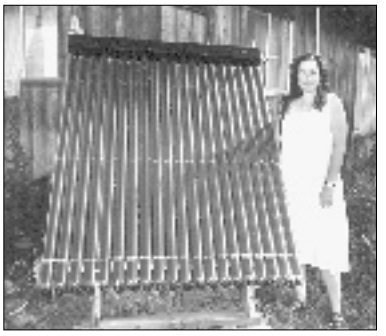

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Microwaves—

What are they, where do they come from, and are they a hazard?

John Mills

Clarisa Moore is 12 years old and has an enquiring mind. She noticed that students in her high school gathered around the microwave oven to warm their lunches.She wondered if the oven was leaking microwaves. She also wondered if microwave radiation is dangerous. This was to become her science project and, in order to help her, I came up with the coffee "Cantenna" microwave leakage detector (see page 72).

Just what are Microwaves?

Just what are microwaves? They are non-ionizing electromagnetic radiation similar to light, heat or radio waves. They were originally discovered by Heinrich Hertz in 1888. Professor Hertz built the first radio transmitter and receiver which just happened to work in the microwave band. At first microwaves were thought to be useless, but, just before the second world war, scientists realized that microwave pulses could be used to detect aircraft. The subsequent development of radar in the 1940s and 50s was largely responsible for bringing high power microwaves into our environment.

Several generations back our ancestors lived in an environment almost free of microwaves. True, minute amounts come from the sun, the stars, and warm objects but this level is so incredibly small that it is almost, but not quite, nonexistent. Many types of radiation bombard us daily from natural sources and it is curious that so little occurs in the microwave region. For some reason we have been relatively sheltered from this type of energy throughout human history.

Heinrich Hertz, discoverer of microwaves.

Early radar researchers discovered that microwaves could penetrate nonmetallic substances and heat them from the inside. Dr. Percy Spencer, while working for the Raytheon Corporation in the early 1940s, noticed that a candy bar melted in his pocket when he was near a microwave source. In 1954 Raytheon Corporation produced the first practical microwave oven. In 1967 Amana introduced the Radarange™. Consumers liked the idea enough to make this a successful product. In response to safety concerns in the late 1960s the industry and the U.S. government instituted design changes and testing programs to improve things. Interlock switches were designed to insure that the oven would not operate with the door ajar. New hinges, latching mechanisms and door gasket designs improved long-term reliability. All ovens were tested at the factory for excess leakage. Today the food and drug administration assures us, "In F.D.A.'s experience most ovens tested show little or no detectable microwave leakage."[1] This sounds great.

It All Depends on How You Look at It

Before we make a safety judgement, however, we need a frame of reference. The question of how little is a little or how much is a lot is important. In testing microwave ovens the F.D.A. and industry use instruments that are very accurate but very insensitive. These meters respond to the r.m.s. or average heating value of the leakage being tested. Our "Cantenna" is a different kind of animal. Instead of measuring averages it measures peaks and is about 1000 times more sensitive than professional instruments commonly used to measure oven leakage. If you measured a number of ovens with the "Cantenna" you would find that virtually all would be leaking. So here we see that the type of meter one uses can affect the test results and our interpretation of them.

To illustrate this important difference in another way, suppose we measured the average depth of a river and found it to be two feet. That sounds quite safe. If, on the other hand, we measured the maximum places we might find treacherous spots 20 feet deep. Both systems of measurement are accurate and honest but they might well lead us to different conclusions about the safety of the river.

Microwave measurements have this same problem. It's quite easy to visualize a 20 foot deep spot in a river but few people can visualize the significance of a leakage measurement. Microwaves are normally measured in milliwatts or microwatts per square centimeter at a five centimeter distance. Let's say your oven is leaking 100 microwatts per square centimeter. Is that a lot, a little, or what? Looking at it one way it is 50 times lower than the current U.S. government safety limit. That's reassuring. Looking at it another way it is perhaps 100 billion times higher than the natural microwave level of times past. That's scary.

Microwave Health Effects

Just how dangerous are microwaves? What are the health effects? Anything that can cook a meatloaf can surely be regarded as a potential health hazard. The cornea of the eye and the testes seem to be especially sensitive to damage by heating. If a candy bar in your pocket ever starts melting from microwaves you might be in immediate danger, but this is not likely to occur. The exposure that you would receive from being within 10 feet or so of an operating microwave oven meeting current leakage standards would cause no detectable heating. It would, however, be perhaps 100 million times higher than the natural level. This is considered "low level" exposure.

Has low level exposure been associated with health problems? Yes. It has been known since the 1950s that low level pulsed microwaves can be sensed or felt by humans and animals. In the late 1950s the Russians examined workers in their microwave industry and concluded that low level microwave exposure can effect human sense of smell, the stamina of rats, and has an exhausting effect on the central nervous system Microwave exposure has been associated with hypotension, alterations in hearing, and had various effects on the thyroid gland.[2] The U.S. F.D.A. notes that some researchers have found low level exposure associated with: genetic changes, an immune response, and decreased ability to perform certain tasks. A well-known American researcher, Allan H. Frey, recorded brain wave changes on microwave exposure and noted that humans can hear microwave pulses. Recent media reports have linked microwaves from hand-held cellular telephone units to brain cancer.[3] Cellular phones emit microwaves at a frequency of 870-890 MHz while microwave ovens operate at 2450 MHz. It has been suggested that microwave energy does not cause cancer directly but rather promotes its growth.

The Lid on the Can of Worms

Other scientists are more cautious. James Jauchem, a research physiologist working for the U.S. Air Force concludes, "scientists should attempt to place potential health risks in their proper prospective and present a balanced account of the data."[4] One researcher who seems to have aimed at a balanced account is Nicholas Steneck. He is a professor of history at the University of Michigan and has examined the microwave problem with grants from the National Science Foundation and the National Endowment for the Humanities. Professor Steneck is concerned that industry and military control of microwave bioeffects research in the U.S. has resulted in too little study of low level exposure. He writes, "The scientific community has allowed social, economic, and political pressures to influence its activities thereby destroying the credibility of its product."[5] If this is true, it is not surprising. Government and industry are heavily committed to microwave technology. Any new studies that might question the safety of our present products or systems would most likely be seen as a can of worms. You, or Miss Moore standing in front of a leaking microwave oven, "Cantenna" in hand, might see things in a different light. You might wonder if pulsed microwave exposure at school could affect young people's memories. Could microwave exposure of sick people in hospitals or the elderly alter the healing process? How much microwave energy would an unborn child receive from a counter top microwave oven and would this have any effect? Do microwave chefs have an impaired sense of smell? Good questions all, and deserving of honest answers.

What Can We Do?

We could try not to worry and hope for the best, or we could build a "Cantenna" and check our homes and work places for microwave leakage. The "Cantenna" can check cellular phones and also identify "hot spots" in your kitchen that have higher levels of leakage from your oven. It's a great project that can help young people become aware of microwaves in our environment. It is sensitive enough to detect most ovens at a distance and perhaps even from another room. Remember that microwaves can pass through most walls with little loss in power. When you move twice as far away from an oven the microwave leakage becomes one quarter as strong. This suggests that standing away from an oven while it is operating is one of the simplest ways to minimize personal exposure.

While preparing material for this article I found that there are quite a few concerned and conscientious people in industry, the government, and the military. Many of them welcome our comments, so we might consider making some calls or writing some thoughtful letters. What about improved microwave ovens? Yes, it is possible. Clarisa and her dad were able to accomplish just that. They built a cage out of aluminum window screening and wood. It had a tight-fitting,

latching door and some small microwave absorbers made from salt water soaked paper towels or fine steel wool placed inside plastic sandwich bags. These absorbers were placed outside the oven but inside the wire cage around the door area. By using these simple low cost techniques they were able to reduce the oven leakage to less than one tenth of what it was originally. If you are able to shield your microwave oven so that no leakage is detectable with the "Cantenna", give yourself a pat on the back. Your unit will be about 5000 times lower in leakage than the average.

Some final words of caution: you should never make any changes or modifications to the oven itself that might interfere with its safety systems. If you suspect that your oven is damaged or leaking excess microwave radiation, have it checked out by a service facility with a calibrated meter. Good luck, have fun, and stay safe.

Access

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The author is grateful to the following for providing material and information related to this article.

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• Bureau of Radiation and Medical Devices, Room 238A, 775 Brookfield Road, Ottawa, Ontario K1A 1C1, Canada

• Australian Radiation Laboratory, Lower Plenty Road, Yallambie, VIC. 3085, Australia

• Department of the Air Force, Headquarters Human Systems Center (AFMC) Brooks Air Force Base, Texas, USA

• Naval Aerospace Medical Research Laboratory, Naval Air Station, Pensacola, FL 32508 - 5700 USA

• General Microwave Company, 5500 New Horizons Blvd., Amityville, NY 11701 USA

• Holaday Industries Inc., 14825 Martin Drive, Eden Prairie, MN. 55344 USA

• Loral Microwave – Narda, 435 Moreland Road Hauppauge, NY 11788 USA

• Amana – A Raytheon Company, Amana, Iowa 52204 USA • 319-622-2142

• General Electric Company, Appliance Park, Louisville, KY 40225 USA • 502-452-4557

• Frigidaire Company, POB 7181, Dublin, OH 43017-0781 USA

• Maytag Company, One Dependability Square, Newton, IA 50208 USA • 515-791-8588

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The Cantenna

Microwave Oven Leakage Detector

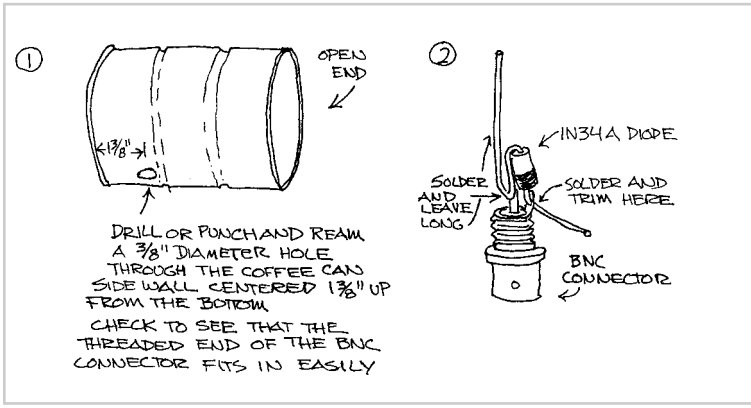
Homebrew

John Mills

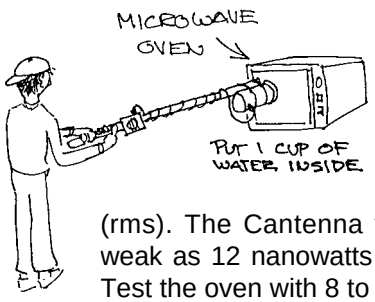
Most microwave ovens leak radiation around the door, through the vent holes,and where the power cord comes out. Some responsible scientists think that this leaking microwave radiation is safe. Other responsible scientists think that it is dangerous, especially for pregnant women and young people. Until we know more, it's probably best for us to be careful with leaking microwave ovens. The "Cantenna" is a simple microwave oven detector you can build for around $20.00 to listen to microwaves in your environment.

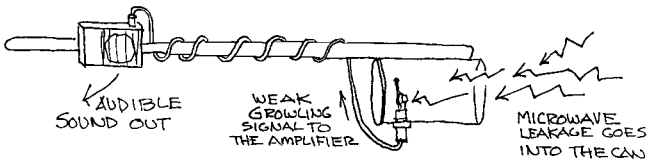
Turn It On and Stand Back!

Install the battery and turn the amplifier on with the volume to max. Point the plastic lid end of the cantenna toward a microwave oven that is turned on. If you hear growling noises from the amplifier this indicates you are picking up microwave leakage signals. Loud growling means more leakage.

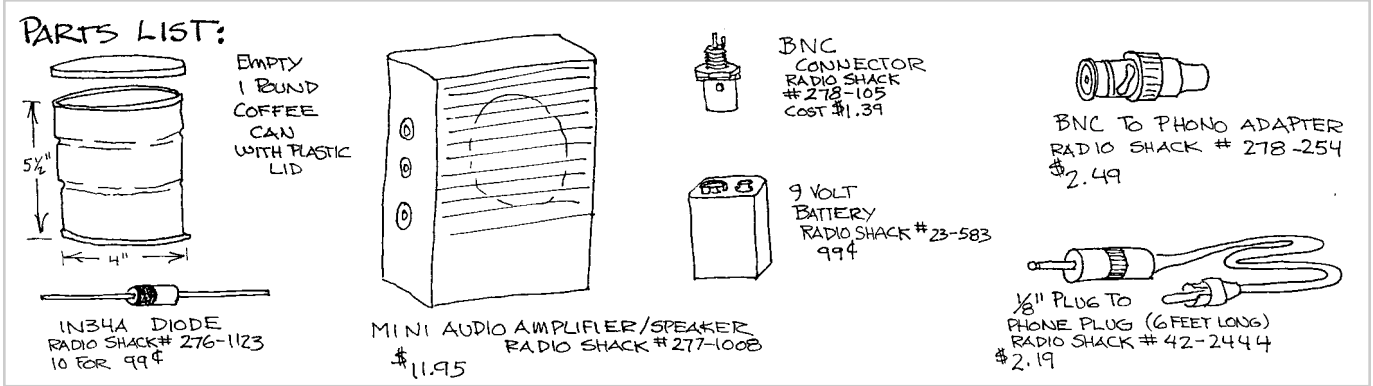


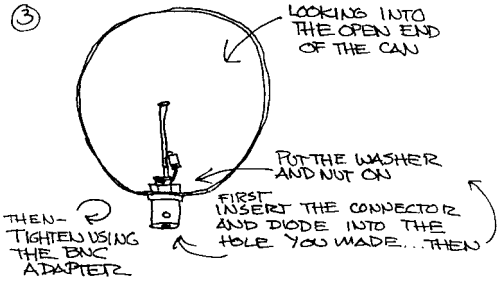
The Cantenna is 800 to 1000 times more sensitive than most professional instruments used to measure microwave oven leakage. For example, the Narda 8201 microwave detector can detect signals above 10 microwatts per square centimeter (rms). The Cantenna will pick up signals as weak as 12 nanowatts per square centimeter. Test the oven with 8 to 10 ounces of water and measure five centimeters from the oven surface. The U.S. government standard requires less than 1 milliwatt (1000 microwatts) per square centimeter (rms) for new ovens, and less than 5 milliwatts per square centimeter for ovens after use.

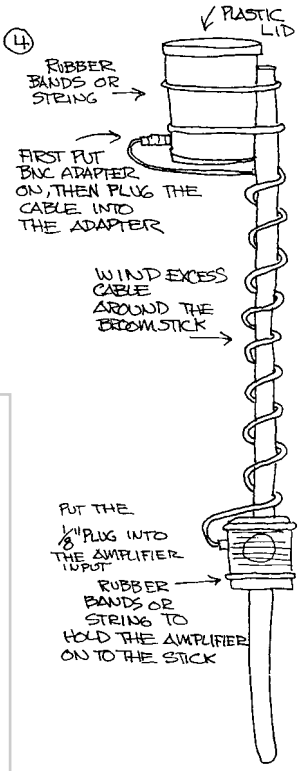




To reduce spurious signals, make sure to keep the audio amplifier away from the oven power transformer (usually in the back of the oven). Also, the diode is sensitive to light, so unless your coffee can lid is opaque, put black paper on the inside.







How it Works

The coffee can and the diode wire work as a mini antenna to collect the microwaves. The diode changes the microwaves into pulses that our ears can hear. The amplifier and speaker make the growling signal loud enough so that we can hear it. The broomstick lets the person making the measurement stand away from the oven for safety and the plastic lid on the coffee can keeps the metal part of the can from touching the metal parts of the microwave ovens.

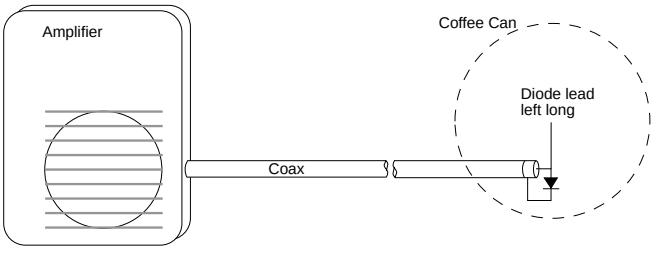
Access:

Author: John Mills, 10475 Vineland Rd., Ben Lomond, CA 95005

Parts: Your nearest Radio Shack

Technical Notes on the Cantenna Coffee Can Waveguide

The “Cantenna” is a circular waveguide to coaxial transition with a point contact diode mounted as a shunt element. The extended wire serves as an **E** (electrostatic) field probe. For the $\mathbf{TE}_{11}$ mode the circular guide exhibits cutoff at a wavelength equal to 1.7 times the diameter. The next mode will exist at 1.3 times the diameter. The coffee can is optimized for frequencies near 2.45 GHz but is sensitive to others as well. It has a polarization axis parallel to the **E** field probe and should be rotated during measurement for the



Things that Work!

Trace Engineering's 2512 Inverter

Bob-O Schultze - KG6MM

Six years ago, Trace Engineering introduced the 1500 series inverters. At the time, they represented a major breakthrough — a high efficiency, high reliability inverter. The Trace 2500 Series inverters are now ETL Certified to Underwriter Laboratories (UL) standards and output power is up to 2500 watts.

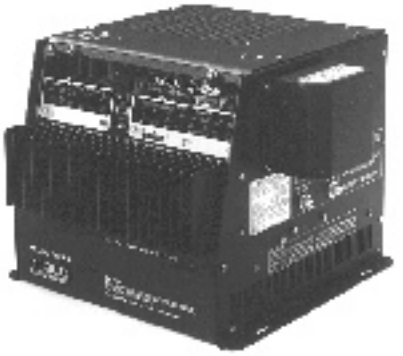
Inverter ABCs

Most American home appliances are designed to run on 120 volts of alternating current (vac) at 60 cycles per second (60 Hz). On the other hand, most renewable energy sources (photovoltaic, wind, microhydro) produce 12 or 24 volts of direct current (VDC) to be stored in batteries. An inverter is a device which electronically changes this stored, low-voltage DC power into the standard household voltage and current that most of our appliances love to eat.

The Trace 2512

The 2512 is a 12 VDC input, 120 vac 60 Hz output, powerhouse. It produces 2500 watts in continuous operation. RMS voltage regulation is ±2% of 120 vac and frequency regulation is crystal controlled to ±0.04%.

The new package has a thermally-activated cooling fan and adjustable low-battery protection as standard features. Both were options in the earlier 2000 series inverters. Insulated battery cable terminal covers and improved hard wire output connectors have also been added. The overall mechanical design has been improved by combining three circuit boards into one and seven chassis panels into five. This should reinforce an already outstanding record for reliability and ruggedness.



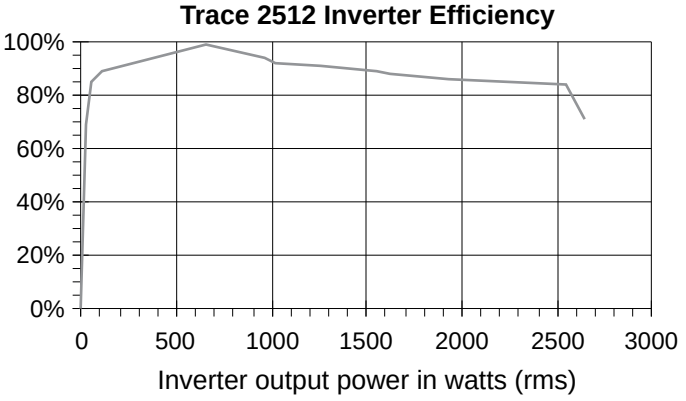
Certification

The Trace 2500 inverters are certified to UL1778 for commercial/residential and UL1236 in Marine/RV applications for the white cased “M” model 2512. What’s the difference? Well, a design known as “ground switching” is used for US Marine/RV applications. This feature disconnects the inverter’s internal ac grounding system when the inverter is connected to shore or RV Park power. The technique ensures that the boat/RV electrical system’s polarity will be set by the power’s source while hooked-in and the inverter when standing alone. Ground switching, however, is prohibited by the National Electric Code for commercial and residential applications, hence, the two separate UL listing and inverter configurations. Got a black cased 2512 in your RV? Not to worry, since all 2500 series inverters have the ground isolated from the chassis and the appropriate UL listing, they meet the RVIA guidelines as they now stand. The white cased inverters are designed to meet the stiffer marine service guidelines.

Certification means different things to different folks. To a licensed installer working with a local electrical inspector, it might mean a great deal indeed. To an RV or summer cabin owner installing an inverter for him or herself, a fancy sticker might take a back seat to reliability and safety. Part of the certification process requires the manufacturer to submit his product extensive testing designed to simulate years of use. Some of the testing included 14 hours in a vibration jig, 5,000 cycles of a 10G shock test, and 48 hours running at full 2500 watt output with the fan and all protection circuitry disabled! Ya gotta be tough…

Packaging and Documentation

I’ve mentioned before that Trace packages their inverters like they’re heading for the African bush via Land Rover. A stout cardboard box containing a molded 1¾” foam coffin surrounds the plastic wrapped inverter on all sides. Last spring I shipped a Trace to the US Midwest with a well-known carrier. Six weeks later it ended up in Georgia. When I finally got it back, the external box was all but shredded and generally trashed. The inverter didn’t have a scratch. Trace



owner's manuals are among the best in the industry. Fifty-eight pages of easy to read and understand instructions, diagrams, tables, and troubleshooting help.

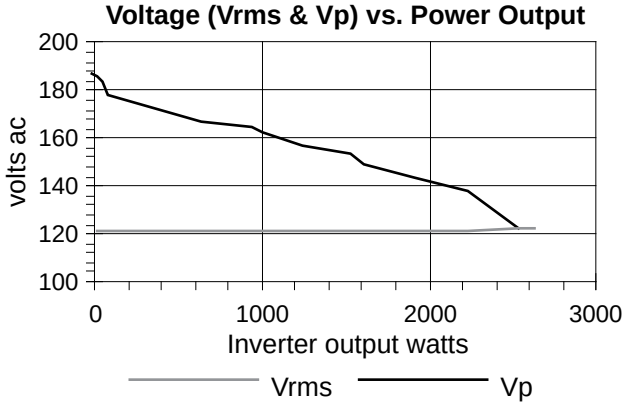
Options

Trace's best optional feature is the standby charger (SB). This is a built-in 3 stage battery charger and automatic transfer switch. It allows for fully-adjustable supplemental battery charging and equalization. For a complete, in-depth review of this feature, see *Home Power* #25, pp 58-60. Other options include a four function digital meter, a stacking interface which allows parallel operation of two identical 2500 series inverters for double the output power, and several remote control modules which allow the user to access the inverter functions from a distance.

Operation

The graphs pretty much speak for themselves. It's interesting to note that while Trace claims (and meets) only 85-96% efficiency from 50 to 2500 Watts output, the Home Power Crew's measurements indicated over 90% between 100 and 1200 Watts output. My experience tells me that most of a typical inverter's on-time is spent in this range.

Other insights about the 2512 were more subjective. I really like the new easily-adjustable low battery voltage cutout. By setting it rather high, a user can go away for an extended period leaving security lights, refrigerator, etc. on without fear of harming the battery system due to over discharge. A low setting, on the other hand, might allow a deeper discharge with a nickel-cadmium or nickel-iron battery system.



A few problem loads, like my ½ HP air compressor, started faster and surer than they did with the 2000 series Trace or some other inverters. I like the 30A circuit breakers on both the input and output connections. I had no trouble inserting 6 AWG wire into the wire blocks. That's a big plus if you need to move the power over some distance. All little things, yet...

Warts

All modified square wave (or modified sine wave, if you prefer) inverters that I've lived with inject a little noise into things. Telephones, tape recorders, and musical instrument amplifiers seem to be the worst. It ain't that bad, still...if I had my druthers, I'd druther not hear it.

Conclusion

Trace inverters quickly became the benchmark against which we've measured new inverter technologies. Trace upgraded the 1500 to the 2000 series. More power out, same price. Mid-1991 saw a vastly improved, easily programmable, standby battery charger added to the 2000 series. Trace's current model, the 2500 series, has upped the output again and gotten certified to UL standards into the bargain. If you take into account that two formerly optional features are now standard equipment, it's more power out, same price — again.

As I write this in April of 1993, there are more powerful inverters available than the 2512. Some inverters have matched the high efficiency and low "sleep mode" power consumption. A few have a better waveform. Still others are quieter. In other words, no one has invented the perfect inverter — yet. Trace still covers more of the bases better than anyone else.

Access

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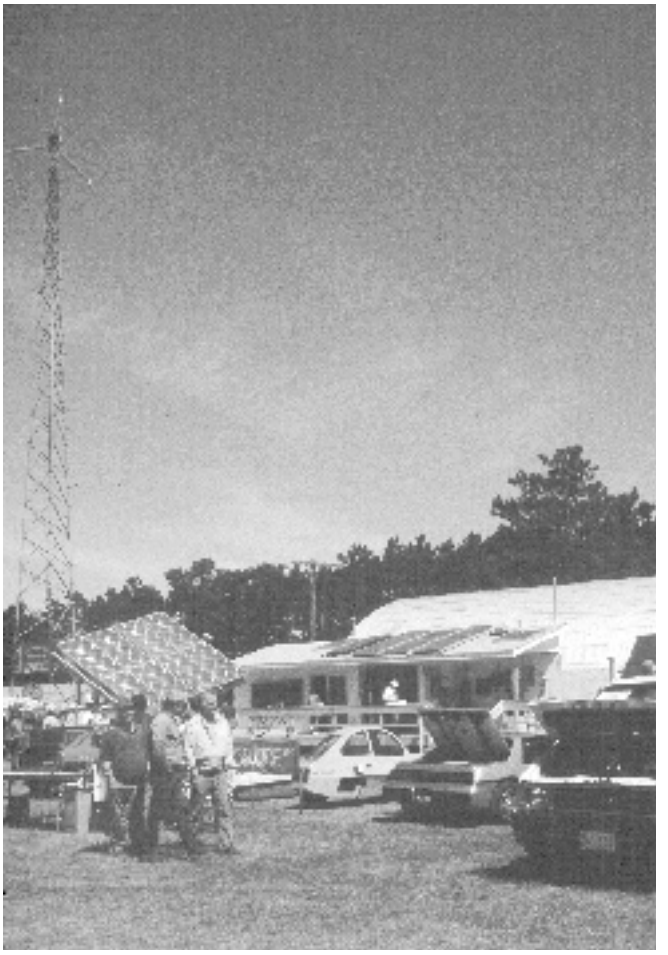

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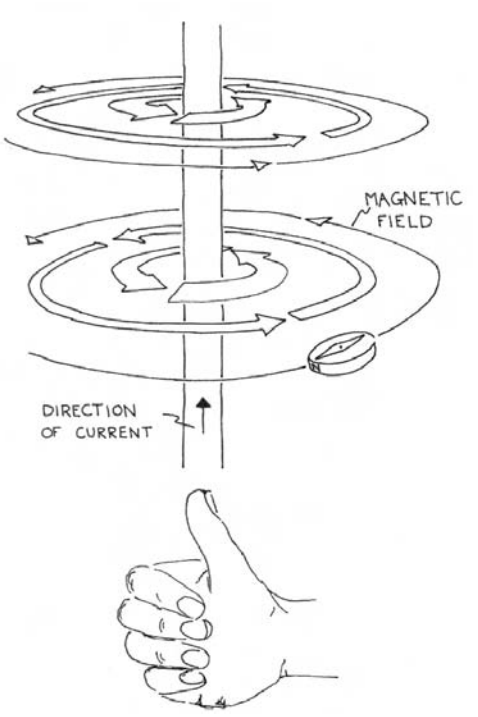
Getting the Buzz Out

Electromagnetism for Beginners

Chris Greacen

Any time electricity flows in a wire, a magnetic field is produced. In turn, a changing magnetic field can make electricity flow in a wire. This sounds innocent enough, but these two physical laws are the keys to the strange world of electromagnetism.



In renewable energy homes, microhydro and wind generators convert mechanical motion into electrical current by way of magnetic fields. Indeed, most of the utility electricity produced in the world is made this way. Transformers, DC to DC converters, and inverters use magnetic fields to convert power from one voltage to another, and from DC to ac. This link between electricity and magnetism is also the root of most obnoxious electrical noise problems in renewable energy homes. Notice a buzz on your stereo when your inverter is running? How about spurious lines on your television? Does your radio crackle and hiss when your charge controller starts regulating? Can you hear your inverter in your telephone? These are the sounds and sights of magnetic fields from your renewable energy equipment getting where they shouldn't. Knowing a little about how electricity and magnetism effect each other will give you a leg up in understanding how to reduce electromagnetic "noise" in your home.

Magnetism Basics

In physics, four equations called Maxwell's equations link electricity and magnetism. Let's take a non-mathematical look at two of them.

1) **Ampere's Law**: current flowing in a wire creates a magnetic field wrapping around the wire.

To determine the direction of the magnetic field, look at your right hand. Point your thumb in the direction the current is flowing, and your fingers wrap around in the direction of the magnetic field. This is called the "right hand rule".

The magnetic field diminishes in strength as you get farther from the wire. If the wire is a long straight single wire, its magnetic field decreases as $\frac{1}{r}$ where r is the distance from the wire.

2) **Faraday's law**: A changing magnetic field produces a voltage in a wire in the direction which opposes a change in current flow.

Snakes!

Imagine current is a stream of mice in a glass tube. They want to get to a hunk of Jarlsberg Swiss which Dr. Klüge has placed on top of the tube. This cheese provides the incentive (or voltage) for the mice to climb through the tube. We might expect that the more cheese is put on top, the more mice would attempt to make the trip. Also, if the pipe was wider in diameter (less resistance), more mice (greater current) would flow. To keep the mice from piling up at the cheese, Dr. Klüge removes them from the cheese after a small nibble. So far, so good, for the mice...

Note: None of the mice are harmed by this experiment. In fact they don't mind the boa constrictor — they only mind it when she grows!

The Boa Constrictor

But there's a strange bit of magic at work. The travelling mice create, as a bizarre product of their collective unconscious, a boa constrictor (magnetic field) wrapped around the tube. The more mice travelling in the tube, the bigger the boa. Now remember, this is an imaginary boa. It doesn't eat any mice. But still, seeing this boa appear from thin air is disturbing, especially if you're a mouse. Understandably, some of these mice re-evaluate the relative merits of eating cheese — at least right away. But some of the brave mice continue.

Strangely enough, these mice don't mind the boa constrictor, as long as she doesn't grow. If the stream of mice is constant, the boa doesn't grow, and the mice decide it is safe after all. Of course, the more mice running through the tube, the bigger the boa grows... There's a balance reached in the steadily growing stream of mice that run through the tube, keeping the boa growing slowly enough that the fear of the growing boa (and the crowding in the tube) is outweighed by their desire for cheese.

Eventually a limit is reached caused by crowding in the tube, how fast the mice can pile out of the cage, and how fast Dr. Klüge can put them back into the cage. In an electrical circuit, the limit is determined by the circuit's resistance.

The Cheese Is Gone

Once the Boa is nice and fat, Dr. Klüge takes back his hunk of gnawed Jarlesberg Swiss cheese, but he stays at the tube to watch what happens. For an instant the mice no longer have an incentive to go through the pipe, and as the stream decreases, the boa starts to shrink. The shrinking boa has the opposite effect that the growing boa did. All the mice want to catch a glimpse of the snake before she disappears. Even without the cheese, mice are enticed to journey through the tube. The faster the boa shrinks, the more frantic the mice are to see the snake before she's gone. But again, the more mice, the slower the boa shrinks, and the less incentive the mice have to travel in the tube. Again a balance is reached in the steadily decreasing stream of mice. Eventually the stream dies to zero, and the snake disappears.

Ok, so it's a strange way to imagine electricity and magnetism. If you come up with a better way which doesn't involve large imaginary snakes and small rodents, let me know. It does have one thing going for it: the symbol for magnetic field is **B**. Think **B**oa.

To recapitulate:

• apply cheese (an external voltage like a battery)

• mice start up the tube (current starts)

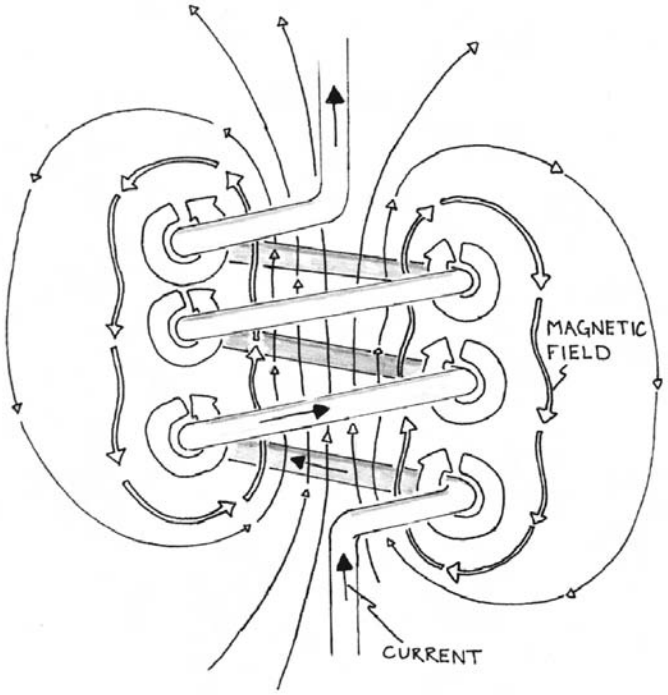
• the bigger the stream of mice, the bigger the boa (magnetic field wrapping around wire is proportional to current in the wire)

• The faster the boa grows, the less the mice want to make the journey (a growing magnetic field induces a proportional negative voltage which opposes growing current)

• Remove the cheese (remove the external voltage)

• Shrinking boa entices sight-seeing mice (a shrinking magnetic field induces a proportional positive voltage encouraging current to continue to flow).

The snake adds "inertia" to the stream of mice. It makes the stream of mice harder to get started, and harder to stop. In a circuit, this inertia is called induction, and a circuit piece designed to cause induction is called an inductor. If it causes lots of induction, it is said to have high inductance. The inductor stores energy building up the magnetic field, and releases it as the field collapses. The energy stored in an inductor's magnetic field is equal to $\frac{1}{2}LI^2$. L is the inductance measured in Henrys, and I is the current in Amperes.

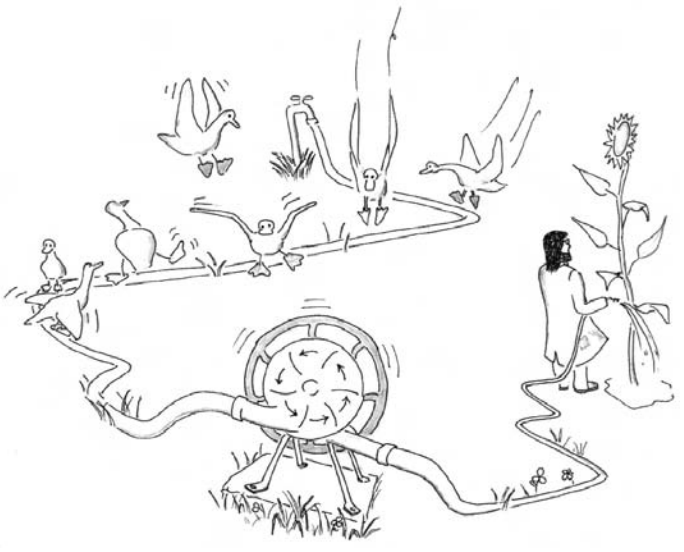


How to Increase induction

A straight piece of wire has very little inductance. To increase inductance, make the wire into a coil. Two things happen. First, current in each turn of the wire creates a magnetic field wrapping around it. Inside the coil, these magnetic fields add to make a strong magnetic field in the center. Therefore, in a long tightly wound coil, the magnetic field inside is proportional to N, the number of turns. Second, when the magnetic field grows or shrinks, it crosses over each wire turn. So the voltage induced in the wire from a changing magnetic field is also proportional to N. These two go together to make up inductance. For a tightly wound inductor, the inductance (the "inertia" of the current) is proportional to N^2. The mice would see the snake growing N times as fast. But even if the snake didn't grow N times as fast, the mice would still be N times as reluctant to go to the cheese because they'd have to pass through the boa's coils N times. To make even more inductance, stick a hunk of iron inside the coil. Magnetic fields like to travel through iron much more than they like to travel through air. Iron inside the core can increase inductance by thousands of times.

Dr. Klüge's Plumbing Inductor

Dr. Klüge's ducks are back. The good doctor has found, to his annoyance, that they derive great joy from jumping up and down on his garden hose when he



goes out to water his sunflowers. Dr. Klüge, as always, has found a technical solution: a plumbing inductor to smooth out the flow of water. When he turns on the faucet, current flows slowly because it has to get the turbine and the flywheel spinning. When ducks jump on the hose, the inertia of the flywheel keeps the pumping water, maintaining an even flow as the flywheel slowly looses momentum. When ducks jump off the hose, the flywheel gains speed. In this plumbing model, the heavier or bigger the flywheel more energy. moment of energy it can store — and the less it allows pressure pulses to pass. In an electrical inductor, it's the same story: the larger the inductance, the more energy it can store, and the more it resists voltage changes.

An electrical inductor is useful in a similar problem. The output of modified sine wave inverters have sharp, abrupt changes in voltage and current. This is like the ducks jumping up and down on the hose. If your radio is plugged into your inverter, and it buzzes, adding series inductance might help by smoothing out these abrupt voltage changes. Ac line filters, available from many electronics stores, are commercial products which do this.

Broadcasted Magnetic Fields

The magnetic field from a long straight wire (like a single power line) is most intense right next to the wire. Away from the wire, the field decreases in strength as ⅟. Go twice as far away, and the field is half as strong. If the source of a magnetic field is a single object (like an inverter or a transformer) then the magnetic field drops off faster than ⅟.

Faraday's law said that changing magnetic fields will induce voltages in a wire. It didn't say anything about where these changing magnetic fields have to come from. In the snake and mice example, the current in the wire made a changing magnetic field which affected current in the same wire. But also, changing current in one wire will induce voltages in a neighboring wire. This is the principle behind radio. The radio station makes big changes in the current in their transmitting antenna, making big changing electric and magnetic fields. This forms an electromagnetic wave travelling outward in all directions, with power sloshing back and forth between an electric field and a magnetic field (see your favorite physics book for more on this). Miles away, the antenna on your radio is the "neighboring wire" with induced voltages from these changing magnetic fields. Your radio changes these voltages into signals you can hear.

Unfortunately, inverters, linear current boosters and some charge controllers and generators also act like radio transmitters. These devices can make big pulses of current in your wiring. Then your electrical wiring acts like an antenna, broadcasting noise. The effect is strongest in low voltage wiring because of big current pulses, and magnetic fields are proportional to current (Ampere's law). The result is a buzz or crackle in anything which works as radio receiver (your radio, TV, or radio telephone).

Reducing Electromagnetic Noise

Since field strength drops off the farther you are from the source, the first solution to noise problems is to banish the offending electromagnetic banshee to the hinterlands. Put your inverter out in a "power shed" away from your house. Avoid running your stereo speaker wires and telephone wire parallel to or next to power wiring. Also, establishing a good ground (with a ground rod) for radio, etc. will help reduce noise.

For more reduction, twist long positive and negative (for DC) or hot and common (for ac) wires into a twisted pair. Since equal currents travel in opposite directions in the two wires, they create magnetic fields which oppose and cancel each other. The hundreds of feet of large gauge wiring to our PV arrays form potentially a huge antenna. When our charge controller begins regulating, the full current from the pvs is quickly turned on and off. Changing currents means changing magnetic fields, which means a broadcasting antenna. To reduce the broadcasted energy, we twisted together the hundred of feet of 0 gauge copper wires (Grunt!) going to each array. This is done with five good humored people — one at the middle of the two wires, and one at each end, in a May-pole like dance with the wire ends. Twisting small signal wires will reduce the noise they pick up.

The next step is shielding. If wires are encased in a grounded conducting sheath (like metal conduit), then the electric field in an electromagnetic wave is grounded out, and therefore much less electromagnetic noise escapes. A conducting shield with high "magnetic permeability" can provide some isolation from magnetic noise.

For more on magnetic fields see:

Health Effects: "ElectroMagnetic Fields and Home Power Systems", *Home Power 23*, p.24; "Reducing AC Magnetic Fields", *HP 24*, p.62; "Some Environmental Hazards of Lighting Systems", *HP 30*, p.32.

"Yer Basic Alternator", *HP 20*, p.10; "How Electric Motors Work", *HP 34*, p.38

"How an Inverter Works", *HP 23*, p.53; "What's an Inverter", *HP 32*, p.22; Linear Current Boosters, *HP 29*, p .53; *HP 12*, p.19; *HP 17* p.39; *HP 25*, p.16; *HP 28*, p.34.

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Sir Thomas Lipton — 1870

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Preparing for a PV Future

Allan Sindelar

The United States currently has a surplus of electric generating capacity. However by the year 2010, the Department of Energy estimates that 248,000 megawatts (MW) of capacity will be needed for new generation, as well as to rebuild or replace old power plants. Although no one expects PVs or even renewables to supply all of this power, PV technology can impact our national energy economy. Each article in this series on utilities and PVs will focus on a different aspect of the growing public and private utilities involvement in PVs. This article describes recent national efforts to hasten its commercialization.

Recent Beginnings

In December 1991, key players from the PV industry, Department of Energy, utilities, regulators, state energy offices and consumer advocacy groups convened in Tucson, Arizona to discuss how to stimulate utility use and commercialization of PVs. This workshop was unique—some have said magical—in that these stakeholders met not as adversaries but as potential collaborators. Two major recommendations were drafted at this meeting: that the utilities should form their own users' group, and that collaborative groups should form at the state level. Out of this were formed the Utility Photovoltaic Group and the Photovoltaics for Utilities initiative.

The Utility Photovoltaic Group (UPVG) is a new nonprofit national organization of utilities and their trade groups. It is organized specifically to represent the utilities' perspective as potential PV buyers. Its mission is "to expedite and facilitate the deployment of cost-effective and emerging high-value applications of PVs for the benefit of electric utilities and their customers." To date, the UPVG has just over sixty utility members.

Photovoltaics for Utilities (PV4U) has a broader function. It is made up of individual state working groups, and is structured more as an initiative than a formal organization. This is because many of the issues that will be addressed are state-based, and vary substantially from state to state. The investor-owned (or private) utilities are regulated by the states rather than by the federal government, and each state has its own policies and practices. The PV4U state working groups have formed an alliance to communicate with each other and coordinate their efforts. Since no one state has all the ingredients, a collection of states together can form innovative and creative ways to best integrate this technology into the mainstream.

About a dozen states have formed PV4U State Working Groups. Membership varies from state to state, but maintains the same basic representation as at the Tucson meeting. Most working groups include member utilities, state energy offices and public utility commissions, ratepayer advocacy and intervenor groups, and module and balance-of-system (BOS) hardware manufacturers. Some state groups also include federal power agencies and laboratories, commerce departments, universities, and organizations such as the Union of Concerned Scientists and Greenpeace.

The Uniqueness of PVs

Photovoltaics are unlike any other energy source that has ever been available to utilities. PV generation requires a large initial expense, but the fuel costs are zero. Coal- or gas- fired plants cost less to build initially (relative to their output) but require continued fuel expense. Fuel expenses fluctuate and are difficult to predict due to the uncertainty of future environmental regulations. Fossil fuel prices will rise over time, while the overall cost of PVs (and all renewable energy resources) is expected to continue to drop, especially as their environmental advantages are valued.

PVs are also unique in that their modular nature ignores traditional economies of scale. Systems range in size from a few watts to a megawatt or more, and the value of the electricity produced by a PV system varies according to its location and situation. This allows for distributed generation, where a small amount of power is carefully matched to a specific need and produced close to the point where used. This is worth more to the utility than a larger amount produced at a large, distant power plant. For example, commercial buildings use most of their power during daylight hours, and use much more during summer than winter because of air conditioning. The utility must size its transmission and distribution (T&D) equipment to handle the maximum

amount of electricity that will ever be needed, even though the T&D equipment is generally used well below its capacity. If each of these buildings had a PV array on its roof that was sized to offset this peak demand, the entire distribution system serving these buildings could be downsized. This adds the savings in T&D costs to the bulk value of the electricity produced by the array.

PVs offer many other nontraditional benefits. These solar benefits include improved power quality and reliability, reduced transmission losses, lower maintenance costs, and myriad environmental benefits. But most utility economic analysis is still based on central-station planning. To understand and quantify these benefits requires utility planners to create and use entirely new analytical models that realize the unique characteristics of PVs.

The Problem

Until the 1973 oil embargo, utilities operated on business and economic principles based on "bigger is better". As larger central plants were constructed the cost of electricity went down. Consumers were encouraged to use more electricity in order to lead to further economies of scale. Environmental concerns, rapidly rising fuel prices and high interest and inflation rates in the 1970s abruptly ended this approach. Increasing facility size now raises costs. Most utilities have directed their focus toward transmission and distribution improvements, rather than new centralized generation.

Until recently, PVs' potential has been seen in accordance with this old model. The expectation was that laboratory breakthroughs would lead to such significant cost reductions that PVs would be cost-effective in large bulk power plants. This has not happened: technology improvements have been incremental, and have not contributed to significant cost reductions in recent years. Balance-of-system (BOS) costs, which generally have accounted for about half of total system costs, have been equally slow to drop.

Production volume can bring costs down through economies of scale. PV prices have averaged a steady decline over the last twenty years as production has increased. Historically, PV module prices have dropped by 20% for each doubling in cumulative production volume. At this historic rate, the amount of production necessary for an additional 20% drop will take five years or more. This pace will not create sufficient demand to increase PV production enough within the next few years to supply much of our anticipated need for new energy by 2000 or 2010.

More than sixty utility applications using low power (5 W to 10 kW) PV systems are cost-effective to utilities today. While the number of these niche applications (which include water pumping and remote small-scale systems) is high, their total kW capacity is small. PG&E of California, for example, is considered the national leader in the use of early cost-effective applications, yet its 1000 systems total less than 44 kW. Crude estimates have placed the total market potential for low power PVs at around 100 MW. A study of 25 rural electric cooperatives in Colorado and nearby states indicates a market potential for remote water pumping alone of 3 MW.

While these figures are significant, the consensus within the PV community is that the sum of the current cost-effective utility applications is inadequate to allow module manufacturers to substantially increase production. The demand for modules is not enough for the PV industry to ask their investment community for expansion capital. Occasional large purchases by a utility are not enough to effect price reductions, and may dry up the market and increase prices rather than lower them. All of this leads to the central "chicken or egg" problem facing large-scale commercialization of PVs: declining costs require large purchases, and large purchases require declining costs. At current selling prices, the domestic market potential is capped near present production levels, a cap that exists because PVs are now competitive only in niche applications. Until production volume increases, prices will remain too high to permit the mass utility purchases of PVs necessary to bring prices down.

A Two-Tracked Plan

UPVG's challenge is to capture the increasing public enthusiasm for utility scale PV use while expanding the market beyond current cost-effective applications. The goal is to create an accelerated market for suppliers of PV systems that allows investments in larger manufacturing facilities. This will reduce PV unit costs through economies of scale and generate even broader market potentials.

The UPVG's work will be done through two parallel tracks or themes. The first track focuses on promoting current cost-effective PV applications. Awareness of the use of PVs is limited among most utilities, and education will be a fundamental goal of the UPVG's work. This effort can also give traditionally conservative utilities low risk firsthand experience with PVs. It can help them to establish procurement procedures, specifications, and follow up support.

The real potential for driving PV costs down lies on the second track, in emerging high-value applications. These are larger-scale, grid-connected, distributed generation PV systems. PV technology has a number of indirect attributes which are not included in traditional

utility economic analyses (such as reliability, flexibility, lower financial risk, and no military costs). As new accounting methodologies are adopted reflecting these values, the cost gap will close toward further cost reductions. Most utilities are not yet aware of these high-value applications and their nontraditional benefits, so the first task is educating both utilities and their regulators. The next task will be encouraging high-volume PV purchases.

The Diffusion Model

The current thinking among progressive utilities includes the "diffusion model" of PV commercialization. Here high-value applications are developed and filled, then the next value level developed in a logical progression. This model suggests that while system costs remain high, utilities will use PVs in remote applications where new distribution lines are too expensive. As prices drop, PVs will expand into grid-connected applications. Using the distributed generation model cited earlier, PV systems will be placed on residential and commercial rooftops, as well as in ground-mounted, utility-sited installations. Finally, when costs drop substantially, PVs may be used for peaking and bulk power in large centralized power plants. Doubts persist whether this level will ever be developed, as it requires major breakthroughs in PV and BOS technology. Both wind power and bulk solar thermal electric power have clear economic advantages over PVs for these applications.

Three Central Concepts

The California PV4U Working Group has developed a model commercialization strategy to increase production and decrease PV prices. This strategy is based on three concepts. The first, called "sustained orderly development", means simply that the solar industry needs a reliable and long term market volume for expansion. This volume will be achieved through multi-year, substantial and sustained utility purchases of PVs.

The second concept is called "commercialization path life-cycle costing". This concept states that higher costs for early applications are a good investment if they contribute to accelerating lower costs and higher performance. Most utility purchases of generating capacity are based on economic analyses of costs and benefits over the particular project's lifetime. This strategy requires that analyses be based on the life cycle of the entire PV commercialization path.

The third concept is termed "proactive leadership to stimulate early adoption". According to this idea, the passive approach suggested by the diffusion model will not result in sufficient purchase commitments to allow the needed expansion of PV production. Utilities and other bulk buyers must commit to the proactive role of early and sustained purchases permitting the industry to invest in expanded production.

This is not, however, a one-sided utility subsidy to the PV industry. It requires, in turn, some form of aggressive pricing of modules and BOS components with short term selling prices at or below manufacturing cost. With sustained purchases of PVs, production costs will decline. Manufacturer losses during the early stages will be recouped through ever-increasing sales volumes at prices exceeding production costs. In addition, incremental decreases in PV system prices will make already cost-effective applications more cost-effective and will open new market niches. Thus this strategy intends to assure manufacturers' financial stability and business viability.

Opportunities for the PV Industry

The market for PV modules is growing at an average rate of about 30% per year. In 1991 U.S. manufacturers shipped about 16 MW of modules worldwide; of these, about 1 MW went to grid-connected applications. This number is tiny compared to overall utility generating capacity, but new sales of a few to tens of MW to utilities represent a substantial increase in volume for PV manufacturers and installers.

PVs have been a mom-and-pop industry at the distributor and dealer levels. The playing field is changing as utilities begin to get involved. Few of the 3200 utilities in the U.S. will be hiring PV specialists in the near future, and fewer still are large enough to afford to develop custom designs when standard packages could do. Most utilities will use outside contractors to supply packaged systems. The potential market for both small-scale and emerging grid-connected applications presents an opportunity for systems distributors and installers who will service the utilities' requirements.

Most utilities do not know how to specify their standards for PV systems, and most suppliers do not know how to serve utility customers. Utilities' needs are very different from those of the typical home power user. Specifically, utilities need complete PV system packages that meet their standards of acceptance. Utilities apply a "turnkey" perspective that includes capital, construction, and operations and maintenance costs, as well as system operability and reliability. They expect guaranteed performance, on-time delivery, package warranties, and industry safety standards. To broaden utility acceptance of PVs, the people involved in utility planning, operating, and customer service must be presented with systems that fit their requirements.

If the PV industry will be ready to supply a substantially expanded utility market by 2000 or 2010, the process

must begin today. Markets develop slowly. Each utility using PVs must complete its testing and evaluation processes. Suppliers must learn the utilities' needs at an early stage, to allow themselves time to engineer packaged systems to meet these requirements.

Two important considerations must direct the accelerated commercialization process. The first is not to set up false or misleading expectations, as happened with early PV bulk plants. The other is to create a sustainable market that will not die away with another change of administration or policy.

Nobody knows whether these commercialization efforts will succeed. This entire strategy could be affected by aggressive marketing efforts by overseas manufacturers, as happened in the consumer electronics industry. Within the PV4U initiative itself some people are pushing a "let's really get moving" acceleration of the commercialization process. Others prefer more of a research work plan than a commercialization work plan, and would rather proceed at a slower pace.

Personal Observations

The potential benefits of large-scale utility PV involvement outweigh the risks. The utilities will both invite and demand the PV industry's maturation, and the benefits of lower costs to the utilities will spill over to home power users. Standard designs and packaged systems will make home systems more familiar to building inspectors and bank lenders. Utility involvement will give PVs a mainstream recognition that can be of tremendous benefit to local dealers and installers.

This scenario is not without its risks. The widespread availability of reliable packaged power systems in remote areas could open many rural and semi-wilderness areas to residential and commercial development. Also, it is practically inevitable that as the PV industry grows it will attract the interest of big business. Indeed, this process has already begun. Whether this growth spawns a new generation of local entrepreneurs, or small business integrity and personal attention are drowned by the growth of another consumer industry, remains to be seen.

The PV business is changing. PVs have the capacity to fundamentally change how utilities are structured. The better informed we are of these potential changes, the better we will adapt to them and benefit from them.

Many of the ideas and concepts in this article have been compiled from the working documents of the groups I have discussed. These include the Program Development Plan for the Utility Photovoltaic Group, the (draft) California PV4U Commercialization Strategy, and the PV4U State Working Group Handbook.

Special thanks to Kay Firor of Blue Mountain Energy and Jane Weissman of PV4U for their assistance with this article.

Access

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You Can Give Solar a Boost

Michael Welch

Home Power Magazine is officially kicking off its "Put Solar Panels Back on the White House" campaign. President Carter, during his term, installed a solar hot water system on the White House. This was part of his campaign to increase national emphasis on renewable energy, conservation and energy efficiency. When Ronald Reagan took control, one of the first things he did was to tear the panels down.

Now, the solar industry has grown and developed reliable and cost effective products, a symbolic boost from the Clinton Administration would do wonders for the industry. We will be taking this letter writing campaign with us when we visit various energy fairs this summer. If you'd like to help us in getting more letters written, please call or write me. It would be wonderful to have a letter writing booth set up at every energy fair and other community events throughout the nation.

SAMPLE LETTER TO THE WHITE HOUSE

Dear President Clinton and Vice President Gore,

Please re-install solar hot water panels on the White House. You have the opportunity to send a powerful message to the people of the United States. It is time for Presidential leadership to put our nation back on the path of renewable energy, conservation and efficiency.

At the same time, please invite our nation's energy leaders and the press to participate in a public dedication of the new solar hot water system to let all citizens know that they, too, can contribute to a clean energy future for the entire nation.

Please also introduce legislation to improve the watered-down version of the National Energy Bill which passed last year before you took office.

Sincerely, Pat Q. Solar Everywhere, USA

It's important to write your letter right away. OK, OK, I know how hard it is to put down the new issue of HP until you have completely gone through it. Might I suggest that you place a paper clip on this page now so that you will remember to go back and write this letter, then send it to:

The White House
1600 Pennsylvania Ave. NW
Washington, DC 20500

Please don't underestimate the influence that your letters can have. Politicians usually want to hear from their constituents. It gives them the opportunity to do what you want rather than what the special interest groups are constantly pressuring them to do.

The sample letter should only serve as an example of what you could send to our President. A personalized letter will carry much more weight than a form letter, so if you have time, make it as unique as possible. Be sure to include the major points of solar panels on the White House, positive publicity for the solar industry, and an improved National Energy Strategy.

Some additional points you may want to include in your letter: • A symbolic boost to the solar industry could develop thousands of much needed new jobs without spending tax dollars to directly create them. • In the 1970s and '80s, the first efforts to assist the solar industry were marred by fly-by-night dealers who took improper advantage of customer tax incentives by offering shoddy equipment, design and installation. Since then, the solar industry has managed to mature greatly. Now, solar is ready to serve our nation well, especially if it can get a much-needed symbolic boost from the Clinton Administration. • Mention that a renewable energy future is so important to you, that you are willing to have your hard-earned tax dollars go to boost that industry rather than the expensive and polluting fossil fuel and nuclear industries. • Encourage the Clinton/Gore philosophy that polluters should pay while clean industry should be rewarded. • Urge the administration to adopt the provisions in the "Sustainable Energy Blueprint and Budget" as presented to President Clinton by renewable energy proponents earlier this year.

Readers Feedback

I do want and appreciate your feedback on this column, and I'd like to encourage you to continue sending me information and ideas for future Power Politics columns.

Here are a couple of comments I'd like to pass on. Mick Sagrillo felt that the Clinton administration included hydroelectric as taxable in their new energy tax plan because that particular technology is fully matured and could not benefit from a tax advantage over other technologies, not to discourage the damming of rivers as I reported in my last column. Steve & Sherry Robertson wrote to suggest, among other things, that removing the heavy government subsidization of oil production should be the Clinton Administration's first step, rather than starting with the energy tax on fossil fuels. Sounds like a great idea.

Access

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Codes and Standards

John Wiles

Like many behind the scenes areas of society, codes and standards are not in the public eye, are somewhat dull and boring and, at best, cause gleams only in the eyes of engineers. The renewable energy user and dedicated enthusiast should be aware of the fact that codes and standards have a very direct bearing on the performance and safety of their electrical power system.

The Photovoltaic Power Industry is rapidly spreading beyond its grass-roots beginning and sustaining audience. The U.S. Coast Guard and the Forest Service are PV converts and ever growing users. Billboards are being illuminated all across the country by PV systems. Utilities are installing PV systems from 10 Watts to 500 kiloWatts (both grid connected and stand alone). Municipalities are finding that PV systems are cheaper than grid power even in central urban areas. Numerous residential consumers are being shocked into PV systems when they are told the costs of slightly remote grid connection. Public Service Commissions in many states require that the utility company provide the potential customer with a list of suppliers of alternate energy systems.

Renewable Energy Systems Are Not Standardized

At the present time, much of the equipment that goes into PV systems is not being produced to any particular standard. Three manufacturers (Siemens, Solarex, and Tidelands Signal) produce modules that are tested and listed to the same Underwriters Laboratories Standard; other modules that are widely available are not manufactured to any nationally recognized standard. Heart, Trace, and Dimensions Unlimited produce listed inverters, but they are listed by different testing agencies to different standards. Ananda Power has their Power Center listed by UL, and it includes a charge controller, but there are no separate charge controllers that are listed. DC-rated, UL-listed load centers, switches, fuses, and circuit breakers are available to the PV dealer/installer, but there are substantial amounts of non-listed equipment being manufactured and used by the PV industry. What is the import of using non-standardized equipment?

Safety and Performance Are The Issues

In practical terms, while the system may appear to work, it may not be working efficiently or safely. In some systems, if a fuse were to blow or circuit breaker to open under fault conditions, the charge controller might not respond well to the new configuration and be destroyed. If disconnects are in improper locations or opened in the wrong order, the charge controller may be damaged, or unsafe voltages might be applied to the load circuits. If accidental grounds occur, the charge controller might not be able to control the charging process properly.

When non-standardized generators and inverters are connected to the ac load center, currents can travel in unexpected, unsafe paths and create hazards (see Code Corner in *Home Power* #34).

The improper selection of cables for the PV array wiring and the battery to inverter wiring can cause fire hazards, particularly if overcurrent devices have not been used.

Ac Systems Are Standardized

The alternating current power system that has been in residential and commercial use in the U.S. for the last 80 plus years is relatively safe because all of the equipment commonly used is built to standards written by Underwriters Laboratories (UL). Every piece of equipment in the ac system bears the UL mark, from the 19-cent plastic outlet cover plate to the service entrance load center. This UL-listed equipment is installed in a manner that meets the requirements established by the National Electrical Code (NEC). The NEC was first printed in 1897 and has been revised every three years under the auspices of the National Fire Protection Association by professional volunteers from throughout the electrical power and equipment industries. Licensed electrical contractors or trained electricians install the equipment to NEC requirements.

Standardized equipment with specifically defined interfaces, when installed using a code that is in harmony with the equipment standards, provides for a safe, durable, and high performance electrical power system.

Renewable Energy Users Unite

Users of renewable energy should be afforded the same levels of safety and performance that the ac users of the nation enjoy. They should demand standardization of the equipment and compliance with

the appropriate codes. Standardization is coming and code compliance can be achieved today.

The NEC has had a section on PV since 1984 and 90% of the remainder of the code is applicable to any electrical power system including renewable systems. The user has to require that his or her installer meet the NEC requirements. An electrical inspection by the local inspection authority will help to ensure that the system is safe.

The author of this column had four changes accepted for the 1993 NEC and is submitting over 40 changes for the 1996 code, all of which will benefit the renewable energy industries and the renewable energy user.

The author is also working, under the sponsorship of Sandia National Laboratories, with the Institute of Electrical and Electronic Engineers (IEEE) and Underwriters Laboratories to get standards published for inverters and charge controllers.

Standards and Codes won't solve all of the problems that we face. Sometimes "Things Don't Work." PV equipment manufacturers need to continue to improve the basic product and build it to the available standards. Dealers and Installers need to learn more and more about their trade. Systems that have been installed by a team consisting of the user, the dealer/installers, an electrical contractor, and the electrical inspector have proved the most durable, the safest, and the best performing. Consumers should expect and demand nothing less.

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For details, see HP#33, p. 58, or call 916-475-3179.
Home Power, POB 520, Ashland, OR 97520

Building a Home Business

Mark Newell

If you are hot on the trail of an idea for a home business, chances are that you have been daydreaming about all the things that you can do, how nice it would be to have the freedom, the independence, the.... STOP! Reality check! Developing a business plan will help you get a clear idea of just what kind of project you are getting into. Lets look at each of the foundation pieces of a home business: your product, market research, start-up expenses, and local, state and federal permits and licenses.

Your Idea

You know what your product is, right? Can you write it in twenty words? How about ten? The point is to see if you can write down exactly what you want to do. Now is the time to be specific as possible. Trying to take on too many things at one time, especially in the beginning, can cause you to go in too many directions at once. Next, think about why people are going to want your product and then describe why your idea is a good one.

Market Research

A key element of your business plan is your market research. This cold, commercial term is really just a means of helping you "look before you leap". It is like listening to the weather report before going sailing, instead of just assuming that the weather is perfect. Getting out there and doing your homework is really critical. The rest of the plan is just nuts and bolts. Start with your market, your customers. How will you find customers and keep them? Do you expect to find them through advertising, and if so where? Name specific places. Are there enough people who want your product for you to make a living? You need money spending customers, not just interested, supportive friends.

The next step is to analyze the competition within your market. First of all, who is your competition? Consider talking to them. Developing a positive relationship with your competition can be helpful. Are they doing well? Why or why not? Why should customers come to you over an established business? This is a good time to think about what will make you different, what will your way of standing out. Some reasons could be a different product, better service or faster response.

Start-up Capital

Capital is a business term for all money invested in a business. Included are all equipment, inventory and cash. Start-up capital is the amount of money needed just to get started. Started, however, is a general term. When figuring your start-up costs, plan on enough money to keep the business running for six months to a year before seeing a profit, and longer before it will support you.

The amount of start-up money needed will vary tremendously with the type of business. As you plan your budget think about tools, office supplies, and initial inventory. Do not forget to figure in your living expenses as you look at your budget. As a home business, you don't have rent as an expense that kills many start-ups. But there are some universal costs of starting a business that you have to plan for. These include permits, licenses and insurance. You may have to hire a lawyer to help you wade through all the regulations (especially to set up a corporation). Before we get to specifics on these start-up fees we need to take a quick aside into the world of legal structure.

Legal Structure

There are two basic business structures, incorporated and unincorporated. There are two variations on the unincorporated theme, sole proprietorship and partnerships and several types of corporations. The most common choice for small businesses is a sole proprietorship. It is the simplest to set up and the most regulation-free. All that follows applies specifically to a sole proprietorship, though some may apply to incorporated businesses.

Regulations and Fees

Regulations and fees vary from state to state and county to county so you need to make some calls to get the specifics on what will apply to you. You may call anonymously if you like.

Start with your city or county. There almost certainly will be a local business license. If you live within city limits check with the city hall, otherwise count on one from your county. You will, as a sole proprietorship, have to file a Fictitious Name Statement, or Doing Business A

Statement, with the county unless you use your name as the business name. There will be a filing fee and you will have to refile every five years or so. Watch for this. If you miss the date somebody else can slip in and legally take your business name. You will also have to publish the Fictitious Name Statement, at your expense, in an accepted publication. The county clerks office, found in the phone book's county listings, will be able to give you all the particulars. Check also with the city or county for other permits or licenses that might apply to your particular business.

State Regulations

On to the state. For some business people, such as CPAs, contractors, insurance people, counselors and lawyers, a state license is required to do business. This is changing and more businesses are falling under state regulation. The state agency on consumer affairs can help here. The state also administers resale permits. If you live in a state that has sales tax, you will have to collect taxes on all taxable items sold within your state. Every state has its own way of ensuring that you collect and remit these taxes. Some require you to purchase a bond, or put down a security deposit. You will have to prepare quarterly or annual sales tax returns, depending on the amount you collect. The state tax office will give you the specifics when you obtain a resale permit. If you are going to be dealing with hazardous chemicals, employ people, or charge interest to your credit customers, you should contact the Attorney General office or the Secretary of State office of your state to find out how your state handles these things. All of these offices can be found in the state listings section in the phone book, usually in the front.

Finally, there are the federal requirements. Fortunately there are not that many that apply to small businesses on start-up. They get you on taxes. As a sole proprietorship, you are identified by your Social Security number until you hire employees or deal with excise taxes. In either of these cases, you need a Federal Employer Identification Number. There is no fee for the Federal Employer Identification Number, but don't get one unless you need it because you will have to fill out tax forms that you would not otherwise have to deal with.

You won't need a federal business license unless you are making drugs, building radio or television towers, selling meat or investment information. If so then contact the Federal Trade Commission. Exporters of goods worth more than $2,500 will need to contact the Department of Commerce. The Federal Trade Commission has regulations on the following areas which you might want to know more about: product guarantees, mail order business, textiles, fabrics, wool furs and clothing, packaging and labeling and advertising of credit terms.

Insurance

One last expense that hasn't been covered is insurance. It's hard for a young business to consider the expense of insurance. But when you consider the cost or potential losses associated with any disaster, insurance is cheap. Some businesses are required to carry insurance by the state, and if you get a loan the bank will require some insurance too. My suggestion is to talk to a company or two and then decide.

The purpose of this simple business plan is to make yourself aware of what rules you have to follow, how much money you have to have, and what you need to know in order to get off the ground. Remember, starting a home business doesn't mean that you have to quit what you are doing. The business will have to grow and it grows slowly, so expect it. I hope you'll have fun with it because it is going to take a lot of your time.

Access

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Federal Trade Commission, Washington, D.C. 20580

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Small-time Operator, by Bernard Kamoroff, is a true nuts and bolts kind of book, great for those ready to act! $16.95 from Bell Spring Publishing, POB 640, Laytonville, CA 95454 • 707-984-6746

Meter, meter on the wall...

Therese Peffer

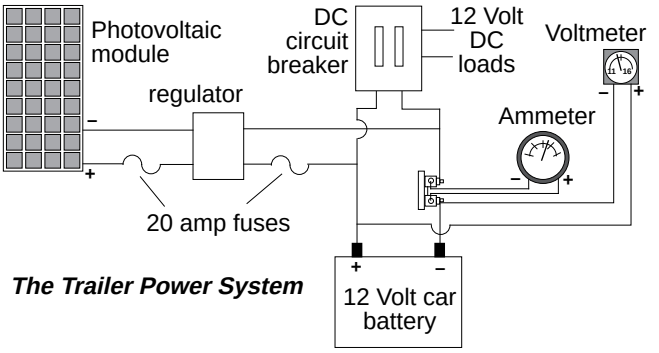
Finally, the last piece fell into place. I'd grown used to my pretty blue photovoltaic module out on the grass soaking up the sun's energy and filling up a car battery. I'd installed a charge controller, fuses, and a circuit breaker, but one thing was missing. I didn't feel comfortable about unplugging from the Home Power Office & Power "grid" until I had meters — a voltmeter and ammeter — in place.

I knew the panel was charging the battery. The regulator has LED lights, so I know when it's "regulating" (shunting power from the battery when it is full). But just how many of those flowing electrons are going in and out of the battery? What is the battery voltage?

Why Me(ter)?

So why have a round-the-clock, 24-hours-a-day voltmeter on a battery? I suppose I could continue to use a multimeter to measure my battery's voltage every so often. After all, it's 12 Volts — not going to change much, right? Boy have I learned a lot about batteries! I don't have the space or expertise to discuss battery "state of charge" here (Richard promises to write an article for the next issue). But I learned that the voltage of a battery varies depending on whether it is being charged or discharged. The voltage indicates the state of charge, that is, how full the battery is or how close it is to its capacity (measured in Amp-hours). And the voltage will vary as the temperature varies. If your battery's voltage differs from the voltage of a "healthy" battery under the same conditions, you may have a "sick" battery. So constantly monitoring battery voltage is vital to a renewable energy system.

The ammeter I installed to watch how much electricity was going in or out of the battery. I was curious how many amps of current my panel produces when it's cold or very hot, during a day that's overcast or bright and shiny. I also wanted to see how much current some of my loads draw (a few lights and a small stereo).



The Trailer Power System

Take a meter, please

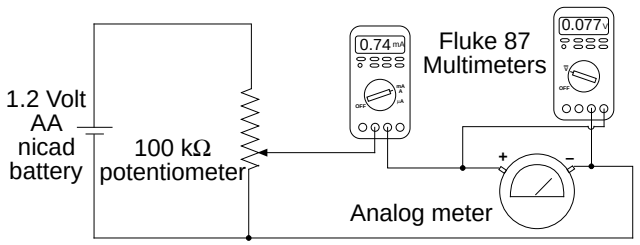
I decided to buy analog meters rather than digital. Digital meters are more accurate, but I find analog meters easier to read at a glance. My analog voltmeter will give accuracy to a tenth of a Volt — good enough for me.

Another decision was to buy surplus meters that I had to alter rather than ready-made meters I could just plug in and use. Richard assured me this would be a cheap and easy solution and it was! I bought two meters from C&H Sales. One was a 0–1 milliAmp DC meter, with a scale from 0–10, and cost $2.95. The other was a 50–0–50 microAmp DC meter (Nullmeter) that cost $4.95. Both meters are ruggedized and can stand to get moved and jostled — great for a portable system.

I used the milliAmp meter to build a expanded scale voltmeter. The meter is mounted in my small plywood power box. Small (#22) copper wire travels from the meter's positive and negative posts to the battery's posts (see diagram above). A typical 12 Volt voltmeter might measure 0–16 Volts. But a lead acid battery's voltage should never go below 11 volts. The ten divisions of the milliAmp meter were perfect for modifying the meter to a voltmeter with a scale that reads 11–16 Volts (see sidebar next page).

The 50 microAmp meter I used as an ammeter. It is also mounted in my power box. The positive and negative leads attach across a shunt connected to the negative post of the battery. This way I can monitor current coming into and out of the battery. The meter didn't have any numbers on it, so I decided that the scale would be $^{-}10–0–^{+}10$ Amps. The amount of current through the meter depends on the resistance of the meter and the shunt.

A shunt is basically a piece of metal with a known resistance. The ones you buy are rated in terms of Amps and Volts, and have bolts for easy attachment. Use Ohm's Law (Voltage = Current x Resistance) to figure the resistance of a shunt. For example, a 500 Amp-50 milliVolt shunt has a resistance of 0.0001 Ohms (Ω) (0.050 Volts divided by 500 Amps). The current rating tells you the ampacity of the shunt, or how much current it can take on a continuous basis.



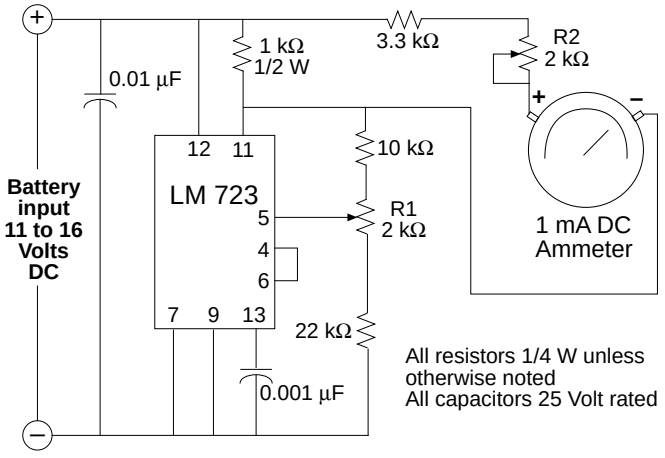
The Test

When you buy surplus anything, you never know what you're going to get, so the first step was to test the meters. Chris and Richard helped me set up the test procedure (see above). We used one nicad AA battery in a holder, a 100 kΩ ten-turn potentiometer (a resistor that you can vary from 0 to 100 kΩ), two Fluke 87 Digital MultiMeters (DMM), and various wires with alligator clips. One DMM measured voltage, the other measured current. We were very careful with the DMM that measured current — if you accidentally leave the multimeter in current reading mode while you measure voltage, you will blow the internal fuse of the meter!!

We checked the 1 mA meter (soon to be voltmeter) for a smooth linear progression from 0 to 1 mA. For example, the meter should read zero when no current is flowing, half scale at 0.5 mA current, and full scale (10) with 1 mA of current. We did the same with the 50 µA future ammeter for both positive and negative scale, but also needed to measure the resistance of the meter.

We started testing with the potentiometer turned to the highest resistance. We measured current in milliAmperes and voltage (V) at zero, quarter scale, half scale, three-quarter scale and full scale. The ten-turn potentiometer allowed us to position the needle of the meter precisely on the scale. Full scale reading of the 1mA meter showed 1 mA of current at 0.104 Volts. The progression was smooth. I measured the

11 to 16 Volt DC Expanded Scale Battery Voltmeter



Need an inexpensive but accurate analog voltmeter that can be left on 24 hours a day? Many analog meters you can buy have a scale from 0–20 Volts, which is not very useful for a 12 Volt battery — only a small portion of the scale is used. Lead acid batteries will read 10 to 11 Volts when empty, and around 16 Volts under charge. Using part of the scale decreases resolution. You can buy meters that have a scale from 10–16 Volts for about $20 to $80 depending on how accurate and rugged a meter you want. Or you can buy a ruggedized surplus 1 milliAmp DC meter and build this circuit for an accurate, cheap, and rugged voltmeter with an expanded scale that reads from 11–16 Volts.

This circuit was designed by Richard Perez and first appeared in *Home Power* #2. I am not an experienced "homebrewer", but once I got the parts together, this circuit took me about 3 hours to put together and solder. I built the circuit on a small piece of perforated board and attached it to the meter with a bolt through my power box.

"This circuit uses a 1 mA DC Ammeter as an expanded scale voltmeter. The meter has its ground elevated to 11 Volts by the use of an LM 723 voltage regulator in shunt mode. This makes the meter very accurate as there are no series semiconductors in the measurement circuit. Full scale reading and the 11 Volt ground level are both adjustable by using the potentiometers in the circuit. R1 is the adjustment for the shunt regulator. Adjust R1 until the negative side of the ammeter (with respect to ground) is at 11 Volts. Then adjust R2 until the meter reads the battery's voltage at the time. Use an accurate DMM to calibrate this circuit.

All the components for this metering project are available at most Radio Shack stores, or from just about any electronics supply house. This circuit is powered by the battery under measurement and never requires the use of small batteries. Average power consumption of this meter is about 5 milliWatts. When on line 24 hours a day, power consumption is less than 0.1 Watt-hours per day. This meter is super-efficient and can be left on line all the time with a minimum of power consumption."

– Richard Perez

resistance at each data point ($R = {}^{E}/_{I}$) and found a steady 104 Ω (the face of the meter read 105 Ω).

The microAmp meter was a little tricky since the needle starts in the middle and can go right or left. I measured right scale (positive) at quarter, half, three-quarter and full scale. Then I swapped the leads on the positive post of the meter with those on the negative post to measure the negative scale. The microAmp meter of course was more sensitive. At first we had the DMM set to read current in milliAmps, but discovered we needed to read in microAmps. I measured the resistance at each data point and found an average of 1908 Ω.

I knew that I wanted the µA meter to read about 10 Amps full scale. The next step was finding the total resistance R_t (the resistance of the meter plus the resistance of the shunt) to get a full scale reading of 10 Amps. The meter can only handle 50 µA of current (hence the large resistance). A shunt in parallel with the meter handles most of the current. Thus the total resistance approximately equals the resistance of the shunt. The resistance of the shunt determines the scale of the meter. Back to Ohm's Law: I measured the voltage at full scale (0.1 V), and I want the scale to read 10 Amps, so $R_t = {}^{0.1}/_{10} = 0.01\Omega$. So I need a shunt with 0.01Ω resistance. (For an exact measurement, use the following equation to find the resistance of the shunt: ${}^{1}/_{R_t} = {}^{1}/_{R_m} + {}^{1}/_{R_s}$. Solving for R_s gives $R_s = {}^{R_t R_m}/_{(R_m - R_t)}$.)

I first thought that I would use wire as a shunt. I made a spreadsheet of wire sizes, Ohms per 1000 feet, and the number of feet necessary to produce the desired resistance. But, even with #18 wire I'd need 2.76 feet (and #18 could barely handle the current). Since space in my power box is at a premium, I ended up using a 10 Amp-100 mV shunt. The resistance is $R = {}^{E}/_{I} = {}^{0.1}/_{10} = 0.01\Omega$. The shunt can handle 10 Amps continuous and 20 Amps surge.

I was curious how the ammeter worked and whether it really read 10 Amps full scale. Chris and I took the DMM down to the trailer, set the multimeter on milliVolts and took a reading across the shunt. (A 1 mV reading across the shunt corresponds to 0.1 Amps). As the sun kept popping in and out of the clouds, we saw 1 to 4.4 Amps! We discovered that the scale was not linear. At quarter scale the meter read 1 Amp, at half scale it read 2.5 Amps, and the 4.4 Amp mark was less than three quarter scale. Then we unplugged the trusty Solarex MSX-60 PV panel and started plugging in loads. We used my 20 Watt DC halogen light and large resistors to draw up to 10 Amps from the battery. At 10 Amps, the needle was not quite at full scale.

I marked the readings. Even though the ammeter does not give a linear reading, with my calibration marks I can tell about what the current is. I don't require the meter to be accurate to a tenth of an ampere.

Now starts the fun...

I can't help it. Every time I'm in the trailer, I'm constantly looking at the voltmeter and ammeter. It's hard to describe the feeling of producing your own power, watching the power come in and out. I feel, well, empowered!

Access

Therese Peffer, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

Surplus meters: C and H Sales Co., 2176 E. Colorado Blvd., Pasadena, CA 91107 • 1-800-325-9465 • 213-681-4925 • 818-796-2628 • FAX 818-796-4875

HAPPENINGS

INTERNATIONAL
CANADA
SW Alberta Renewable Energy Initiative Information Centre–This group provides Canadians with information and workshops on renewable energy. For more information contact Mary Ellen Jones, Information Centre Manager at POB 2068, Pincher Creek, Alberta, Canada T0K 1W0

The 19th Annual Conference of the Solar Energy Society of Canada will be held July 9-12, 1993 in Québec, Canada. For more information contact SESCI, 420-301 Moodie Dr, Nepean, Ontario K2H 9C4 Canada.

MEXICO
LA CARRERA FORMULA SOL, Mexico's solar, electric and hybrid car race, will take place from the 11th to the 18th of July 1993, in the state of Sonora (which borders with Arizona), covering a total of 930 miles. For information, please contact Beatriz Padilla, race coordinator, at (52 5) 281-0655 (phone and manual fax).

NATIONAL
Independent Home Tour - National Energy Awareness Month will have a special attraction this year. On Saturday, Oct. 16, 1993 people who live in energy independent homes powered by sun, wind, water or grid-intertie systems are being asked to open their homes to the public so that others interested in energy independence may have first-hand experience in observing the lifestyle. Tour logistics are being coordinated by Real Goods Trading Co. The tour is being promoted so that anyone interested can have access to people who have actually living on renewable energy. Although Real Goods is physically coordinating the Tour, the event is being handled as an industry-wide, non-commercial effort. The goal is to have 100 participants in locations across the United States by Oct. 16. Interested parties-volunteers to show their homes or people interested in visiting an energy independent home in their area may call 800-762-7325 or write Karen Hensley at Real Goods, 966 Mazzoni St., Ukiah, CA 95482-3471.

Electric Vehicle Safety Survey: In order to establish meaningful standards, the Electric Vehicle Industry Assoc. is seeking data on the safety of EVs already in actual use. Anyone who has had any experience with EV accidents is invited to share their information. The survey takes 10 minutes to complete. Final data will be made available for publication. To participate, contact Shari Prange, Electro Automotive, POB 1113, Felton, CA 95018-1113 • 408-429-1989.

The Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS) is a national service, funded by the U.S. Department of Energy, that provides the general public and educators with free information on renewable energy and energy conservation. They also maintain a referral network of approximately 500 organizations that provide more technical information. CAREIRS is interested in organizations that can benefit from being part of their monthly mailing list. The mailings are most useful to organizations who have direct contact with the public". For more information contact CAREIRS, POB 8900, Silver Springs, MD 20907, or call 800-523-2929.

HOME ENERGY MAGAZINE is offering a free Directory of Energy-Related Graduate Programs in US Universities. Over 60 programs in the fields of energy, resources, the environment, and development. This directory was produced by the Energy Foundation, with the cooperation of Student Pugwash USA, a national educational, non-profit organization. The free directory is available via book, IBM 3.5" disk, IBM 5.25" disk, Macintosh disk, (please specify MS Word 5.0, Filemaker Pro (Mac) or delimited ASCII). Contact Home Energy Magazine, 2124 Kittredge St #95, Berkeley, CA 94704.

FREE NATURAL GAS VEHICLE MAGAZINE Send SASE to Frank Rowe Circulation, NGV Magazine, 1410 Grant St Ste A-201, Denver, CO 80203, 303-863-0521, FAX 303-863-0918.

EV NETWORK - Ken Koch will search his file of 2,000 customers and let you know if there's an EV owner near you. Send him an SASE: 12531 Breezy Way, Orange, CA 92669.

Got a hot new solar oven design? Build it, test it, and enter Home Power's 2nd Annual Cooker Contest! You could win a Solarex MSX-60 PV panel, POW200 inverter or MSX-10 PV panel, or a Solar Dynamo radio. See HP #33, page 57 for details, or call us at 916-475-3179. Preference given to simple designs. Better get cookin', contest ends July 1. Judging will take place July 30 –31, 1993 at the cookoff at Camp Creek Recreation Area, near Hornbrook, California.

ALABAMA
THE ALABAMA ENERGY EXTENSION SERVICE is offering free energy consultation and literature on a wide variety of energy related topics. Contact: Alabama Energy Extension Service, The University of Alabama , Box 870201, Tuscaloosa, AL 35487 or 1-800-452-5901 (AL only) or 205-348-4523.

ARKANSAS/MISSOURI
OZARK RENEWABLE ENERGY ASSOC. (OREA) is dedicated to providing RE enthusiasts regional connections and promoting the use of alternative energy in the Ozarks. OREA is working on a Networking Directory which is meant to be a vehicle for getting interested folks in touch with each other. For more info about OREA and a Directory Questionaire send SASE to Julie Courtney at RT3 Box 4305, Reed Spring, MO 65737, 417-338-8688.

CALIFORNIA
SEERs SOLAR SUMMIT! SEER is not having a public event this year, instead a SOLAR SUMMIT is planned for the renewable energy and transportation industry. Proposed topics include industry & governmental interfacing, financing, industry networking, current technology, educational programs, contract opportunities. Representatives from CALSEIA, EVA, ERA, SCCA will be present. The Solar Summit is scheduled for August 6, 7, & 8 in Willits, CA. A local resort has been reserved for the event. For more information contact Solar Summit, 733 S Main St #234, Willits, CA 95490 or call 707-459-1256.

North San Francisco Bay Chapter of the Electric Auto Assoc. (EAA) holds meetings on the second Saturday of each month at the PG&E Business Center, 111 Stony Cir, Santa Rosa, CA from 9:30 AM–Noon. For information on the EAA and the chapter nearest you, send an SASE to 1249 Lane St, Belmont, CA 94002, or call 415-591-6698 (10 to 5 on weekdays).

The American Hydrogen Association's Silicon Valley Chapter is now offering access to a bulletin board system with information on solar cells, hydrolyzers, gensets, windmills, hydropower, ocean thermal energy, converters (OTRCs), bio ponds, thermal cracking and other means of converting solar energy in Hydrogen. Learn about technologies for transporting hydrogen by pipeline, storage of hydrogen as a liquid, a gas, and a hydride, combustion of hydrogen with air and by catalytic burning and how hydrogen is electrochemically combusted to produce electricity within fuel cells. Contact: The American Hydrogen Association-Silicon Valley Chapter Headquarters, 1401 Pointe Claire Ct., Sunnyvale, CA 94087, BBS@408-738-4014 Voice@408-235-1177.

The American Wind Energy Association (AWEA), the National Renewable Energy Laboratory (NREL) and the US Dept. of Energy (DOE) is sponsoring WINDPOWER '93 on July 12-16, 1993. The meeting , AWEA's 23rd national conference and exposition, will take place in San Francisco, California at the Fairmont Hotel, Nob Hill. For more information contact Windpower '93, 777 N Capitol St NE Ste 805, Washington, DC 20002.

Siemens Solar Industries is offering its training program, Photovoltaic Technology and System Design. Siemens has been

presenting this week long course since 1981. Learning begins by purchasing the two volume set of Training Manual and Technical Appendix for $175. The fee includes their award winning 30 minute videotape "The World of Solar Electricity". Step two is a 5 day training class at Siemens Solar in Camarillo, CA on July 19-23 and October 4-8, 1993. The training class, including the two set manual & video, is $1500 (food and lodging not included). The course offers hands-on experimentation with inverters, controllers, batteries, modules, trackers and loads. For more information contact Mark Mohrs, Siemens Solar Industries, 4650 Adohr Ln, Camarillo, CA 93011 or call 805-482-6800.

COLORADO

SOLAR HOME WORKSHOPS will be held at the Sustainable Technologies International (STI). These workshops are for owner builders and persons seeking careers as solar professionals. For a detailed description of SOLAR HOME PROGRAM WORKSHOPS, costs and scholarship information, write STI, POB 1115, Carbondale, CO 81623-1115 • 303-963-0715.

4th ANNUAL CRESTSTONE, COLORADO ENERGY FAIR-July 31 & August 1 1993. The Fair committee wishes to thank all the folks who made the 3rd Annual Creststone Energy Fair such as success. Anyone interested in participating in this year's Fair should contact Citizens for Clean Energy, P.O. Box 17147, Boulder, CO 80308, 303-443-6181.

FLORIDA

Florida Solar Energy Center - 1993 PV System Design Workshops: Learn about solar electric technology and the proper way to design stand-alone PV systems. Registration fee: $300 Sept. 14-16 1993. For more info contact JoAnn Stirling, 300 State Rd 401, Cape Canaveral, FL 32920, 407-783-0300 ext 116, FAX 407-783-2571

The 10th World Hydrogen Energy Conference is being held on June 20-24, 1994 in Cocoa Beach, Florida. Abstracts due July 1, 1993. For additional conference information, please write or call Carolyn Burby, Florida Solar Energy Center, 300 State Road 401, Cape Canaveral, Florida 32920. 407-783-0300 extension 112.

IDAHO

Backwoods Solar Electric Systems is offering Saturday workshops on June 19 and September 4 1993. The workshops will cover photovoltaic theory, equipment & installation. Classes are limited to 10 people. The non-refundable, prepayment of $40 covers class, lunch, and textbook, or $30 per person for couples sharing the book. For more information contact Steve or Elizabeth Willey, 8530 Rapid Lightning Creek Rd, Sandpoint, ID 83864, or call 208-263-4290.

MAINE

Hands-On Workshops will include: solar air heating, solar water heating, solar cookers and ovens, solar electric home, passive architecture, greenhouses and sun spaces, and the immensely popular photovoltaics workshop. The fee for each of these workshops is $25.00, which includes lunch. For information on sites and dates contact Richard Komp, Maine Solar Energy Assoc., RFD Box 751, Addison, ME 04606 • 207-497-2204.

MICHIGAN

Northwoods Energy Alternatives is offering workshops. The current schedule includes Wind Generators - July 24th 10AM-3PM , Stand Alone Hybrid Systems - October 16th, 9AM-5PM. People are encouraged to suggest additional topics of interest. Workshop fees are based on a sliding scale of $20-$50...you determine what you can pay. Off grid home tours are regularly offered. For more info contact Maggie or John, Northwoods Energy Alternatives, POB 288, Lake Leelanu, MI 49653, or call 616-256-9262 or 616-256-8868.

MINNESOTA

MINNESOTA SUNFEST 93, A three day renewable energy exposition will be held June 25-27 1993. Events include the finale of the SunRayce 93, featuring 36 solar vehicles designed by college students from across the US, Solar Boat Regatta at Lake Nokomis, Student Science Contest, Kids Programs, a non-polluting commuter vehicle demo, solar powered hot water exhibit, entertainment featuring strolling musicians and a live radio show, solar workshops and a variety of exhibitors featuring commercial solar products, ecological exhibits, and food booths. Most of the activities will be held at the Minnesota Zoo. For more info contact Stephen Dess, PO Box 36, Crosby, MN 56441, 218-546-5369.

MISSOURI

The International Academy of Science is presenting Project Energy '93, an international conference featuring presentations on environmentally responsible energy technologies which have come through research and development and are ready for commercialization. The conference will be held June 20-24 1993 in Kansas City, MO. There will be technical sessions on hydrogen, solar, wind, utility strategies, waste & bio-mass, zero emission vehicles etc. For more information contact, International Academy of Science, 26900 E Pink Hill Rd, Independence, MO 64057 or call 816-229-3800, FAX 816-229-1000.

NEVADA

Solar Electric Classes in Nevada taught at remote solar home site. Maximum of four students for more personal attention. Two day classes on weekdays & weekends upon request, minimum of 2 students. Class will be full of Technical info, product evaluation, sizing systems etc. Students will build a solar system $75 per person. Call 702-645-6571 or write Solar Advantage, 4410 N. Rancho Dr #148, Las Vegas, NV 89130.

OREGON

The Appropriate Technology Group is a grassroots and hands-on group formed to explore how to educate, demonstrate projects, provide a community resource for designers and builders, do experimental projects involving energy, transportation, sewage, hazardous and solid waste , etc., etc. The group meets once a month in Portland, Oregon. For more information call 503-232-9329 (evenings).

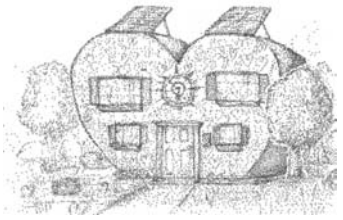
VERMONT

Photovoltaic Home Electric Systems: Seminar and Workshop is a one day program held at Sunnyside Solar in Gilford, Vermont. This introduction to independent solar electric systems will include a hands-on portion assembling a four module system. The dates for 1993 are scheduled for June 5, July 17, August 28, September 11 and October 9. Each date is a complete program, held on a Saturday from 9 am to 4:30 pm. The $130 fee ($90 for folks sharing materials) includes lunch, a full packet of product information and related articles and both Joel Davidson's "The New Solar Electric Home" & Steven Strong's "The Solar Electric House". A $45 deposit, advance registration is required. For more information contact Carol Levin, Sunnyside Solar, RD4 Box 808, Brattleboro, VT 05301, 802-257-1482.

WISCONSIN

The 4th annual Midwest Renewable Energy Fair is June 18-20, 1993 at Amherst, Wisconsin. The Energy Fair introduces the public to a wide spectrum of renewable energy technologies and their contemporary applications. The Energy Fair is a fun and educational experience for individuals and families. At the Energy Fair you will have the opportunity to: • watch wind and solar power actually power the fair • see, handle and purchase products that will help you conserve energy, protect the environment, and save money • attend informative hands-on workshops (beginner to advanced) presented by experts from across the country • walk through a model home demonstrating energy efficient construction and appliances, and renewable energy, power and heating • see vehicles powered by alternative energy • network with others who share similar interests • dance to live music played on a solar and wind powered stage. Have fun and more! For more information about the Energy Fair contact: Midwest Renewable Energy Association, 116 Cross St., Amherst, WI 54406, 715-824-5166.

Home & Heart



Kathleen Jarschke-Schultze

Solar Barrel Composter

I had always looked with envy upon the high priced barrel composters in my gardening magazines. I hate turning compost heaps, and in fact, I don't do it. I always mean to, but I don't. A barrel composter would eliminate the hassle of turning the heap. It seemed like the answer to me. Of course the price always stopped me short.

Boneyard Recycling

Our friend, Harry Rakfeldt (see cover story HP#6) was moving and gave me some choice items from his boneyard. Besides a lot of gallon jars he gave me the kitchen sink. No kidding. It's a sink, counter and cupboard set up made of metal. I ended up building a shed for it in the garden. I scored two plastic 55 gallon drums. Some day I was going to make beer and I figured they would come in handy.

The barrels got me thinking. All I had to do was paint them black, drill air holes in them and figure out a way for the barrel to turn freely. It was easy to paint the barrel black once it was turning freely. My Makita made drilling the air holes so easy it was fun. There are two rows of holes around the top and bottom of the barrel. The holes are three inches apart. I cut a rectangular door on one end of the barrel and attached it with two hinges. Nuts and bolts, with lock washers, were used as fasteners. A boughten latch was attached to keep the door closed and as a handle to open it.

We had some rebar around so that decided the support and turning mechanism. One piece of rebar would stick through the middle of the barrel horizontally. Two pieces of rebar would be pounded into the ground across from each other the width of the barrel. These needed to be driven deep enough — about two feet — to support the weight of the barrel even when half full of compost.

Construction

Now I needed Bob-O's help to drill ½ inch holes through the barrel for the cross bar. He used a Hole Hawg® since the Makita doesn't hold a drill bit that big. He then drilled a four inch deep hole in one end of two eight inch 2 x 4 blocks. Turning the two blocks sideways, he drilled each with a ½ inch hole completely through the side.

The composting area is located in the corner of the garden. I used a big hammer to drive the rebar into the ground. I kept hitting rocks, so I had to move the rebar around a bit, always making sure they were two feet apart (the width of the barrel). The blocks of wood sit on end on top of the rebar. With a section of rebar through the barrel I could lift it up to push and pull the rebar through the blocks' side holes. It worked! The barrel was off the ground and turned freely.

The barrel's color was a bright blue which had to change. One can of flat black spray paint quickly transformed the blue barrel into a solar barrel. Even as I was spraying on the paint, the barrel was heating up.

The Formula

Everything I had read about composting said the more air a heap got, the faster it would compost. There are many recipes for compost. Most are for large piles. All include carbon materials (leaves, cornstalks, etc.), nitrogen materials (grass clippings, manure, wet kitchen scraps, etc.) and a little soil, plus water.

For carbon I used what was left of some cardboard boxes I had planted potatoes in last year. (They were very easy to harvest.) I also had some corn stalks and garden trash that had sat in a pile all winter without being turned. Floor sweepings from the chicken coop, aged a year, supplied the nitrogen. Dirt was very easy, a random shovelful. One reason for picking the corner location was the faucet close by. Water was sprayed inside of the composter. I turned the barrel vigorously.

It was a pleasant surprise to note the horizontal bar helped break up and aerate the compost mixings as they flopped from one end to the other. So far, so good.

The next morning I went to check the barrel. The sides were hot where the sun was hitting it. I opened the door and stuck my hand in. The air was humid and warm. I saw steam rising from the damp materials. I turned the barrel again. Maybe seven or eight times. This was more like it. I could just see the compost I would have to enrich my garden.

Compost Conclusion

I weeded two days after a rain and put all the weeds into the compost barrel. The barrel became harder to turn the more I filled it. I stopped filling it. After turning it everyday I checked the contents. It seemed to be working into some nice compost. Within two weeks there was some useable compost in the barrel. When the weather warms up it should work even faster. Success!

Access

Author: Kathleen Jarschke-Schultze, c/o Home Power Magazine, POB 520, Ashland, OR 97520

The Wizard Speaks...

Patterns And Order

Although there are many forms of pattern and order, it appears they may be grouped into four major classes. These are static, repeating, evolving, and spontaneous.

Static patterns repeat the same signal over and over again. It may be the same picture, the same sound, or the same action. Among numbers, static patterns are represented by the integers. Repeating patterns are those that repeat the same sequence or set of signals. These are the circular or cyclic patterns. They are represented by the rational numbers. Evolving patterns do not generally exhibit the repetitive behavior of static and repeating patterns. They do, however, evolve according to perceptible formulations. Evolving patterns are represented by the real numbers. Spontaneous patterns are those that follow no apparent orderly progression. They may be perceived as purely random or they may be perceived as following subtle paths which are not yet conceptually formulable. Mathematically they can be represented by elements of those continua with cardinality greater than aleph-one.

Practical science is mainly concerned with static and repeating patterns. Disciplines like Chaos Theory, Quantum Mechanics, and General Relativity deal also with evolving patterns as well as touching upon the realm of spontaneous patterns. New sources of energy and resources will come from a deeper understanding of evolving patterns and a new science of spontaneous patterns.

Letters to Home Power

PV Maintenance Manual Needed

We are looking for a simple illustrated manual on the maintenance and operation of a small PV system. Our organization, Terrasol, assists the installation of small one and two panel PV systems in Central America, mostly in Nicaragua. The systems use one panel, one deep cycle 12 Volt battery, a charge controller, and typically are used to run 12 Volt fluorescent lamps in a community room. We instruct two members of the village in maintenance and have hired and trained a Nicaraguan to periodically visit each system. Still, we could use a two or three page instruction manual to leave with new installations. Because the literacy levels are often quite low, it needs to be heavily illustrated. If you have one in Spanish, that is even better, though we can translate it, even if it is in French, Tagalog or anything else. Please send to Cal Broomhead, 204 Ellsworth St, San Francisco, CA 94110 • fax 415-864-6919, evenings • 415-550-0151

Hello Cal: To the best of my knowledge, there is no manual such as you request. I know that are there are bilingual organizations that could produce such a much needed manual. Contact Sustainable Technologies International at 303-963-0715, they often do educational work in Latin America and are wizards at small-scale PV. Also try some of the major PV manufacturers, I know that both Kyocera and Siemens are active in Latin America and certainly have the expertise to produce this much need "comic book" manual. —Richard

Hi Cal; Just wanted to add that Terrasol is a non-profit organization run by volunteers doing great work — hope someone can help you out. — Amanda

On The Lam

Dear Home Power; I recently found HP#31 on the shelf of a local magazine shop. I was surprised and delighted to find a magazine covering subjects so dear to my heart. I have read the magazine from cover to cover several times and am now writing to several of your advertisers.

I am considering buying some solar panels. The best price I have been quoted is $806 (US$435 approx.) each for new MSX60s, (comparable to US prices with freight and NZ sales tax added), so the used panels advertised in your magazine caught my attention. The panels I am considering are the M52L Mud from Kansas Wind Power (pg 67) and the 83W Quadlam from Abraham Solar Equipment (pg 76), both choices based purely on price. The Quadlams cost US$2.40 per watt and the M52s $2.64 per watt. Your opinion on used panels in general and these in particular would be greatly appreciated. My budget will stretch to about US$900 including freight.

I am interested in finding a source of Sterling cycle engines up to a couple of hp which could be solar powered but have been unable to find information. Anything on this subject would be greatly appreciated.

As you can imagine we are not in the mainstream of AE down here and finding information can be difficult. I plan to subscribe to several of the magazines and newsletters advertised in your magazine. I am also hoping to build an electric vehicle in the next year and I'm part way through building a wind generator. Thanks for a fascinating magazine, and (I hope) for answering my questions. Justin Southam, 17a Pimlico Pl., Newlands, Wellington 6004, New Zealand

Justin, a "quadlam" is four ARCO M52 panels in series. Each M52 puts out about 6 Amperes at 4 Volts. Quadlams are grouped into "Golds", "Bronzes", and "Muds" depending on how abused they were during their life in a commercial solar plant in Carrizo Plains, California. Many of the panels were used with concentrating mirrors, and the "Muds" especially suffered from the heat, with surfaces turning brown from the heat and light. I've been told that the Ethylene Vinyl Acetate used to seal the modules formed small amounts of acetic acid, which erodes the metalization (traces and contacts) and darkens the cells' anti-reflective coating. We've noticed a bit of degradation of the cells' contacts on our set of "Golds". Muds will be more degraded.

We've only tested bronzes and golds. Electrically, they perform very well. We found our golds to be about 20% underrated in power output, whereas new modules tend to be overrated. If you plan to buy muds, understand that they don't come with frames. This makes installing them a little more difficult. Also, if you're short on space, I wouldn't recommend 'lams. They use about twice the area per watt as, say, a Siemens M55. But as far as dollars per watt, they're the best show in town.

Sterling engines: Detroit Diesel Corp, Peter L Perdue, 13400 W Outer Dr., Detroit, MI 48239 • 313-592-5441, and Cummings Power Generation, Jerome Davis Box 3005 - Mail Code 60125, Columbus, IN 47202 • 812-377-3743 both do sterling engines, but I think they're into big ones (20 or 30 kW). On the Home Power size scale, contact Reliable Steam Engine Co. P.O. Box 671, Waldport, OR 97394 • 503-563-2535. Also contact Phil Manke, RR2 Box 320, Valley Road, Markesan, WI 53946 • 414-394-3431 —Chris

Foreign Exchange
ATTENTION DOWN UNDER! We have great interest in finding out more about NEW ZEALAND. We have been living with PVs for over nine years and are willing to correspond about our experiences in exchange for your local knowledge. Ultimate goal would be "face to face" exchange in either or both places! Katcha & Bill Sanderson, 20295 Panoche Rd.,Paicines, Ca. USA.

How about it, renewable energy New Zealanders? Katcha & Bill: the Alternative Technology Association, 247 Flinders Lane, Melbourne, VIC. 3000, Australia • 03-650-7883 publish an RE magazine called Soft Technology. They might be able to put you in touch with some RE Kiwis — Chris

Cool Reflection
Dear Folks; I have thought about writing this letter every time I see articles referencing solar panel output vs. temperature and/or the use of reflectors to amplify light gain. Having used reflectors in installations for both hot water collectors and photovoltaics, I have made some observations. To wit: metallic surfaces reflect heat and (to the degree that they are polished) light. This is very helpful in heat gathering and hot water panels. The metal surface does not have to be exposed for the heat fraction to be reflected (painted metal will reflect heat about the same as bare). Porous, non-metallic materials (masonite, cardboard, etc.) which have been painted white will reflect almost as much light but very little heat.

Oddly enough, I discovered these facts while designing and building greenhouses. In a greenhouse it is critical to gather and bounce as much light around as possible, but the accumulation of heat presents a serious problem. While there is a net loss of light to have glass on the north wall of a greenhouse, if you are north of 30 degrees latitude, you should not use foil-faced insulation in that wall. The foil, behind the wall surface will raise the internal temperature of the greenhouse significantly. When I first discovered these facts, I was dubious.

I set up the following simple test to confirm my theory. I took a white styrofoam sheet used to separate photovoltaic panels in their shipping boxes (a 1 foot by 4 foot piece of cardboard, painted white, will do as well) and covered one half of the sheet with aluminum foil. I faced this panel toward the sun and, with a light meter, measured the reflected light from the foil covered end and again from the white end. The reflected light was almost the same (<10% difference). I did not have equipment to accurately measure the difference in reflected heat, but just a hand in front of the respective ends gave the answer. The white end felt no different than ambient air while the foil end was distinctly warm. I have since read technical documents which support this empirical finding. My conclusion is that if you wish to reflect light onto a photovoltaic, use a non-metallic reflector. If you want a heat gain, use a metallic reflector. I have found masonite to be a good base for the non-metallic reflector, with at least two coats of good, flat white paint. I'd appreciate anyone else's observations on this. Bill Sechler, Solarwind, POB 780, Bandon, OR 97411 • 503-347-3316

This sounds like a great idea. But be aware that adding reflectors of any kind invalidates the PV module's warranty. Also, I'd still recommend not doing this in hot climates — even if no heat is reflected, the panels will still get hotter, from the increased light levels and decreased air circulation.— Chris

Seasonal Hybrid
I'm interested in whatever back issues you have dealing with small hydro/solar crossover systems. We have enough water in winter and spring, enough sun in summer and fall, probably not enough of either out of season. Have a moderate water source (will be measuring flow this year, since it varies) with approximately 175 foot drop over a long (maybe ½ mile) run. Have two cabins approximately ¼ mile apart. Is it possible to set up a hydro half way in between and run both ways? Or is it too far? Thanks for your info, Jennie Elford, Whitefeather Farm, POB 29, Tiller, OR 97484-0029

Jennie; Issue 15 has an article on a small hydro/solar system. Your best option (according to Richard and Bob-O) is to locate a few batteries at the point of power generation, to serve as a flywheel to supply power surges your loads require. Then, at that point, invert the power to 120 volts ac to minimize voltage loss during transmission. Assuming the round trip wire lengths to each cabin are ¼ mile (1320 feet) and that you have a 2400 watt inverter (20 Amps at 120 vac), you can use #3 copper (or #1 aluminum) wire with a voltage loss less than 5%. If you have a smaller inverter, you can reduce your wire size accordingly. You might also consider a pair of 2.4 kVA 120/240 vac transformers to save on wiring costs by transporting the power at 240 vac.See Therese's Back to the Basics article in issue 33, page 86 for more on wire sizing. The cost of this wire may seem expensive but assuming you're producing 240 watts (20 gal/min, 150 foot head), 24 hours/day, you've got 6 kw-hrs a day. You'd need 24 PV modules to produce that much power (assuming you have 50 Watt modules and 5 hours of sun a day). The hydro system will be well worth it! — Amanda

Getting Dowsed
Dear Home Power; I read with interest, and not just a little dismay, your article on obtaining water for a remote home site. First let me congratulate you on an ever improving magazine! The following information is meant to fill in where your last article was lacking... on dowsing.

There are some areas of the country where the water saturates a sand bed that makes locating water a simple matter of choosing a convenient spot for the well. In most areas, however, the underground strata is a complex combination of saturated layers, fractures, solution channels and the classic small water vein. In this situation, dowsing is the only way to determine where the water is flowing.

Since 1975 I have been locating underground water for clients by dowsing, the modern term for locating water with a divining rod. My track record over this period is a good well in 19 out of 20 locations. First, there is nothing particularly special about the dowsing rod. It simply amplifies the slight, subconscious muscular reaction in the dowser. Anything can be used as a dowsing device, the most common being the forked stick, now called a "y" rod, and made of nylon rod. Other instruments include the pendulum, bent wire rods, bobbers, and rotating devices like the Russian Loop.

Much has been learned in the last twenty years about the mind and the validity of the dowsing reaction. Electro-encephalographic studies have shown that the rod moves from a subconscious muscle reaction triggered by the mind, not some aqua-tropism pulling on the stick! We have also learned that dowsing is part physical detection of changing energy anomalies and part psychic perception of information. Among experienced dowsers, it is common to hear of accuracy rates between 90–95%. I would caution the new home owner to find a dowser with references and some record of his performance. This is a skill, like anything else.

Generally the more experienced the dowser in a given geographic area, the less time and effort required to locate a well site. I first visit the property with the client. Hopefully the client has not already started the house or put in the septic. Put the well in first! It's very disheartening to find the only good location to intercept an underground stream is in the middle of the septic field! I'll ask the client what water needs there are and estimate minimum acceptable quantities to look for. Often a well site is a compromise of water quality, quantity and location. Several sites are often located and the client can then decide for themselves what priorities to follow. During this first outing the client is allowed to follow along, ask questions when I'm not dowsing (to limit distraction) and provide background information on the property if needed. I may look for water moving in fractures or simply set parameters for water that will meet the minimum needs of the client, letting the dowsing process lead me to a suitable well site.

With some preliminary sites selected, I'll go home and re-dowse the area remotely over a map of the property (yes this can be done!). This is not as accurate, but gives me a general overview picture of major fractures and water flows crossing the property. The field dowsing will be redone the next weekend or as soon as possible to check old findings and further explore new information turned up in map dowsing. This will usually be done without the client, preferably alone. I find this much less stressful and I can concentrate more fully on my dowsing. It also gives me additional time and flexibility to carefully sort out various flows, levels of strata, faults and geologic structures that may impact the well. Generally, I will look for the largest high quality flow of water obtainable. I essentially develop an image of the underground situation.

When the driller sets up the rig, it may be important that the rig is maintained plumb. Often a dowsed underground water vein or small stream is flowing in a fracture or small solution channel and may require fairly accurate drilling to intercept it. The tools used can provide a nice plumb hole, but the high air pressures used to clean the hole of rock dust and cuttings often also clog the small water veins that are encountered. If the hole is drilled in this way and water is not found, a thorough scouring with dry ice and water often will pull the cuttings out of the impacted water veins and produce a usable well. Also, the driller may want to drill just ten feet deeper after hitting the water source to help prevent the aquifer from silting up.

I would encourage anyone planning on drilling a well to get in touch with a local chapter of the American Society of Dowsers. They will be able to teach you the basics and refer you to an experienced dowser in your area. Write to American Society of Dowsers, Danville, VT, 05828-0024 for a list of local chapters and a book list for further study. Everyone has the capacity to learn dowsing to some degree. Practice is the key. Prove up your initial dowsing, gain confidence and increase your limits. After gaining experience with water, you may want to try dowsing for minerals, lost items, pipelines, buried cable, fluid and electrical breaks, etc. This list is as long as your imagination and as useful as anything else in your life. May your search be fruitful! Stephen Bosbach, 16304 Westview Trail, Austin, TX 78737 Pres. Armadillo Chapter, ASD

Thanks for the info on dowsing, Stephen. Actually both the dowsers that sited our well were right, we hit water. It was deeper than they expected, but then we drilled in the summer and they dowsed during the spring. — Richard

Golly Stephen, and I thought it was just magic! Bob-O

Sensitive Environment

Dear Home Power Folks; I'm still hoping to someday live off the grid, but I have two big concerns: First, my family

does not seem to appreciate the importance of energy conservation — they leave lights on all the time when they're not needed, use the clothes dryer instead of the clothes line, etc. We live in area where electric power is relatively inexpensive, and so have all electric appliances, and electric water and HVAC (heat pump). I've talked to my wife and 5 year old son about conservation a few times, but they always seem to forget. Do you or any of your other readers have any suggestions that might help? I can see that if we ever do manage to make it off the grid, that we'll have difficulties keeping the batteries charged...

My second concern is that my family has severe allergies and Multiple Chemical Sensitivities (MCS). The only way that AE is practical is to reduce your electrical loads as much as possible, which usually means propane or natural gas appliances and hot water heating. Unfortunately, my family gets sick when they're around propane or natural gas appliances. I don't know if improved ventilation, exhaust fans, etc. would make it possible for them to tolerate living with propane or natural gas appliances, but since they're so sensitive, it doesn't seem likely. I'd like to try hydrogen as an alternative, since when it burns, it only produces water as a by-product; but it seems like a big undertaking to generate and store the quantity necessary to power a household year-round. By the way, can you tell me if it is possible (and practical) to convert natural gas or propane appliances to hydrogen fuel? I intend to buy and read the book *Fuel From Water: Energy Independence From Hydrogen*, by Michael Peavey, but I haven't done.so yet... Again, do you or any of your other readers have any suggestions that might help?

Finally, I have a suggestion for a Homebrew article: How to build a pyranometer for under $100. Off-the-gridders (or wannabees) interested in passive solar heating could design their system better if they had some way of measuring the solar radiation at their site. Commercially built pyranometers are too expensive for most people to consider buying. The homebrew pyranometer should be calibrated in Langleys, which is the unit that the literature uses for solar irradiance data. A digital display is preferred and an RS-232 output for unattended computer monitoring would be a bonus. Keep up the good work! Bruce L. Broweleit, 21312 Wanapum Village Loop SW, Beverly, WA 99321

Bruce, sometimes it's difficult for people to see the incentives for conserving energy when it doesn't affect their pocketbooks and they can't see the pollution caused by the central power plant. Living on a stand alone system is a different story though. It doesn't take many low energy days to learn to do without the appliances you don't really need! Hydrogen's an alternative to natural gas and propane worth looking into (if you'd like an interesting hobby) but again reducing your demand is the first step —solar water heating and a solar oven can go a long way to this end. HP33 and HP34 have hands-on articles on converting a natural gas/propane stove and catalytic heater respectively to run on hydrogen. Electrolyzers for producing hydrogen can be bought from Hydrogen Wind, Rt 2, Box 262, Lineville, IA 50147 • 515-876-5665. Walt Pyle of Richmond, CA is just about to replace his propane use with hydrogen — we're hoping to write it up soon.— Amanda

We use the LI-COR LI-200SB pyranometer. It measurers solar radiation from the whole hemisphere (global sun & sky radiation) and puts out a 10 mV signal at 1000 W/m^2. We plug it into a Fluke 87 multimeter or a data logger. The company will calibrate it to within ±5% (max) ±3% typical. The LICOR costs $200 plus shipping: LI-COR, Box 4425 Lincoln, NE 68504 • 402-467-3576. Typically, you don't need to know the solar radiation of your site with great precision, since it will vary day to day anyway. You do, however, need to find where the sun shines the most on your land. The best tool we've found for this is the Solar Pathfinder (see ad on page 114). You can also build a cheap & dirty model. See the Homebrew article in HP 28, page 61 — Chris

TANSTAAFL

Dear HP; I have seen a video tape put out by Dennis Lee, of Conserve Inc. He contends that he has the technology to produce a flat plate condenser, super heat pump with a C.O.P. of up to 12. With a heat box storage unit, 33% efficient electrical generator, and a heat engine. He has made some incredible claims about rethinking energy production. Are you aware of his work? Is it credible? Do you have any desire to explore heat pump technology as a viable sustainable/renewable energy? If not could you refer me to someone who can critique his claims?

Aside, I am building my first house. I could find only two articles to help me on architecture (HP#19 pp. 40-41; HP #26 p. 77) in my back issues, which are incomplete. Are there more? Aside, aside, the amount of energy it takes to make a PV panel exceeds the energy it can deliver over its lifespan - true or false? I terminated my solar engineering B.S. at New Mexico State University in 1982 when I found the answer was true. I have rekindled enthusiasm with the heat pump issue. Any response is appreciated. You are doing noble work. I hear about you at HPV (Human Powered Vehicle) meetings in Massachusetts, to part time homebuilders while fishing in Bristol Bay, Alaska. A sincere "Thank you", John Fleming, 734 N Baker St., Port Angeles, WA 98362

Hi Jeff; so we've been skeptical of everything we've seen or heard about Dennis Lee's heat pump. We saw

their video tape, and it just didn't make sense. As an engineering student you should recall that any heat engine cycle, can, in theory, be made from Carnot cycle engines, and that a Carnot engine's efficiency is: 1 – T_c/T_h where T_c is the temperature of the cold heat well (the ambient temperature, radiator water temperature, etc.). and T_h is the temperature of the hot temperature well (the burning gases in your car's cylinder).

If you were to "run" a heat pump off the ambient air temperature, then $T_c = T_h$ = ambient air temperature, so efficiency equals zero. We've talked to a couple of these heat pump guys on the phone and offered to test their product the way we test PVs, inverters, etc. We've never received anything.

Otherwise heat pumps are a great idea. Look into ground coupled heat pumps for low cost home heating.

PVs used to use more electricity in their manufacture than they ever produced, but this is no longer the case. Now energy payback time is less — down to a year or less. Some manufacturers say six months. Single crystalline cells are most energy intensive, followed by polycrystalline, and then amorphous.

We usually run an article every couple of issues (lately more) on solar architecture. See the interview with Stephen Heckeroth on passive solar design HP#32, glass & glazing HP#30, Earth Berm Homes HP#29, architecture software review HP#29, Radiant Barriers HP#28...— Chris

Overshot Option

Dear HP; I just read the letters in #33, including Bob-O's advice to Ed LaChapelle of Olympia, Washington on page 103.

Very low head hydro is a difficult proposition because of the high cost, low speed, and limited availability of equipment. If Francis turbines don't work out for Ed, he might look into building or buying an overshot wheel, which will be about 80% efficient if properly designed. The primary drawbacks are the low speed, vulnerability to high tailwater, and a need to be housed for operation in subfreezing temperatures.

I am familiar with Francis turbines in the 100 to 500 kw range. I have neither experience with or specific information about overshot wheels. For advice or design information Ed might try the Society for the Preservation of Old Mills or one of the millwrights advertising in its publication, the Old Mill News. The Society is rather decentralized. The magazine is published by Michael LaForest, 604 Ensley Dr., Rt 29, Knoxville, TN 37920, while its Technical Editor is Steve Kindig, RD2, Lobachsville Mill, Oley, Pa. 19547. The Mill Bookstore has, among other items, reprints of literature published by the Fitz Waterwheel Company, the nation's last waterwheel manufacturer, and is run by Frank Kehner, 2265 Fallen Oak Cir. NE, Massillon OH 44646 Good luck. Matt Foley, Riverat Glass & Electric, Box 593 Church St, Wadhams, NY 12990 • 518-962-4514

Cheap & Easy Greenhouse

Here's a great design for a greenhouse that we learned from some friends of ours that built one. It's clean and quick to build. Cattle panels are the main structure. Cattle panels can be bought at any local feed store for $14.00. Bend the metal 16 foot by 52 inch cattle panel into an arch. Put as many next to each other as you like depending on how long you want it. Attach the bottom of the panels to a wood frame which is on the ground. Put a vertical support beam on each end with a horizontal beam between them the length of the ceiling to help stabilize the structure. Cover with plastic, add a door on one end, and you're done. For a more efficient greenhouse place thin strips of wood on the outside arched over the plastic then add a second layer of plastic. John & Deb DuMont, Rt 2 Box 337, Salem, MO 65560

Grid Bottom Line

Greetings All; I just finished reading yet another letter from someone who's already hooked up to utility-power and can't quite justify to him-(in this case)-self the expense of purchasing and installing an AE system.

Electrickians here in our area have stated "authoritatively," quite recently, that PV watts still cost much more than utility watts. Does anyone ever figure in access fees? Here, for instance, just for the privilege of being hooked into the local REA, one will pay somewhere around $10–15/month. That's if you use no electricity. That works out to at least the price of a panel or storage battery per year.

What originally pushed me over the edge, so to speak, was when I was quoted $4,000 just to bring poles and service across the creek to our house. Total, our system has cost us $1,182, to date. That's collection, storage, regulation, wires, solder, ring-terminals, 12V motors for Maytag wringer/washer, outlets, fixtures, cover plates, everything! We used to do the washing in town, and we feel that the washer alone has just about paid for the system in savings. (It used to be that the nearest laundromat was a two-hour round trip away.) We're completely 12V and intend to stay that way. I feel that EMF radiation very well could be more deleterious to our health than anyone knows for sure. Yet, driving down a highway with the radio on and passing under a power line often causes noise through the speakers. What is happening to the micro-circuitry in my brain? That brings to mind a friend recalling riding on his bicycle in the cooling fog of a DDT-spraying truck of a warm summer's eve back in the fifties. Taking everything for granted – or

as touted by the powers that be – can be a dangerous undertaking. Gee Whiz, am I glad you folks exist! Thank you.

OOPS! The point of this was to ask if you have current cost comparisons of (particularly) PV-to-utility? And is there a formula whereby one could figure in their access fees? Maybe a graph with an x-y break-even line? Thank you folks, David T. Bearman, POB 356, Guadalupita, NM 87722

David, in your case it's clear that you saved money by going with RE. Let's say you put your $1,182 into the bank earning 3% interest instead of buying a system. You hooked up (for free, say), and used the bank account to pay $20 a month to the power company. In five years, three months your bank account would be dry, and you'd have no renewable energy system. But goodness, so many variables! If the initial sum was $8000 instead of your $1,182 then the interest off the money would exactly cover your power bill. It's a good application for a spreadsheet or a small program.... Also, do you want to count in the value of your labor building and designing the system? How much of your system was scrounged? Your point is a good one — small AE systems are very cost effective. — Chris

Step by Step

Greetings! We are soon to move (May) into our log cabin with 100% solar, wood heat & cookstove, small propane stove and, oh joy, a Sun Frost refrigerator. We were able to locate almost everything recycled, except the Sun Frost, alas. We hope to run a word processing business and medical transcription, so we still need a fax and answering machine. We invested in an FM radio telephone that will handle a modem, etc. Now we just need the work.

Your magazine has proved to be an invaluable resource throughout our five learning and building years. We're still learning and building. But we were able to make some major decisions with your help. We are two women building an upright (palisade) log cabin with a full basement (unintentional!). While continuing to work in the city, we managed to acquire a Trace 2012, eight Kyocera panels on a Zomeworks tracker, and two sets of 1340 Amp-hr batteries, along with a Backwoods charge controller and power distribution box. The plumbing is still in progress. But we got a Sears low flush toilet for $100 based on a Consumer Report study, and a Real pump, so far. We'll have a 1,000 gallon holding tank and our 50 gallon pressurized tank. The rest is still pending. We are also hoping to design a good gray water system, as many folks have. We would love to have visitors, advice and questions. All for now, Jan Revell, Highland Enterprises, Beaver Canyon Rd., Wauconda, WA 98859 • 509-486-1006

Wow, you're doing it all and doing it right. The move to the country is shock and work enough for most folks. Add to it renewable energy, building one's own home, and earning a living from a home business and you have a deed indeed. I salute you and your energies! — Richard

Good Wood

Hello Folks, In regards to the question of what materials make good containers for lead-acid batteries, I am a strong advocate for good ol' renewable wood. About ten years ago I repaired the rusted out, acid worn battery tray in my VW bus with a piece of ¾" pine for a temporary piece to fit under the battery. The wood is still holding strong... no paint or polyurethane or poly anything!

My wife, two daughters and I are now living under construction, in our off-the-grid house here in Bridgewater, Connecticut. Despite the status quo skepticism, the sun has provided us with all the power we need to build and live in our home. Four PV panels (Solarex MSX56) mounted on the roof of my bus charge Exide 6C 5 batteries which are regulated by a Buss controller. A Trace 2012 inverter powers the 120 volt loads. I have never had any problems with that setup in the four years it has been in operation.

In the last month we wired the house and installed the PV system. It consists of 20 Siemens M75 panels, charging a 24 Volt Trojan T105 battery bank (20 batteries). We are using two Trace C30 controllers and the Trace 2524 inverter. The battery shelves are made of, you guessed it, pine! Thanks for your energy, Ed Witkin, 74, Tappen Rd, Bridgewater, CT 06752

Thanks for the tip, Ed. As it turns out, the shelves holding the cells in our battery room are also made of wood — fir. They show no degradation as yet (less than two years). I had a lead-acid cell explode and disgorge three quarts of sulfuric acid onto the plywood floor. Cleanup was less than graceful and a substantial amount of acid soaked into the floor. After neutralizing the spill and washing the floor, no damage was in evidence except a deep brown stain. The floor still gets walked on daily. While high-tech plastics seem best for the cell cases housing the reactive innards, wood is just fine for battery shelves and containments. — Richard

We could send out renewal notices. We could use up the trees. We could pay the post office to burn the fuel to get the dead trees to you. Or we could let you know the expiration date of your subscription on the mailing label of this issue.

Check out your mailing label!

Q&A

SUN-R-US
I'm looking for a rechargable battery-operated remote control toy car (or truck) or other similar innovative, off the grid power toys that help kids learn about the positive uses of alternative energy sources. Any input? Stephany Schenker, POB 431, Anahola, HI 96703

Stephany, you can buy off the shelf solar toys and solar experimentation kits from a number of suppliers. Alternative Energy Engineering and Real Goods Trading Co. are two that come to mind. You can find them in the advertiser's index in the back of this issue. George Hagerman of Seasun Power Systems is a teacher who has been putting together solar education kits and teaching teachers how to teach kids about renewables and conservation for years. You can find George ar 703-549-8067. If you're feeling a bit more adventuresome (or have a tighter budget), I've found that many battery operated toys can be easily modified to run directly from a PV. My favorite is the Capsela® 1000 motorized construction kit. You can make all manner of wheeled, tracked, or paddle driven vehicles, pumps, cranes, and even a vacuum cleaner. Replacing the AA battery pack with a 5 Watt PV in full sunlight will run darn near anything in the kit. — Bob-O

Positive Switch
We've been using a PowerStar 200 to run a few lights and our radio. But because of the high idle draw of the PowerStar 200, I put a switch on the positive wire to disconnect the inverter when not in use. This switch is more convenient to use than unplugging the inverter. Is there any reason why not to do it this way? And another thing, what can we do to make sure Bill Clinton incorporates renewable energy in our energy policy? Many thanks. Forever Alluvial, Mike Redman, POB 2825, Del Mar, CA 92014

Hi Mike, If you put your switch in the positive wire between the battery and PowerStar's cigar (do people still smoke cigars in cars?) lighter plug, AND that switch is DC rated to 20 Amperes or better, it's a fine idea. Put a 20 Ampere fuse in the positive wire on the load side of the switch. If you were to use say, a 20 Ampere Square D QO Series circuit breaker as your switch, you'd be covering a lot of safety bases at the same time. On the other hand, if you break the input wire between the cigar plug and the inverter for your switch, there went your warrantee. Politicians say that they are most likely to respond to well-written individual letters from citizens than form letters, fax flurries, and the like. I think we should direct our thoughts to Al Gore rather than the Big Cheese hisself. Gore has already committed himself toward a more benign environmental stance, so you'd be speaking to something he already believes in, and I think we can pretty safely assume that he has the BC's ear. Bob-O

Paint It Black
I'm looking for black chrome paint for collector. Where to buy? Page 61, HP #31, Tom Lane stresses use of same. Contact with Sunelco and the Real Goods people, along with two local paint companies, netted negative results and no knowledge of it. Hope you can help me. Thank you, Robert Crumley, POB 1482, Graham, WA 98338

Here, Robert, is the access for Selective Black Solar Collector absorber paint. This paint collects more and reradiates less solar energy than BBQ or woodstove type high temp flat black paints — also it will not 'outgas' as other paints will. Dampney Co.,85 Paris St., Everett, MA 02149 • 800-537-7023 — Bob-O

Contractor Concerns
Regarding the use of AC or DC to pump water from a well using PVs and an inverter (ac) or only DC, which is more reliable and and/or more efficient? Which are the most efficient appliances, refrigerators, dishwashers, etc., for use on a PV system? The best "on demand" hot water units? I want to build homes off grid and believe your magazine has the best information available. Is there a problem with inverters breaking down? Thank you, Don Thompson, Thompson Construction, 900 Indiana SE, Albuquerque, NM 87108

Don, ac and DC pumping both have their advantages. DC pumps are more efficient and don't require an inverter which further increases the efficiency as well as the reliability of the system (though 95% efficiency in inverters are common and inverters are reliable). AC pumps, on the other hand, are more common, less expensive, and do not have brushes that need to be replaced (though only every 5 years). If you want to pump more than five gallons a minute or from deeper than 250 feet, ac pumps are the way to go. We're pumping 100 feet, 1 gal/min and decided to go with a DC pump to keep the system simple. Our system is array-direct, so we don't need batteries either. When the sun shines, water pumps up to a storage tank. It's separate from the house electrical system. The most efficient refrigerators available now are Sun Frosts, 824 L Street, Arcata, CA 95521 • 707-822-9095. They use seven times less power than the average refrigerator. Fluorescent lighting is also very important in home power systems. Jim Forgette of Wattevr Works, POB 207, Cedar Creek, San Andreas, CA 95249 • 209-754-3627 sells kits which replace

standard washing machine and swamp cooler motors with more efficient ones — maybe he can do the same with dishwasher motors. Inverters are solid state devices which are in general reliable. Appliances, such as laser printers, with thyristors blow up on modified sine wave inverters. — Amanda

The 12 V Answer Machine Answer

Dear Home Power; We have lived with solar since 1980 and gradually expanded to where even our camcorder batteries are juiced by the sun. Everything seems to work well. The problem I'm having is how to change my answering machine, so it would like 12V instead of 120v, without investing in another answering machine. I have written G.E., but you know big business. I don't like to use inverters for every little thing I add for our convenience. The two large TrippLite inverters have worked well all these years. So, if you could tell me how to change the answering machine I would appreciate it very much. Sincerely, Ludo van Helsding, RD1 Carhill 4073, Cortland, NY 13045

Ludo, it's impossible to tell what kind of power your GE machine likes to eat without seeing either it or a schematic, but here's a clue. If the machine is fed thru a "wall cube" type of power supply which runs the power thru two small wires to a detachable round plug in the back of the machine, you are probably feeding it DC power already. Look on the wall cube name plate to see what the voltage OUT is. Match that and be mindful of the polarity of the plug. (There is usually a drawing showing the tip and ring polarity stamped into the plastic housing of the machine) — Bob-O

Hello, Ludo. Actually the problem of 12 Volt DC powered answering machines goes deeper than just supplying power to the machine. It seems that the telephone companies have been grounding the positive pole of their power supplies since Alexander Graham Bell first phoned, "Mr. Watson, come here, I want you." on March 10, 1876. If you power the answering machine from a 12 Volt battery that has its negative pole grounded, then you have a great ground loop going with both positive and negative power poles earth grounded. I have tried this with a variety of answering machines and none worked. The line ceased to function—no dial tone out and no ring in. If you want to power the answering machine on 12 Volt DC, then don't ground its negative pole. In most systems, the inverter accomplishes and assumes negative battery pole grounding. So, if the main system's battery is attached to an inverter, or a standard 120 vac mains distribution panel, or another radio that uses common grounding between the negative DC input and the RF ground, then that battery cannot power an answering machine. Use a battery with no ground connections at all. Power the answering machine, and only the answering machine, from this small, but dedicated battery. Charge this dedicated battery with its own small but dedicated PV module. This way the phone company can have whatever grounding dementia it may wish, and you can power your answering machine however you may wish. I did this for several years and it always worked fine with any answering machine that ate 12 VDC from its wall cube power supply. —Richard

Now You're Cooking

Home Power; In issue #31 Therese Peffer wrote about your experience of buying a new gas/propane range. I wish you would have written that article two years ago, so we wouldn't have bought one with a piezoelectric ignition. Never thought to ask how much electricity was used to run a propane range. On cloudy rainy days I would have loved to do some baking, but I couldn't because of the large power usage of the range. Anyway, we found a company who only makes spark ignition ranges. It only uses electricity to spark the pilot. Then the pilot stays on throughout the oven cycle. The company name is Peerless Premier Appliance Co. • 1-800-858-5844. You can either call them for a distributor in your area or go to an appliance dealer who deals mostly in gas appliances. Be aware most salespeople don't even know there are two types of ignition systems. In California they use the brand name of Modern Chef (don't get it confused with Magic Chef or Modern Maid) but the name could change regionally. They make a lot of different sizes, colors and styles so you don't have to be stuck with white. They also make some without clocks — a miracle in itself. They have a nice brochure that pictures their entire line. Hope this helps anyone in the market for a new range (gas) on or off the grid. Renee Thompson, POB 79, Boonville, CA 95415

Hey, this is great, Renee, I am in the market for a new gas range. I got my old one for $50 and it's worth every cent. It has a grill, which I really like, but when I put the oven on low it heats to 600°F and when I put it on broil it cooks at 325°F. Those are my only options. I've looked into getting it fixed but it costs more than the old stove. The control knobs are disintegrating from age and heat leakage from the oven. I called Peerless-Premier's 800 number and ordered the brochure. I received a prompt reply in the mail consisting of a letter with the name of the dealer in my area and a color brochure of the available models. Nice pictures of lots of models and good spec chart on all models. Thank you — Kathleen

[It wasn't the Magic Chef's piezoelectric ignition that drew so much — it was the 600 watt electric glow bar ignition in the oven — Chris]

Equal Rights for 120 VDC

You should give equal time to Alternative energy users who prefer DC appliances, instead of using inverters. Issue #32, pages 96, Q&A, “Wire We Here” letter was a discouraging answer. I get the impression that your inverter advertisers have you in a “conflict of interest” situation. Also, there is an interest in 120 volt DC systems. There are electric tools and appliances still rated 120 AC-DC. Look in a Milwaukee tool catalog. The Croft Manual has a page on DC fluorescent lighting. Jeff Hammer, POB 168, Tyrone, NM 88065

Jeff, the possibility of cancer from EMF from 60Hz ac power is reason enough to consider DC electricity. But I said in my answer in HP #32, finding DC appliances is difficult, and quality will probably be lower for the price you pay. You can run heaters, incandescent lights (and the special fluorescents you mentioned), and “universal” series motors on 120 VDC. But 120 VDC is dangerous stuff. Make sure your fuses and breakers have sufficient A.I.C. (Amperes Interrupting current) ratings for DC voltages. A fuse or circuit breaker has an easier job of stopping a short circuit current in an ac system because the voltage and current goes to zero 60 times a second. In a DC system, once a short circuit current arc starts, it’s harder to stop it. (This is especially true for higher voltage systems.) For the same reason make sure your switches are DC rated.

Also, be aware that switches will wear out considerably faster in high voltage DC applications — again, because they must break the DC arc.

If you do install a 120 VDC system and find you want to run standard power tools, a television, computer, stereo, etc., you’ll need an inverter. Chad Lamkin of Michigan Energy Works builds a fine 120 VDC to 120 vac inverter. 9605 Potters Rd., Sarnac, MI 48881 • 616-346-9445 — Chris

Jeff, I’m told by Ron Carter of North Carolina that most late model color televisions without an ac power transformer will run just fine on 120 VDC too!—Bob-O

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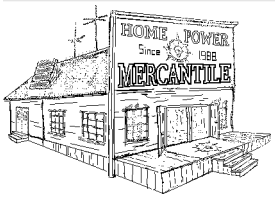

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