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HOME POWER

THE HANDS-ON JOURNAL OF HOME-MADE POWER

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HOME POWER

THE HANDS-ON JOURNAL OF HOME-MADE POWER

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Home Power Magazine
POB 520
Ashland, OR 97520
916–475–3179
voice & FAX

Think About It

"Como tierra soy estéril, como madre soy fecunda."

"As soil, I'm sterile; as mother, I'm fertile."

Ramón Paz Ipuana — 1984

Cover

Mosoco, *Tierradentro*, Colombia folks enjoy hot rice cooked by the sun in a SunOven. Story on page 99.

Photo by Juan Livingstone.

From us to YOU

The Spirit of the *Chivas*

A *chiva* is a Colombian mountain bus. The *chivas* carry everyone and everything around the high Andes. Each *chiva* is different. No two *chivas* are painted the same, driven by the same *chivero*, or follow the same route. It's not these busses themselves that are so amazing but the spirit of the drivers and passengers.

The *chiva* is an impossible collection of worn out, overloaded, ancient machinery. Things break regularly and everyone expects delays. A *chiva* with a flat tire parks in the middle of a one lane road cut through impossibly steep terrain. All passengers are outside holding the chiva up while the *chivero* changes the tire. All traffic is blocked. Everyone gets out of their vehicles and stands around talking. Someone starts coffee brewing. No one doubts that the *chiva* will be repaired. It's just a question of time and no one is in any hurry.

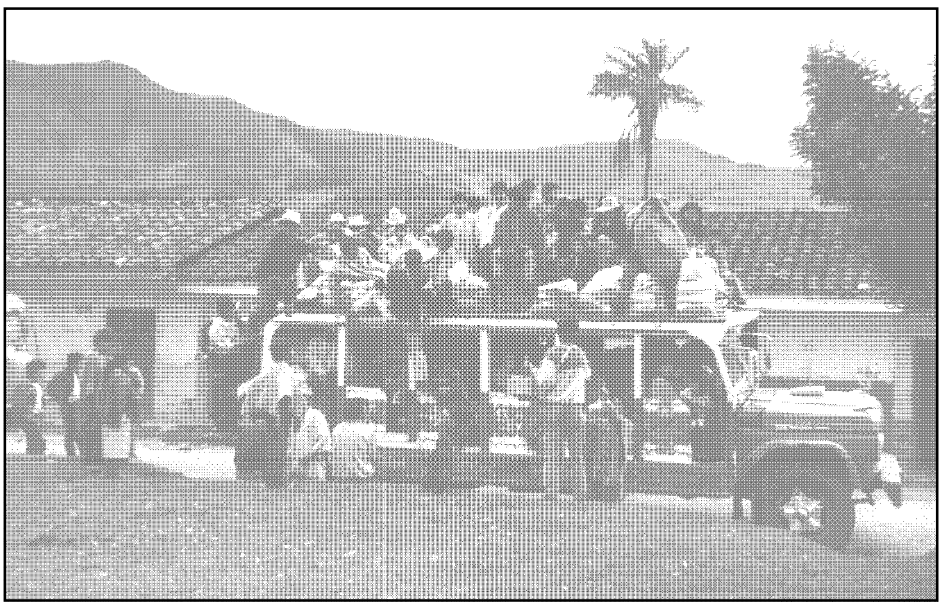
The *chiva* riders are equipped for the long haul. The have brought warm clothes suitable for racing around mountain roads in an open sided bus. They have brought dinner, lunch, and breakfast for tomorrow. They have brought chickens, pigs, plants, corn, beans, and other stuff all lashed to the *chiva's* top. They are enjoying the view and visiting with their neighbors.

The *chivero*, an independent businessman, repairs his bus. He is assisted by his associate who collects all the fares and keeps a sharp eye pealed for any trouble. While the passengers relax, the *chivero* and his associate are doing whatever is necessary to breathe life back into the *chiva*. Roadside engine rebuilds with a crescent wrench and hammer are a snap for these fellows.

When the *chiva* is fixed everyone reboards and the ride begins again. Since the *chiva's* schedule is plus or minus two days, no one minds running through villages at 2 AM with the horns blaring. Everyone awakes, and those taking the bus scramble to hop on as it races through town. On a *chiva* there is always room.

I learned a lot from the *chivas*. An optimistic, can-do spirit can accomplish the plainly impossible on a regular basis. And have fun doing it.

Richard Perez



Above: There's always room on a *chiva*. Photo by Karen Perez

People

Barry Brown
Sam Coleman
Will Emerson
Bijou Gomez
Chris Greacen
Stephen Heckeroth
Kathleen Jarschke-Schultze
Elliot Josephson
Juan Livingstone
Don Loweburg
Terri Markatos
Mark Newell
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Richard Perez
Amanda Potter
Shari Prange
Rick Proctor
Mick Sagrillo
Bob-O Schultze
Randy Udall
Michael Welch
Eric Westerhoff
Rod Wheeler
John Wiles

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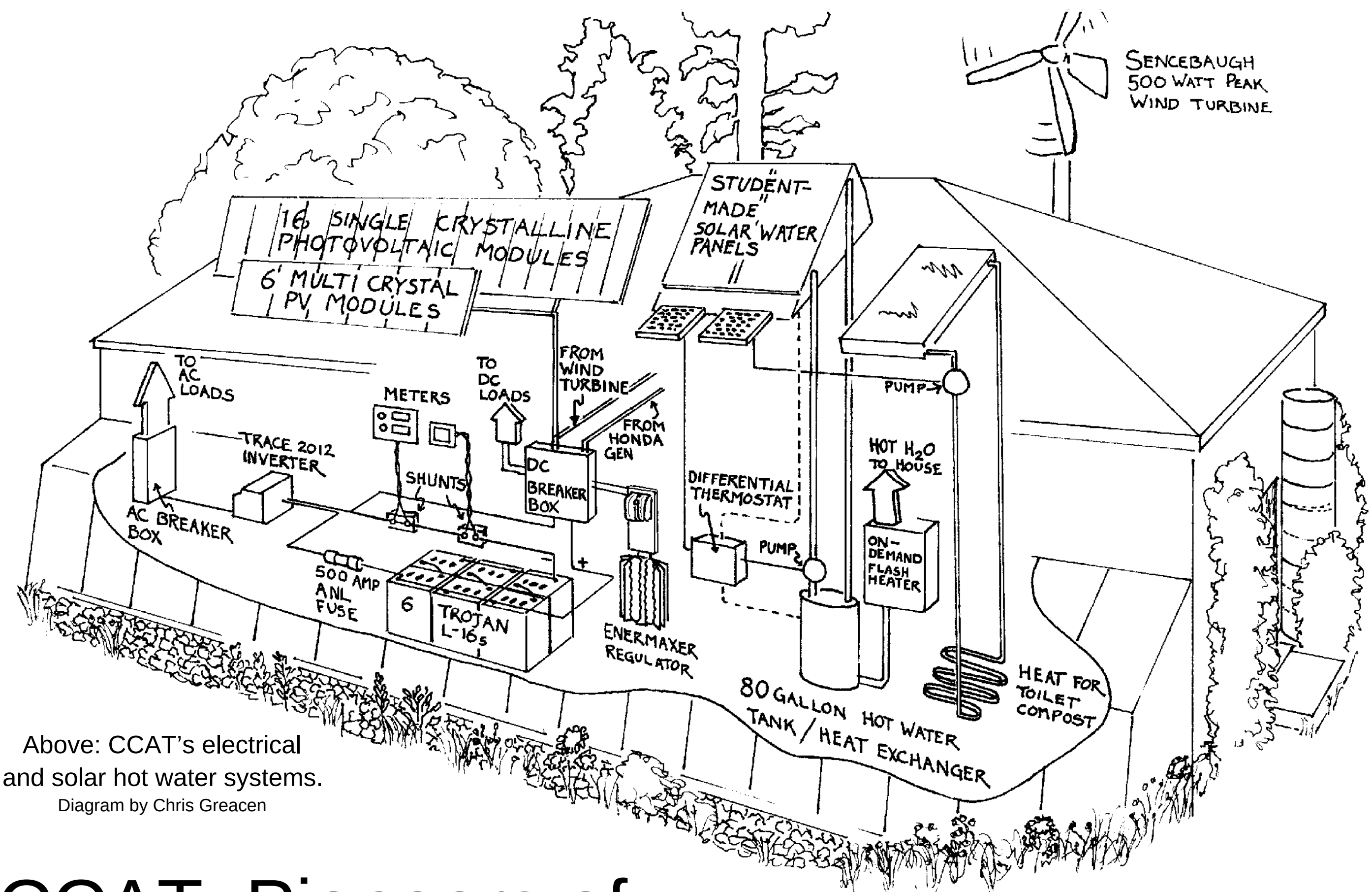


Above: CCAT's electrical and solar hot water systems.
Diagram by Chris Greacen

CCAT: Pioneers of Urban Sustainable Living

Amanda Potter & Chris Greacen

In 1978 the building was not remarkably different than thousands of American houses. Like most houses, it wasn't energy efficient — gas and electricity were cheap. It dumped its waste directly into the city's sewer system. The food that its occupants ate was purchased from distant markets. Perhaps the only thing that distinguished this house on 16th Street and Cluster Lane in Arcata, California, was its scheduled demolition as part of an expansion of Humboldt State University (HSU).

The history of this building's miraculous transformation is beyond this article, but the results are clear. The house is now CCAT, the HSU Campus Center for Appropriate Technology. CCAT is a thriving student-run demonstration center for appropriate technology and self-sufficient urban living. Reliance on outside resources is minimized. Most of the electricity, home heating, and food consumed at CCAT are produced using the sun, wind, and rain that fall on the small city lot. Nutrients such as kitchen and bathroom wastes are recycled to be reused by the house's gardens.

This transformation has been the work of students and community volunteers. HSU's appropriate technology engineering curriculum includes student projects such as CCAT. Three student co-directors live full time at CCAT, and oversee projects, give tours, and run the day-to-day business of managing the demonstration house. They are appointed by a steering committee of faculty, community members, and past directors. This year CCAT received enough funding to hire a few more people to manage the increasing flow of activity. Lots of other folks come in, leading and participating in weekly workshops on everything from beer brewing to hydrogen energy to organic gardening. Last year over 1,200 people toured CCAT, and nearly 800 participated in workshops.

Others come to use CCAT's library. Their well-organized collection of books, magazines, and newsletters on gardening, renewable energy, and appropriate technology make our files here at Home Power look ill. This information is often difficult to track down, and it is good to see it organized in one place. There should be a library like this in every town. Material can be borrowed by anyone in the community, or you can recline on the couch and browse at will. The library is also a self-guided tour which you can take any time the place is open.

Pullin' the Plug
In spring of '91, CCAT asked Pacific Gas and Electric (PG&E) to disconnect the power lines. Most of the home's electricity now comes from 22 photovoltaic (PV) panels mounted on CCAT's roof. All the panels were made by Solec, and were part of a test facility at Jet Propulsion Laboratories (JPL). The panels put out 30 Amperes at 15 Volts on a sunny day. A Sencebaugh wind turbine on a 40 foot tower supplements the PVs on windy days. During wind gusts it has supplied as much as 25 Amperes. Unfortunately it requires 15 mph winds to start generating power, which, at only 40 feet up, it doesn't often receive.

Arcata is on the coast of far northern California. For weeks on end, especially in winter, the town is fogged in. In the renewable energy world, these are "low energy days." For these times, CCAT uses a three horsepower Honda engine, modified to run on natural gas, which drives an 80 Ampere automotive alternator. This 12 Volt DC engine generator uses a student-made Mark VI electronic field controller to control output current. Former co-director Mike Nelson was careful to explain that CCAT has disconnected from the "E" of PG&E, but utility natural gas is still used for back-up electricity generation, and for cooking and some water heating. Fortunately, natural gas is the cleanest burning of fossil fuels.

Batteries Included
Electricity is stored in six 350 Ampere-hour Trojan L-16 lead-acid batteries. To prevent overcharging, a 50 Ampere Enermaxer voltage regulator shunts any excess current to an air heating element. The PV, wind turbine, and shunt regulator circuits are protected with 50 Ampere Square-D circuit breakers. The engine generator circuit gets a 60 Ampere breaker. DC loads to the house are protected with a 50 Ampere breaker. All the electricity flowing into or out of the batteries must pass thorough two 500 Ampere 50 mV shunts. A Cruising Equipment Amp-Hour+, and a SCI Mark III monitor use the voltage drop across the shunts to keep track of the current flowing in and out of the battery. A Trace 2012 inverter, protected with a 500 Ampere ANL fuse, powers ac loads. The inverter feeds directly into the ac circuit breaker box which formerly received PG&E power.

Where the Energy Goes
CCAT's electrical system provides power for household needs of three resident co-directors and people who come in and out, power for office equipment during business hours, and power for weekly workshops (power tools). Power use is detailed in the chart below. The house is wired for both ac and DC. Efficient compact fluorescent lights provide the bulk of lighting, supplemented by 60 Watt DC halogens. Regular ac incandescents are used for intermittent lighting such as closets. The refrigerator is a sixteen cubic foot 12 Volt DC Sun Frost, one of the first ever built. It uses 200 kilowatt hours per year on average, compared to the 1300 kilowatt-hours per year for a typical refrigerator of the same capacity. Sun Frosts are made in a small factory in Arcata, and Larry Schlussler, the founder of the company, donated this unit to CCAT.

CCAT's Big Power Consumers

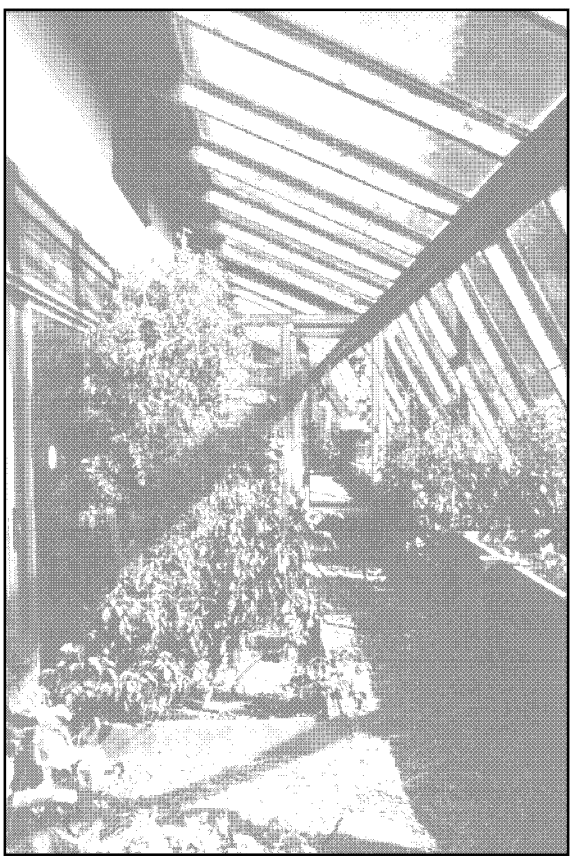
No.	120 vac appliance	watts	hours /week	W-hrs /week	%
1	stereo	40	35	1400	16%
5	fluorescent lights	18	10	900	10%
1	Macintosh computer	60	10	600	7%
1	ac power tools	1000	0–5	500	6%
5	incandescent lights	60	1	300	3%

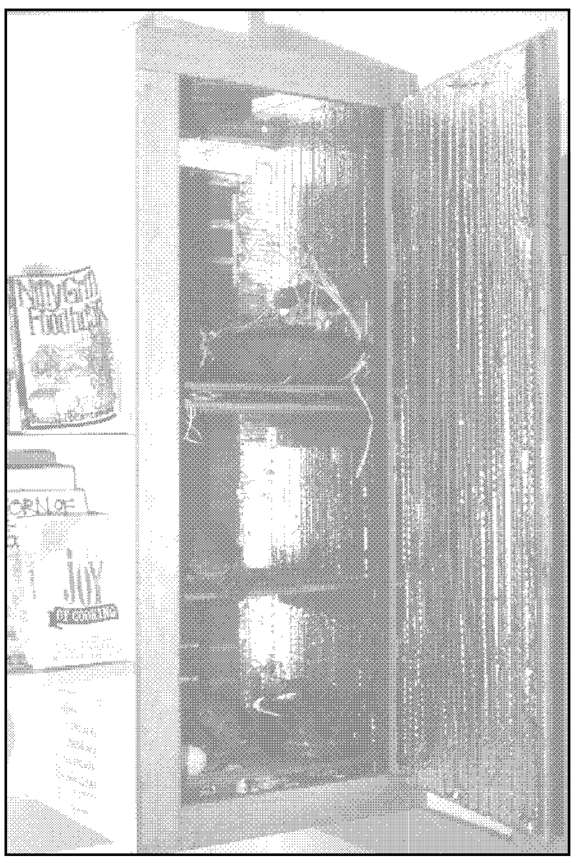
No.	12 VDC appliance	watts	hours /week	W-hrs /week	%
1	Sun Frost refrigerator	80	50	4000	45%
4	halogen lights	60	5	1200	13%

Total Energy Consumption per week 8900

With today's cheap power, it is impossible to justify CCAT's solar and wind electrical system on money alone. The electrical system serves as an engineering political statement, as an education tool, and as a center for ecological R&D. On the other hand, CCAT's solar water heating and space heating systems are cost effective, even in today's energy glut.

Solar Water Heating
During sunny periods, water is heated by an active solar thermal system. One of CCAT's first projects was construction of two flat plate collectors. They heat propylene glycol, a non-toxic antifreeze, which is pumped through a heat exchanger in an 80 gallon hot water tank. The pump is powered by an 18 Watt Solec PV panel, and





Above: CCAT's home in Arcata, California. PV power and solar hot water on the roof and a wind turbine in the backyard.

Far Left: the inside of CCAT's greenhouse. Note window from greenhouse into the building's second story.

Left: a cold box in CCAT's kitchen. Here veggies keep fresh and healthy without electric power.

Photos by Mark Newell

a differential thermostat turns off the pump when the collectors are colder than the tank, or when the tank is too hot. An Aqua Star natural gas flash heater further heats the water if necessary. In order to reduce consumption of hot water, showers are equipped with low-flow shower heads which draw only 1.7 gallons per minute, compared with regular heads which draw between 3 and 5 gpm.

Urban Passive Solar Retrofit

The house is an excellent example of a passive solar renovation. A large greenhouse spans the entire south side of the house. Besides growing food and nurturing springtime "starts", the greenhouse heats the house. Inside the greenhouse a thick rock wall stores radiant heat trapped during the day. On the main floor of the house, windows open directly into the greenhouse. When it is cold these windows are opened allowing heat to rise into the living space. For summer cooling, the upper part of these same windows open to the outside above the greenhouse. The greenhouse can also vent hot air to the skies if it gets too hot for the plants.

The walls, floors, and ceiling are insulated with fiberglass batting, loose cellulose, and bubblepack Reflectix™. Part of the interior of the library wall of CCAT has a plexiglass covering so you can visually compare insulation types. Cellulose is shredded recycled newspaper, treated with boric acid to make it fire resistant. It is generally less expensive and has a slightly higher R value than fiberglass. It is particularly good for retrofits and attics because it can be blown into existing wall spaces. For this reason, it is also much easier to insulate around conduit and junction boxes. Reflectix is a 5/16 inch thick reflective insulation which is made up of five layers. Two outer layers of aluminized polyethylene reflect radiant heat. Two inner layers of bubblepack resist convective heat flow and an inner layer of polyethylene gives the Reflectix additional strength. The R values for a single sheet of Reflectix range from 8 to 14 depending on orientation. Thanks to a large donation by the manufacturer, CCAT uses Reflectix in many of their solar thermal projects.

Currently, all the windows in the house are single-paned glass. Thermal curtains keep the heat inside at night. The thermal curtains are made out of blankets filled with fiberfill or Reflectix. Magnetic strips in the curtains and on the window frames hold the curtains against the window frame. In the morning, pull a drawstring and the thermal curtains fold up like an accordion above the window.

Hot Boxes and Cold Boxes

The kitchen has several homemade, inexpensive, energy conserving appliances. They have a homemade solar oven and try to use it whenever possible. In addition, there is an insulated hot box in the kitchen that keeps pots of food hot. Food will even continue to cook in one. Rice, for example, that has been cooked for 25 minutes on the stove will finish cooking in 15 minutes once placed in the hot box. Their hot box is simply a drawer that has been very well insulated. The hot box at CCAT was insulated with rigid foam and Reflectix. Rigid foam, however, probably isn't the best choice because it will outgas (give off toxic fumes) when directly exposed to cooking temperatures.

A cold box is an insulated cabinet that has a north facing vent which allows cool outside air to flow into the cupboard. Warm air rises up a flue through the roof to the outside, creating a constant flow of air. Cold boxes were common at the turn of the century — in fact the CCAT house originally had one — but they went out of fashion with the advent of freon. Even though it's efficient, the Sun Frost refrigerator uses a large portion of CCAT's electricity. CCAT students reduce the number of times the refrigerator is opened and closed by storing fruits and vegetables in their homemade cold box.

Natural and non-toxic products are used wherever possible in the kitchen. The walls are painted with Safecoat, a waterbased, non-toxic enamel. The liner of the floor is made out of Naturelich, a linoleum made out of powdered cork, jute, tree resins, and linseed oil. All the cleaning products are biodegradable and safe for grey water system.

Nutrient Cycling

The electrical system and thermal systems try to make appropriate use of locally available energy sources, but CCAT is just as concerned with recycling of organic matter. CCAT's Bill Lydgate and Michael Nelson explain the philosophy behind this:

"CCAT is dedicated to promoting independence and self reliance. This basic challenge has led us to try to complete nutrient cycles at home instead of importing and exporting vast quantities of nutrients in the form of food, fertilizer, and sewage at the expense of energy, money, and pollution. Furthermore, we would feel hypocritical about producing our own power while still using petrochemical based fertilizers to grow our own food.

"In nature, nothing is wasted. Waste is a very human concept created as we break the natural cycles in life, and end up with by-products that are out of place because our lifestyles are out of balance. We have set for ourself the challenge to reincorporate our 'waste' materials back into the cycle instead of throwing them away.

"There are three main nutrient cycling programs at CCAT: human excrement composting and reuse; household greywater treatment and reuse; and kitchen, garden and yard composting."

Composting Toilet

The composting toilet is used by the three residents as well as workers, volunteers, and guests. Even with this high use, the toilet is only emptied once a year. The composting toilet is in the bathroom in the house between two bedrooms. This is an indication that the odor is not a problem.

One of the most important factors of successfully living with a composting toilet is to keep the decomposition aerobic. This will keep the pile healthy and prevent bad odors. To do this, urine is separated from solid waste by a funnel (and poured on the outside compost piles weekly to add nitrogen) and the pile is turned weekly with a shovel. Ninety percent of human manure is water, most of which evaporates. Instead of flushing with 6 gallons of precious water, the toilet is flushed with a coffee can of fresh sawdust. This helps to provide the correct habitat for the organisms that break down the pile by balancing the carbon to nitrogen ratio.

The temperature is recorded weekly in a log, and the health of the pile is monitored. After a year of collecting fresh manure, the full pile is turned into a holding chamber where it is stored for another year. The extra year should exceed the life cycle of any potential pathogen that may have entered the system. The pile is turned weekly while it is in the holding chamber, and the composting temperatures are monitored. To help the composting process, the pile is warmed from below by a coil of 1/2 inch copper tubing containing pumped, solar-heated propylene glycol. An 18 Watt Solec PV panel powers pump whenever the sun shines.

Once a year, the two year old human manure compost is dug into the soil around the fruit trees as a fertilizer. Guess who has the best fruit in the county!

For guests who are squeamish about the composting toilet, the CCAT bathroom also boasts a low flush toilet which uses 2.2 gallons per flush compared to conventional toilets which use up to 7 gallons per flush.

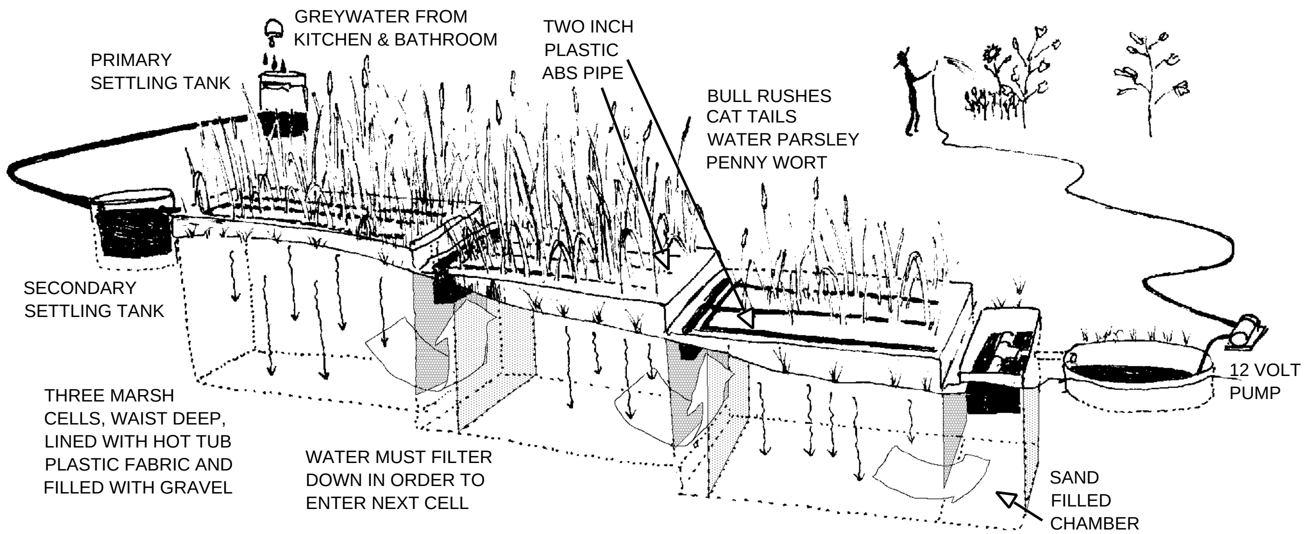
Appropriate Technology

Appropriate technology describes a way of providing for human needs while making the best use of the Earth's finite resources. AT reaps the benefits of both modern scientific advances and effective traditional practices to create solutions that allow people to live comfortably without threatening other peoples or the environment. Appropriate technologies maximize the use of renewable resources through conservation, recycling, and precycling (avoiding packaging). They are designed to be environmentally benign through the understanding of local conditions. The form of an appropriate system is determined by local climate, geology, hydrology, and ecologies as well as by financial, material, and social constraints. This sense of place gives us a deeper understanding of "home".

Appropriate technologies are built for human beings to use, fix, and maintain. As E.F. Schumacher said, it is "technology with a human face", technology which encourages people to rely on themselves for what they need. Small-scale systems such as those in operation at the Buck House help lessen our ties to such impersonal entities as the supermarket or the power company, and make us realize that we are in charge and have the power to guide our future.

At CCAT we seek to celebrate the resourcefulness and creativity of humanity, to find solutions to human problems, and to live a good life through self-reliance and respect for the natural world.

–Campus Center for Appropriate Technology



Above: CCAT's greywater system allows the household sink and shower water to be recycled for use in the garden.
Diagram by Chris Greacen

Greywater to Not-So-Grey Water

The greywater treatment and reuse system is extremely simple and practical. The concept is to catch and treat all the household sink and shower water — all household water except that from the toilet. This enables CCAT to be less dependant upon centralized wastewater treatment facilities with their big expenses and polluting habits. Actually Arcata City's swamp wastewater treatment system is not that bad — one of the best in the nation — but our in-house treatment saves us water and energy.

The sink, shower, and laundry water is diverted to a filter made from a trash can and mosquito netting. The sediment collected (sink spewge!) is knocked into the compost piles, and the water enters into a series of marshes and gravel filters. Aquatic plants take up the nutrients from the marsh while providing habitat for bacteria and other micro organisms that play a role in the biological treatment of the water.

The marsh is habitat for dragonflies, crickets, frogs, songbirds, and lots of other critters. Mosquitos are held at bay with the use of *Bacillus Therenginus* (*B.t.*), a bacteria that attacks the mosquito larvae. Essentially, a living ecosystem has been created that has the capability to clean water and capture nutrients. The whole flow of water is gravity fed, from the sinks through the filters, into and through the marsh, and into a 100 gallon holding tank. A 12 Volt solar powered pump is used for irrigating with the treated water.

Obviously, chemicals and bleach have to be avoided, but avoiding these harsh chemical is better for our environment anyway. All soaps and shampoos used are phosphate free and biodegradable. The users quickly learn that they are connected to the environment and have to be responsible for their waste.

CCAT also catches and filters and stores all the water which falls on the building's roof. This water is used for watering the greenhouse and garden.

Vermi-culture, Wormy-culture

The kitchen, garden, and yard composting program is just your everyday compost pile. All kitchen scraps and organic material is composted and the compost is the mainstay of the extensive organic gardens at CCAT. Sunshine provides the net input of energy into the system, allowing the production of organic matter through photosynthesis.

We let worms help out with some of the composting. A worm culture compost consists of a large box with a screen divider. Fresh scraps are tossed in one half of the box until they are broken down. Then scraps are thrown in the other half. The worms travel through the divider to the fresh material and *voila*! Half a box of rich soil remains, free of worms.

Organic material is layered with dry straw, leaves, and manure, and lots of water. The pile is periodically turned. Three to four months later, the compost is ready to be returned to the garden. Compost crops are also grown. Without returning nutrients to the soil through compost, we would quickly deplete the nutrients in the soil, and be dependent upon petrochemical companies to provide chemical fertilizers.

Visit CCAT

Arcata is a hot-bed of renewable energy enthusiasm — CCAT is one of many organizations doing great renewable energy and sustainable living work in this small Northern California city. Check out the Schatz Hydrogen Project and the fuel cell laboratory. See the Redwood Alliance, and the Sun Frost factory. Visit in April during the Renewable Energy & Efficiency Fair (REEF) on Earth Day. Visit CCAT. See this stuff for yourself. Take notes. Leave inspired.

Access

Authors: Chris Greacen and Amanda Potter c/o Home Power Magazine, POB 520, Ashland, OR 97520 • 916-475-3179

Nutrient Cycling by Bill Lydgate & Michael Nelson, CCAT, HSU Arcata, CA

Campus Center for Appropriate Technology (CCAT): Buck House #97, Humboldt State University, Arcata, CA 95521 • 707-826-3551

Sun Frost: POB 1101, Arcata, CA 95521 • 707-822-9095

Above: Terri Markatos and Barry Glidden's solar powered dome home in Florida.

Solar Dome Freedom

Terri Markatos

We became seriously interested in alternative energy many years ago while on a six month traveling camping trip to Alaska. We were living on the road and traveling with three large dogs; we wanted to be comfortable and independent.

Small Beginnings

We bought a completely self-contained camper and slid it onto the back of the pick-up truck. Our power came from 12 Volt DC truck batteries. We cooked and refrigerated with propane. Periodically, we stopped for supplies, filled the water reservoir, and emptied the holding tank.

The luxury of being independent quickly became a way of life. We grew very familiar with conservation and low-impact living and knew then that our permanent home would be an energy independent one.

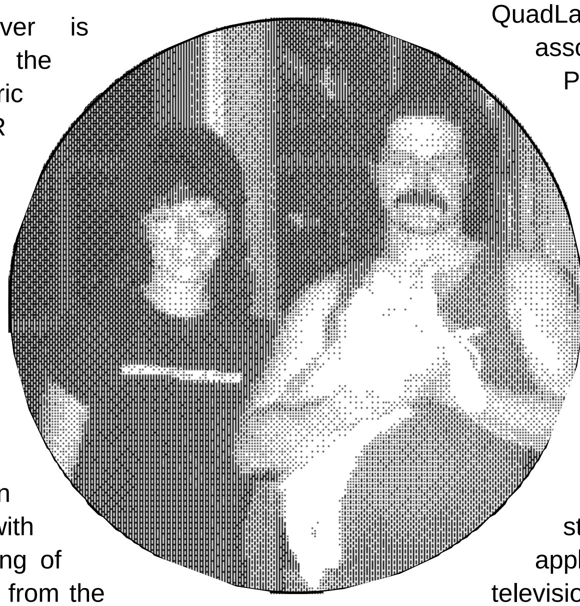
We decided to settle in sunny, central Florida and put all that "solar power" to good use. We also wanted to stay out of debt, so patience and bargain hunting were in our future. We bought five acres in the country, set the camper on blocks and we were home!

Instead of hooking into the grid which hummed right past our driveway, we continued to use the 12 Volt system, and ran the truck periodically to keep the batteries charged. Unwillingly to drive around to charge batteries, we invested in a 3.5 kiloWatt generator. Our system was small. We needed to expand it to power the well pump, power tools, and a second hand washing machine as well as charge the batteries for our lights and other uses. As time passed we added a couple of used photovoltaic panels and a few more batteries.

The Home

Our home is a Bindu Dome on stilts. It is 32 feet in diameter, 21 feet high at the highest point and 14 feet off the ground. The ease of cooling and heating a dome, with its spherical shape and open spaces makes it practical for incorporating passive air cooling. It also enables us to use Grandma's 1922 Home Comfort cookstove for heating. (If our home was in a colder climate we would need another heat source as well).

The insulation and roof cover is polyurethane foam sprayed on the outside, and sealed with elastameric paint and ceramic chips. The R value of an inch of polyurethane foam is 11. We have 2–3 inches on our dome and so the R value of the dome is 22–33. With the outside complete, we were able to live in it as we finished the inside. In the summer, a grate in the floor draws cool air up from the large cool air mass created by the 60 foot by 60 foot deck. Hot air is vented to the outside via a flue in the roof. A wind powered turbine, with marine-type hatches, at the opening of the flue circulates the hot air away from the roof. We draw the blinds to block out the sun and use few strategically placed fans to keep the house comfortably cool.

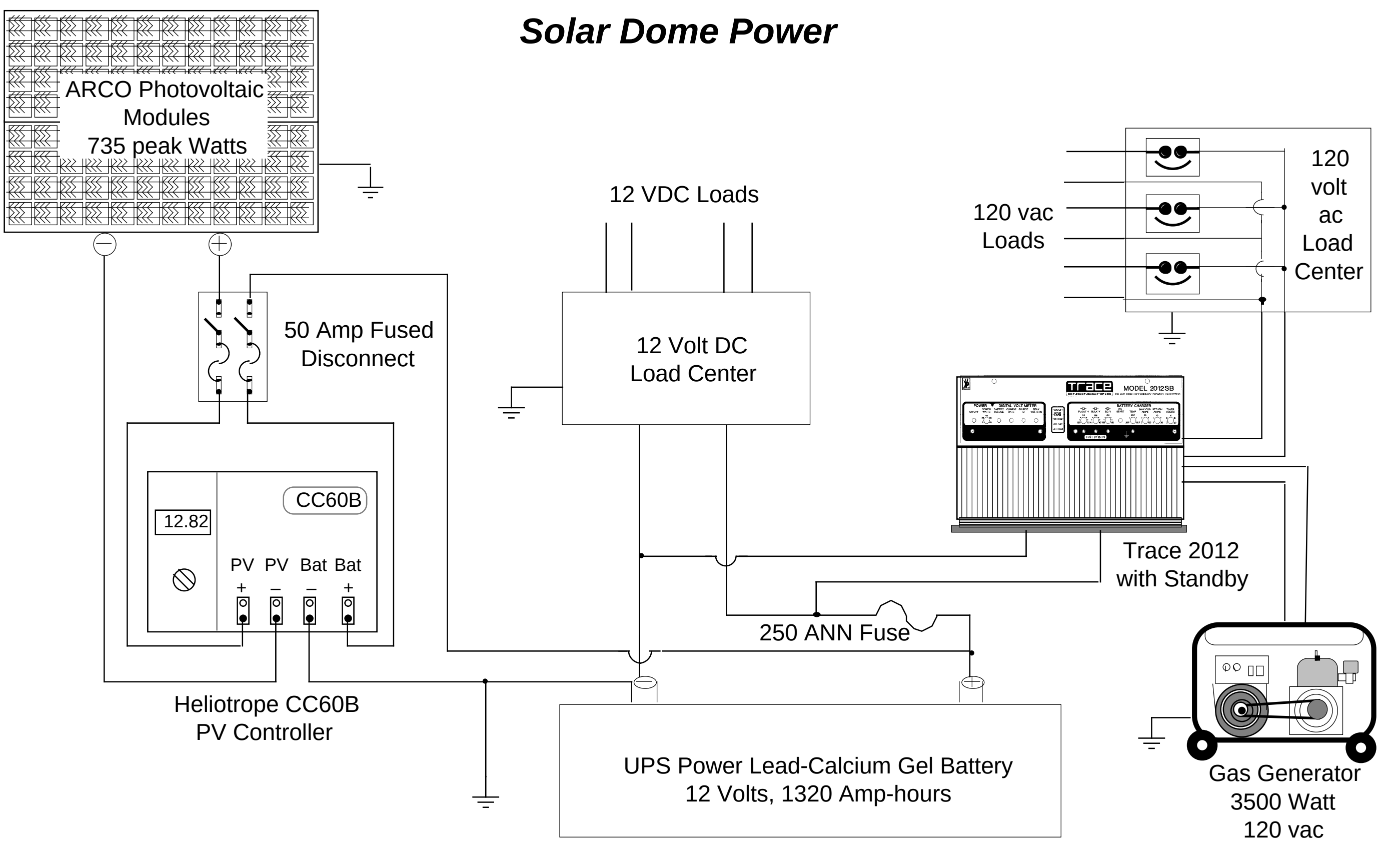


Solar Powered Dome

The dome is powered by used ARCO PV panels (735 Watts peak power) which are regulated by a Heliotrope CC-60B charge controller. We have four QuadLams (sets of 4 M51 laminates) and 18 assorted ARCO M52 and M55 modules. Power is stored in a second hand 1400 Amp-hour used Dynasty Gel Cell battery bank that originally came from a UPS system (uninterruptable power supply). Direct current is inverted to alternating current with a Trace 2012 SB inverter.

Most of the lighting is DC, with a couple of ac compact fluorescent bulbs. The most energy efficient light we found was the Earth Light by Phillips. We still use a 12 Volt stereo, but are gradually adding ac appliances, such as a 19 inch color television, VCR, and a microwave oven. We still use propane for cooking, and use the solar oven whenever possible.

Solar Dome Power



Solar Dome Home Cost

Equipment	Cost	%
ARCO PV modules	$2,200	36%
SunFrost RF-12 cubic foot refrigerator	$1,600	27%
Trace 2012 SB inverter	$1,490	25%
1400 Amp-hr Dynasty Gel Cell battery	$300	5%
Heliotrope CC-60 charge controller	$180	3%
Lighting	$139	2%
12 Volt pump	$119	2%
Total	$6,028	

One of our major decisions was to purchasing a Sun Frost RF 12, the world's most efficient refrigerator. It is more expensive than a conventional model, but very cost effective when savings in our energy system were included. It uses less power than a 60 watt light bulb, and does not drain the batteries.

Waste Not....
Our septic system was one of our main concerns. In this area of Florida the water table is high. An ordinary septic system is not only impractical (it has to sit above ground with dirt mounded over it), but ecologically unsound and wasteful of precious water. It is estimated that 10,000 gallons of water per person per year is flushed away.

The obvious solution was a waterless composting toilet. A Sun Mar with a 12 Volt optional fan was our choice. We turn the bio drum every few days, and a couple of times a year empty compost into the flower gardens.

The last step was the water pumping system. Water is pumped with a low flow 12V pump to a water tower with a 600 gallon tank. The pump uses the excess solar power when the battery bank is full. The tower is twenty one feet above the ground. Water is gravity fed into the house with the help of a small 12 Volt pump. A shower, set up on the deck below the tank, gives us almost year-round showers. With that done, we "officially" moved the kitchen into the dome.

Future Plans
The first of our future plans is to mount solar hot water panels on the tower. A propane fired, on-demand hot water tank will supply more hot water if needed. A graywater reuse system, when completed, will furnish water to drip irrigation and no water will be wasted. We also hope to add an aquaculture tank in the near future and try our hand at raising Tilapia.

Plans to build living room sofas, bookshelves, and an entertainment center are in the thought stages now. Free standing walls for the bathroom, and a circular staircase, or maybe a ship's ladder, to the loft are some of our other thoughts. This summer we plan to add a couple of ceiling fans to keep us even cooler during the Dog Days of summer in Florida.

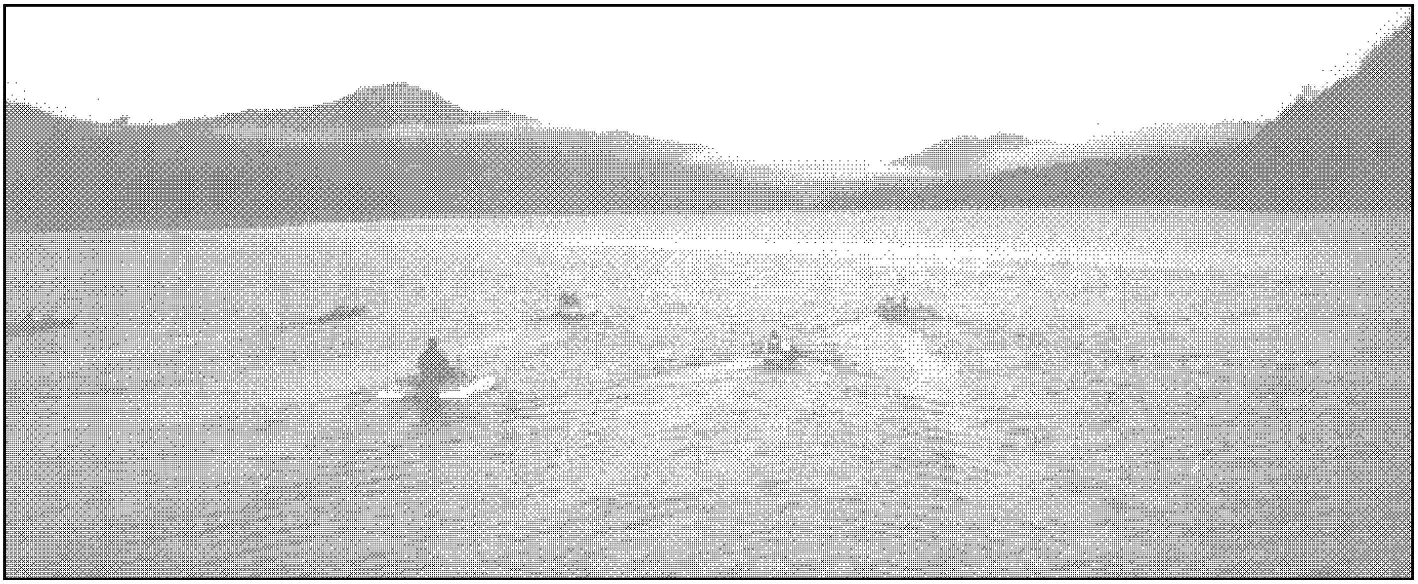
Forever Growing
The Dome will be under construction for quite some time, but for now we are content knowing we are preserving some of Mother Earth's natural resources. Conservation is a way of life that will not cease as more people become aware of the environmental effects of conventional fuels. They tell their friends and more people join the race to save the planet. No one has to die for solar, wind, or hydro power, as in the fight for oil. "If the people lead, the leaders will follow."

We are very happy with our Dome Home and hope to find many years of pleasure living in harmony with nature.

Access
Author: Terri Markatos and Barry Glidden, 4681 Fir Road, New Smyrna Beach, FL 32168 • 904-228-3121

Northern Hydraulics
camera ready

Statpower
camera ready



Spada Lake Electric Boat Race

Rick Proctor

The second annual International Electric Boat Regatta was held over the weekends of August 8–9 and 15–16, 1992. People gathered from all over the country, though mostly from the Pacific Northwest, to participate in the four events. The range of events was wide — from 1 kilometer speed runs for both battery-only and solar-only craft, to 12-hour battery-only marathons and four-hour solar-only.

The Site

Spada Lake is a drinking water reservoir located high in the Cascade Mountains, northeast of Seattle, Washington. When its owner, the Snohomish County Public Utility District, celebrated the opening of the recreation sites in 1991, the festivities included an informal race between five electric boats. The contestants had such a good time and were so enthusiastic the utility knew they had a good idea. Somehow an electric boat race on drinking water seemed appropriate. They decided to hold a more formal regatta in 1992, expand the event to four different races, and offer prize money.

Let the Races Begin!

The first weekend was speed weekend. Saturday, the 8th, was scheduled for boats of any design wanting to attempt to set electric boat speed records. The current world record for electric boat speed was established by a hydroplane piloted by Fiona, Countess of Arran of Great Britain in 1989. The 73 year old Countess ran her 15 foot boat through a one kilometer speed trap at an average speed of 50.825 mph. Two crafts showed up at Spada Lake to attempt this high-speed record. Unfortunately, technical difficulties prevented either of them from getting into the water.

Two new records were established however. The first was for a battery-only electric powered displacement hull. Burton Gabriel, from Port Ludlow, Washington, bolted a one horse-power electric motor on the lower unit of an old outboard motor to his 20 year old aluminum canoe. He powered through the speed trap at 9.6 mph. The world speed record for a solar powered boat was set by Otmar Ebenhoeck piloting Ward Phillip's solar catamaran with 40 square feet of solar panels. Although the attempt was hampered by clouds and a stiff breeze the boat was able to average 5.7 mph.

The following day a four-lap one kilometer race was held on an oval course. The only limitation was that no more than 300 pounds of lead acid batteries be used. Burton Gabriel's canoe dominated throughout the race, winning by a large margin.

The Battery Marathon

The second weekend were the marathons. It was dark Saturday morning at 4:30 AM when the first alarm clock sounded. Less than a minute later a generator started, then another, and another. Fifteen teams rolled out of their sacks to get the final charge on their batteries before the start of the 12 hour electric boat marathon. The rules were simple: any hull shape or motor configuration was allowed. The only limitation was that the batteries had to be lead-acid, weigh less than 200 pounds, and could not be recharged during the race. The race was equally simple: whoever went the farthest in 12 hours won.

The start, scheduled for 6:00 AM, was delayed till 6:15. Fifteen boats lined up along a rocky beach and waited for the starting gun. Nearly four miles away was the first buoy of the three leg, 8 mile course. Every type of boat imaginable was represented: styrofoam pontoon boats, a purpose built trimaran, a long skinny custom wood racer, a five foot long Star (replica of a child's boat), kayaks with and without outriggers, and an assortment of small and large catamarans.

The sun was still behind the mountains surrounding Spada Lake when the starting gun sounded. Fifteen boats churned away with a surprising amount of speed and prop wash. In a few minutes they were out of sight. Radios crackled with reports of Volts and Amps as the pits and drivers tuned in the best energy/speed ratios. Now the pit crews had nothing to do but make coffee, wait for the times to the first buoy, and discuss race strategy.

By the first buoy the order of the race was established. The trimaran SEVA was six minutes ahead of the second place boat NOPEC (an obvious jab at the oil cartel that actually meant North Olympic Peninsula Electric Cruisers). Both boats were designed specifically for racing. SEVA was long, skinny, and had tiny outriggers. She had a 36 Volt 2 hp. motor driving a 10:1 gear reducer. The propeller was driven from the gear reducer through a series of u-joints to get the shaft far enough below the water to swing the 1 inch diameter two bladed propeller. NOPEC, which won the "Best Looking Boat" award, was a tortured plywood hull with an inboard electric motor. She was long and narrow, had a low profile, and had a very fine entry.

The first withdrawal from the marathon came at the second buoy, and a second at the end of the first lap. At the end of the first lap SEVA was ahead of NOPEC by nine minutes. The Photocomm Skimmer was in third, eleven minutes behind the leader. The fifth and sixth place boats passed the first lap neck and neck. There was an hour spread in the rest of the field.

In the late morning the wind started to become a factor. Spada Lake lies east-west in a mountain canyon. About 11:00 AM every day the wind picks up and builds till late afternoon. By noon the wind was a steady 15 knots and small white caps were forming. This was the chance for the boats with less windage to move up against the competitors with larger profile boats. It was also time for pit stops for those boats that had chosen not to carry all 200 pounds of battery at once. The pit activity went smoothly and no batteries or crew fell in. SEVA and NOPEC both stopped for a battery change.

Winning Tactics

Battery configuration and the decision whether or not to carry them all at once varied considerably among the contestants. Battery changes were permitted but had to be done at the dock in the pit area. The batteries could not be charged but they could be returned to the boat later. The first and second place boats both stopped for one battery change.

The most successful boats used 24 Volt or 36 Volt batteries. The batteries were flooded with liquid electrolyte and had been pre-heated to 120°F. Flooded batteries have the advantage of being able to play with the electrochemistry, such as adding more concentrated acid or a battery additive. This increases the available capacity of the battery for added performance. They also used thin plate cranking type batteries (standard car battery) which supply more capacity per pound but can only be cycled 20 or 30 times. Battery life is not a concern when racing.

As the afternoon wore on, the race between the 5th place boat Ra and the 6th place Javelin closed to one minute at the end of six laps. They had been less than 4 minutes apart for two laps and had traded positions once. The heat of the race took its toll in the eleventh hour. Within minutes of completing the sixth lap Javelin withdrew from the race. They did not have enough power to finish the race.

The Finish

Toward the end of the day the gap between SEVA and NOPEC began to close. Radios buzzed as the pits advised skippers how to get the last bit of juice from nearly exhausted batteries. The ninth lap began with only nine minutes between the boats. Eleven hours and 45 minutes into the race only 300 yards separated SEVA from NOPEC. NOPEC was closing fast. The spectators couldn't see any of this because it was at the far end of the course. The committee boat radioed in the separation between the two boats to an announcer in the pit area. The announcer got more and more excited, "Five minutes to go and only 100 yards separate the boats!!" she cried.

"With only one minute to go there is only 20 feet between them!!"

David Janos, the pilot of NOPEC, gives his account of the finish. "In the last few minutes the driver of the lead boat took a look around the lake with his binoculars, but apparently didn't see me. I was behind him. I couldn't go any faster because I didn't have much battery left. Then I saw the other driver open a bottle of water and sit back. I think he thought the race was over."

NOPEC was closing fast. The committee boat, which was right beside SEVA, announced that only one minute was left. The skipper of NOPEC said, "Thank you." The pilot of SEVA turned around, spotted NOPEC only five feet away, and gave SEVA a shot of power that kept her just ahead of NOPEC as the finish gun sounded. The third place boat, Photocomm Skimmer, was about five miles behind.

Race Results ***12-Hour Battery Marathon*** DNF=Did Not Finish

Place	Boat	Skipper	Home	Distance (mi.)
1st	Seva	David Mischke/David Cloud	Edmonds, WA	67.1
2nd	NOPEC I	NOPEC Racing team	Port Townsend, WA	67.1
3rd	Photocomm Skimmer	Concept Development Group	GrassValley, CA	63.0
4th	Ra Rah	Ward Phillips Racing	Friday Harbor, WA	61.3
5th	Ra	Ward Phillips Racing	Friday Harbor, WA	59.0
6th	NOPEC II	NOPEC Racing team	Port Townsend, WA	57.5
7th	Easy Cruiser	Cruising Equipment/Easy Rider	Seattle, WA	52.9
8th	Javelin	Bob Jacobsen/Cliff Shaw	Seattle, WA	48.4 (DNF)
9th	Sun Warrior	Marquette University	Milwaukee, WI	42.1
10th	Arc	Transport	Elk, CA	40.1
11th	Sparky	Mike Renner	North Bend, WA	36.9
12th	Electric Polywog	Matt Galle	Sultan, WA	35.9
13th	Misstake II	James Wallace	Sultan, WA	32.0 (DNF)
14th	Star	Anderson Marine	Edmonds, WA	8.1 (DNF)
15th	"No Name"	Pederson and Son Racing	Arlington, WA	8.0 (DNF)

"If I hadn't heard the other driver say 'thank you' we'd have surely snatched defeat from the jaws of victory," Mischke said after the race. What a finish!

SEVA and NOPEC had traveled 67.1 miles in 12 hours to average more than 5.59 mph. Each had carried 199 pounds 8 ounces of battery. They consumed about 3 kW-hrs of energy. That is equivalent to the energy contained in about 11 ounces of gasoline!

Winning's Not Everything

The boat I helped work on, Easy Cruiser, finished in seventh position. Easy Rider kayaks provided a 20 foot Polynesian style outrigger and Cruising Equipment supplied the batteries and an Amp-Hour+ meter. We spent less than one week preparing for the race, had a great time and felt fine with a seventh place finish.

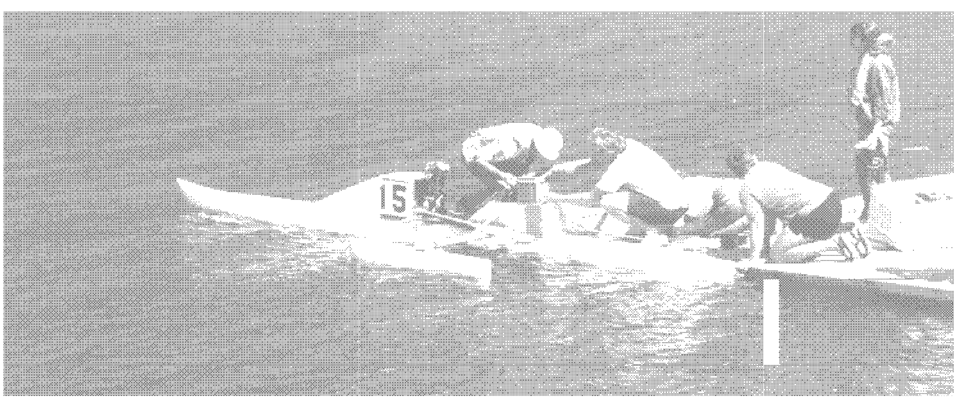
Delco Batteries sponsored the race and awarded David Mischke and David Cloud, the owner/builders of SEVA, a check for $5,000. Not bad for twelve hours work, that is, if you don't count the two months building and testing the boat.

After the battery marathon Craig McCann, the driver of the Photocomm Skimmer, realized his team had made a serious miscalculation. "We had 40% of our batteries still left at the end of the race," he said. "If we'd used all that power rather than saving it, we might have won."

The Solar Marathon

Craig's opportunity to redeem himself came the next day when, with nary a cloud in the sky, he and six other competitors began the Regatta's final event, the four-hour solar marathon. All six boats had competed the day before but, in place of the batteries, the boats had been refitted with no more than 40 square feet of solar panels.

McCann and his partner Sam Vanderhoof of Nevada City, California had spent about a month preparing their 17-foot twin-hulled rowing shell for the race, but it wasn't until 20 minutes before the start of the solar race that the two photovoltaic panels were mounted on the boat for the first time. Nevertheless, their boat, powered by a computer tape drive motor, roared soundlessly to an early five minute lead over Ra Rah, one of the two boats entered by Ward Phillips.



Race Results ***Four-Hour Solar Marathon***

Place	Boat	Skipper	Home	miles
1st	Photocomm Skimmer	Concept Development Group	Grass Valley, CA	20.9
2nd	Ra Rah	Ward Phillips Racing	Friday Harbor, WA	20.8
3rd	NOPEC II	NOPEC Racing Team	Port Townsend, WA	20.6
4th	Ra	Ward Phillips Racing	Friday Harbor, WA	19.8
5th	Javelin	Bob Jacobsen/Cliff Shaw	Seattle, WA	15.5
6th	Sun Warrior	Marquette University	Milwaukee, WI	14.5

Again, the wind played a role. This time, however, it impacted the race because it didn't materialize.

The Ra Rah and several of the other entries had been built with the wind in mind. Their operators fully expected to catch the much smaller Photocomm Skimmer when the water got rougher. But, because the wind never blew, that challenge never came. McCann was able to hold his lead and won the $5,000 first prize with a three minute margin ahead of Ra Rah. Third place went to NOPEC II and fourth went to Ward Phillips's other entry, Ra.

Quiet Thrills

"This kind of event will have incredible impact on the future of all our futures," Phillips said. "This is not an odd game being played by eccentric people. The period of visionaries is returning. We've got to look at the macrocosm to get to the microcosm."

Burton Gabriel echoed those feelings. "The Snohomish County P.U.D. did a great thing putting on this races," he said. "Our utilities must begin to realize what's going to happen in the future. Apparently Snohomish County P.U.D. understands that. The importance of this race is that it gets the people involved in communicating directly with their utilities. This is the way we're going to solve the energy problems of the future."

Perhaps the greatest confirmation of how this event may have impacted the future came from a spectator who drove more than 70 miles to watch the event and was impressed by the boats and the serenity of Spada Lake. "Everyone can enjoy a place like this at the same time," he told reporters for a local newspaper. "A hiker can have his quiet, a boater his thrills, and they don't come in conflict with each other."

Snohomish County PUD were excellent hosts and special thanks should go to Andy Muntz the race chairman.

Electric Boating Just Feels Right!

Electric boat regattas are springing up across the country. Almost any kind of a boat can be electrified easily with a battery and an electric trolling motor. While the top three finishers in this race used inboard motors and purpose built boats, the electric kayaks which placed 4th, 6th, and 7th all went over 50 miles and averaged about 4.5 mph without a battery change. I believe every contestant had a good time. I know we did. Electric boating, it just feels right!

Access

Authors: Rick Proctor, Cruising Equipment, 6315 Seaview Ave. NW, Seattle, WA 98107 • 206-782-8100; Solar Marathon by Andy Muntz, Snohomish County P.U.D.

Inquires regarding next years event: Andy Muntz, Customer Relations Dept., Snohomish County P.U.D., P.O. Box 1107, Everett, WA 98206 • (206) 258-8444

Electric Boat Association of America, POB 11197, Naples, FL 33941 • 813-774-3773

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What’s an Inverter?

or Why can’t the world run on DC and make life easier for everyone?

Elliot Josephson

Alternating current or direct current? How shall electricity be sold to the public? Over a century ago the battle raged, George Westinghouse versus Thomas Edison. Edison had electrified New York City with DC power, to the wonderment of the world. Then along came this upstart Westinghouse, with his foreign friend Nikola Tesla, and changed everything.

Everybody knew DC was simpler. Direct current flowed from positive to negative continuously and did its job very nicely. What foolishness it was to talk of alternating the direction of current flow sixty times a second. No good could come of that!

Editorials were written. Lawsuits were argued. Millions of dollars were at stake. In the end, the battle was decided by economics. No amount of philosophizing could overcome the fact that alternating current was just plain cheaper to make and distribute than direct current.

Why Not DC?

But why? Doesn’t the simplicity of DC electricity make it easy to work with? Yes, as long as you’re reasonably close to the source, and as long as you’re happy with the voltage that’s available. But suppose that your source of power is a great big 12 Volt battery, located a mile away. You’ve seen how heavy the battery cables are in your car just to carry the current a few feet to your starter and engine. Imagine how heavy (and costly) the wire would have to be to carry DC current a mile and still have enough voltage left to light a headlight!

Or suppose 12 Volts DC were available, but you really needed 120 Volts to light your bulb. In Edison’s time, the only way to make this transformation was to use the 12 Volts to run a 12 Volt motor, and then to use that motor to drive a 120 Volt generator. It worked, but it was terribly expensive and wasted a lot of power.

Transformer Magic!

A bit of magic was needed to overcome these problems. Ac provided that magic because, unlike DC, it could operate transformers. Transformers are devices that can change the voltage up or down easily, inexpensively, and efficiently.

To appreciate the importance of the transformer, put yourself in the position of the electric power utility. It costs you money to generate power at your power plant, and you can sell that power only by delivering it to the user, wherever he may be. Any power that gets lost along the way comes out of your pocket. The user will only pay for the power he actually receives.

Suppose that a reasonably sized power transmission line loses 60 volts per mile. If you start with a 120 volt signal, you’ll lose half of the voltage sending it one mile. But if you transform the signal up to 600 volts and send it a mile, the 60 volt loss is only 10% of the total. And if you transform the signal up to 6000 volts and send it a mile, you only lose 1% of the voltage. In fact, the utilities transform electricity as high as 500,000 volts to send power over long distances, and then transform it back down to 120 volts to supply their customers.

Standards

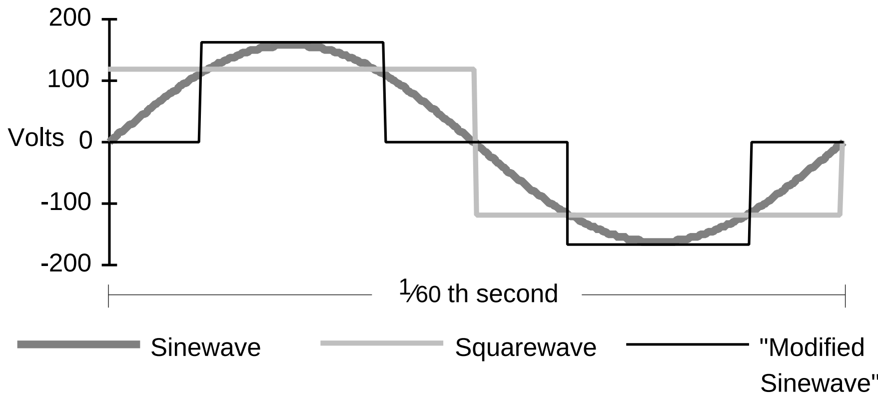
Once the ac versus DC battle was settled, it took a long time before the voltage, frequency, and socket spacing was standardized, but finally a manufacturer could build a toaster and know that it would plug in and work anywhere in the United States. Appliances of all sorts were designed and built to operate on ac power, and DC was used primarily for automobiles and flashlights.

The First Inverters

Where it was necessary to convert DC to ac, a rotary inverter was used. It consisted of a DC motor driving an ac alternator at the proper rotational speed to create ac at 60 Hertz (cycles per second). Some of these inverters are still being sold under the trade name Redi-Line™ and are primarily used in utility vehicles.

As automobiles became more sophisticated, it became desirable to install a radio, first for police and emergency vehicles, and then for the general public. Automobiles used 6 Volt batteries then, and the transistor hadn’t been invented yet. Radios ran on vacuum tubes which needed over 100 Volts to operate. Clearly, a device was required to change the 6 Volts DC into ac so it could be transformed to a higher voltage.

One of the earliest inverters, used in the radio for the family car, was an electromechanical vibrator. The vibrator was a type of buzzer, with contacts that opened and closed many times a second, to switch DC into ac. This ac could then be transformed up in voltage. After transformation, another set of contacts switched the high voltage ac back to DC to be used by the radio. Although effective and relatively cheap, it had very poor reliability and had to be replaced fairly often.



Square Wave Inverters

When the transistor appeared on the scene, it replaced the vacuum tube. Now you could operate a car radio directly from the battery voltage, so radio vibrators were not needed. At the same time, it was also possible to build a transistorized inverter for general purpose use, getting rid of the unreliable vibrator. This type of inverter consisted of little more than a transformer and a pair of transistors. The transisortized inverter is also called a static inverter because it has no moving parts. It is still being sold today as part of the Tripp-Lite inverter line. Instead of the sine wave delivered by an electric utility, this inverter produces a square wave. Because current is a switched, or turned on and off, the generated current had very abrupt changes and over time looks like a wave with square corners. This is very unlike what comes from the power company which has much more gradual changes that look like sine waves. With this type of inverter neither the frequency nor output voltage is regulated, the inverter has little surge capability, and it is not protected against overloads except by a fuse or circuit breaker. However, it is simple and low cost and suitable for many non-critical applications.

The shortcomings of the square-wave inverter become most evident when running a motor. Ac induction motors draw a substantial current surge on startup. They really prefer sine-waves to square-waves and may overheat on the latter. Ac induction motors also store energy during a portion of each cycle, which will create problems if not returned to the battery or otherwise controlled.

Enter the Modified Sine Wave Inverter

In response to these shortcomings, Heart Interface pioneered the development of the “modified sine wave” inverter, and today most of the inverters sold are of this type. The “modified sine wave” is neither a sine wave nor a square wave, but a moderate-cost compromise which runs most loads in an acceptable manner.

The inverters described up to this point are fairly large and heavy. This is simply because they generate power through a 60 Hertz transformer, which, by the laws of physics, must weigh about 30 pounds for 1000 watts.

A smaller, lighter alternative is found in the inverters pioneered by PowerStar and now offered by both PowerStar and Statpower. Instead of converting 12 Volts DC directly to 120 volts 60 Hertz ac, they use a multi-step process. First 12 Volts DC is changed to 160 volts peak high frequency ac (25 kiloHertz). This is converted to 160 Volts DC, and finally inverted to 120 volts rms, 60 Hertz ac. At the heart of this process is the high frequency transformer, which is less than one-tenth the size and weight of a 60 Hertz transformer for the same power level. Thus a 5 pound inverter can do the job of a 50 pound one.

Sine Wave

A few true sine wave inverters have appeared on the market, notably from Dynamote and Exeltech. This kind of inverter will run motors cooler and may offer less interference with radio and TV. However, they are inherently more complex and less efficient, so they may not be justified in many installations.

Ask your local dealer

If you are confused as to which is the best inverter for you, nothing can beat a truly knowledgeable dealer who carries a broad line of inverters. He will know what’s available, what works, and what it costs, and he can translate your present and future projected needs into a solid recommendation.

Meanwhile, look for technology to progress and for inverters to become more efficient, better protected, more reliable, smaller, lighter, less expensive, and easier to use. This trend will undoubtedly continue for many years to come.

Access

Author: Elliot Josephson, PowerStar Products Inc., 10011 North Foothill Boulevard, Cupertino, CA 95014 • 408-973-8502 • FAX 408-973-8573

Utility Intertie Systems

Mick Sagrillo

There are many people currently connected to the utility grid who are interested in renewable energy systems. For them the prospect of tearing out their utility line and installing batteries seems silly. The question arises — how does one use renewable energy to produce electricity without necessarily cutting loose from the utility's umbilical cord?

PURPA

The answer is a federal law known as PURPA, the Public Utility Regulatory Policies Act. PURPA was passed as part of the National Energy Act of 1978 under the Carter Administration. Its purpose was threefold. In response to the second OPEC oil embargo, PURPA would decrease United States dependence on foreign oil and gas. Second, PURPA would encourage the development of new sources of energy and electricity and therefore help to ensure the energy security of the U.S. through diversification. Finally, because the target technologies were renewable sources of energy (solar, wind, hydro, and biomass), PURPA would help foster the use of environmentally benign energy technologies.

The key to PURPA is that independent electricity producers, if they meet the criteria of their local utility, can generate electricity and backfeed their excess into the utility's grid.

The PURPA regulations as they apply to the 800 utilities in the United States are quite complex. However, for small independent power producers like the homeowner interested in backfeeding excess electricity to the utility, PURPA can be simplified into a few rules. These same rules apply whether you generate electricity from a wind generator, photovoltaic modules, a hydro site, or a biomass generator. In exchange for meeting the rules set forth by the utility, the utility must buy the excess electricity you produce.

Intertie Equipment

Utility power is all alternating current. In order to feed your renewable energy generated electricity into the grid, you need equipment that can make electricity exactly in step with grid power. If your renewable energy system produces DC electricity, it must be converted to ac in order to be usable by a utility. The equipment used to change DC to utility grade ac is called a synchronous inverter. Basically, a synchronous inverter takes its signal from the utility's grid, then converts DC to ac, perfectly matching the grid's voltage and frequency. Excess power not used by the homeowner is backfed into the grid by the synchronous inverter.

RE grid-intertie systems which harness spinning mechanical motion can usually be built without a synchronous inverter. These systems use induction generators. Induction generators are very similar to the induction motors that drive appliances such as your washing machine. If an induction generator or motor is spun faster that its rated speed of 1750 rpm, it will backfeed ac electricity into the grid, matching the utility's voltage and frequency.

Utility Requirements

For the most part, utilities are concerned that the electricity you produce is "good enough" for their grid. In virtually all instances, this is not a problem today. Both synchronous inverters and induction generators are capable of producing grid-quality power. As a matter of fact, many of these devices produce "cleaner" power than what is delivered to your house by the utility!

Utilities are also concerned that, in the case of a power outage, your independent generator doesn't keep producing electricity. They argue that this would be a safety hazard to any lineman working on their power lines with the assumption that the line is dead. This is a very valid concern.

All synchronous inverters and induction generator controls that are available today for wind generator applications contain something called a "line activated contactor". Wind is what I'm most familiar with; I'd assume this is true for other generating devices. This is a relay device that connects the synchronous inverter or induction generator to the utility. As the name implies, it works only when the ac line is present. When the line is down, the contactor disconnects the generating device from the utility grid. When the utility line is "hot" again, the contactor reconnects the generating device to the grid.

The use of a line-activated contactor should assure the utility that the system cannot continue producing when there is a power outage. (This type of device is used quite commonly in industrial applications for similar reasons.)

Finally, utilities are concerned about lawsuits. Your utility will most likely require you to carry a liability insurance policy on your generating system. In today's litigious society, this is also a valid concern. For people with homeowner's insurance coverage on their house and property, the additional coverage is not a problem. The generating system is simply added to your homeowner's insurance, just as you would add a garage, barn, silo, or radio antenna tower.

Advantages and Disadvantages
What's in it for you? Why would you want to connect your renewable energy system to the utility in the first place?

The primary advantage of a utility-tie-in system is that batteries are not needed in the system. Remember, you backfeed excess power into the utility's grid. Therefore, the grid is actually your storage system. All of the other equipment used in the typical renewable system is still required, whether you have a stand-alone system or utility-tie-in system. The equipment includes the generating device, wire runs, inverter (note that synchronous inverters and stationary inverters used in battery systems are quite different animals), and various different control and metering systems. Because you do not need a bank of batteries, you save the considerable expense of purchasing the batteries as well as the time required to maintain the bank.

The primary disadvantage of a utility-tie-in system is that when there is a power outage, your system will not operate. Even though you are producing your own electricity, you are dependent on the utility for your electricity, just like everyone else an the grid. Remember, synchronous inverters and induction generators get their "operating orders" from the grid.

The other advantage to a utility-tie-in system is that, if you meet their requirements for connection to the grid, the utility must pay you for electricity that you backfeed into the grid. This can get rather sticky. Utilities are granted monopolies in their service territories. Therefore, the utility may view you as competition and try very hard to dissuade you from operating as a co-generator.

Avoided Cost
As defined by PURPA, utilities are required to pay you their "full avoided cost" for the electricity that you sell to them. "Full Avoided cost" as defined by most utility regulatory commissions includes the fuel cost associated with the production of electricity, the cost of the power plant itself, the transmission line cost, and operation and maintenance cost. It can even include the interest owed on the utility debt for capital construction costs of that power plant, and depreciation on the equipment. Obviously, this can become a considerable sum.

Many utilities have chosen to drop the word "full" and pay only their avoided cost. This is usually their cost for the generating fuel only. Most homeowners don't have the resources to fight a utility on this point and therefore accept whatever the utility offers them.

Dollars and Sense
What's this come down to? In best case scenario, you are paid the retail cost of the electricity. This is the cost, (that is, cents per kilowatt hour) you actually pay the utility for the electricity you consume. In the worse case scenario they pay you nothing, stating that they are doing you a favor by allowing you to interconnect to their grid. This is actually illegal on their part. But unless you push the issue, your regulatory agency will not know what's going on and the utility can get away with this policy.

Many utilities opt to pay the wholesale rate for the electricity they purchase from small co-generators. This will obviously be only a fraction of the retail rate. But all is not lost! You merely adjust the size of your system so that your generating device meets your need, with little to spare. In other words, you want to defer using their expensive kilowatts by producing your own, but not enough that they are able to buy your kilowatts cheaply.

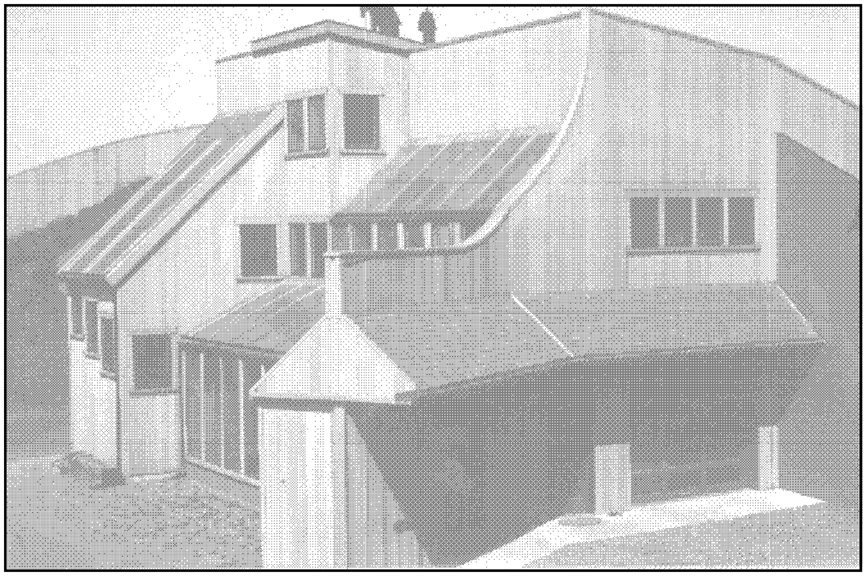
This is easier to do with hydro systems, where you can cut down your production by limiting water flow, or with a biomass generator. It is a bit more difficult with something like a wind generator, because you have little control over your fuel, the wind. One very good way of controlling output is to dump excess electricity in a resistive load, like a water heater or a space heater. While this is not an ideal situation, it allows you to produce hot water or heat your living space with kilowatts that you will not be making a profit on. Thus you defer the use of a possibly more expensive fuel like fuel oil, propane, or natural gas.

To Be Continued...
Next time, we'll take a look at buy-back rates and options, metering options, and how to deal with your local utility to your best advantage.

Access
Author: Mick Sagrillo sells electricity to his utility at Lake Michigan Wind & Sun, E3971 Bluebird Rd., Forestville, WI 54213 • 414-837-2267

Putting It All Together – A Solar House That Really Works

An interview with Stephen Heckeroth by Sterling Norris



Above: The finished product — the solar heated home designed by Steve Heckeroth
Photo by Steve Heckeroth

Sterling Norris, a documentary filmmaker, conducted the following interview of solar designer, Stephen Heckeroth. The interview took place after Steve finished building an energy efficient 2500 square foot family home on the Northern California coast. The only source of heat is the sun, yet the family has recorded temperatures over 68 degrees day and night over the winter months. The monthly electric bill has been between $20 and $34.

The Interview

When you design a house like this, where do you start?

First, I ask the people how they live and what resources they want to put into their home. Then there are a number of elements to create a solar house. The orientation of the house is very important. So is integrating heat storage into the structural mass, and including the mass and the whole house in an "insulating envelope." And you should utilize simple, effective natural systems to get the sun's heat into the interior of the home. Finally, I would suggest conservation approaches, including the use of lights and appliances that require the least amount of electricity.

Building Orientation

When you're talking about orientation, you mean the physical location of the building?

Yes, but each building site has its own problems and possibilities. In a hot climate you want to be protected from the sun, while here on the coast you want to take advantage of all the sunlight that's available and be protected from the wind.

What did you do here, specifically?

Well, this is an ideal site because there is a beautiful view to the south and unobstructed exposure to the sun in the same direction — no buildings or trees blocking solar access and nothing but passing boats to disturb total privacy. So I was able to open up the entire south face of the house to the sun and still protect it from the prevailing winds. Here on the coast a cool ocean breeze comes out of the northwest every afternoon except in the winter when there are southern storm winds. In this cool climate you want to protect the house from these northwest winds. So the wind is deflected over the house by berms on the north and west sides; windows here are small. With all the south facing glass the house would overheat without the small northwest windows that can be opened to maintain a comfortable temperature. The entry is located on the east side because it is the most protected.

Storing Solar Energy

Having to handle overheating I can understand, but how do you keep the house warm enough during foggy, overcast days?

In this area, about three times as much solar energy hits a home's south-facing roof and walls as is used by its occupants over a year's time. Since no energy arrives at night or under cloud cover, and the seasons can make the daily energy input very erratic, you must be able to store solar energy.

Early solar designers used water as the storage medium called thermal mass. Water stores the most heat per volume. Although water is cheap, the containers and the space they take are not.

Some solar designers turned to rock storage bins as reservoirs for thermal mass. It took three times as much rock to store the same amount of heat as an equivalent volume of water and the moist warm environment of the bins became breeding grounds for odor producing fungi and bacteria. The high cost and the foul odors really started to give solar design a bad name.

Both water and rock heat storage require complicated control systems, pumps, and blowers. All of these rely on electricity, require maintenance, and are subject to periodic breakdown.

Concrete has greater storage capacity than rock bins because there are no gaps in the concrete. Why not use the 20–50 yards of concrete that's used in the foundation of most homes as thermal mass? That's what we did here.

Since heat rises, a floor is the ideal place for heat storage. Kids play on the floor. When your feet are warm you feel comfortable. Floor heat is not a new idea. What is new is the idea of including the foundation concrete, floor slab and below grade walls in the insulated envelope of the structure.

The Insulated Envelope

The insulated envelope?

An envelope that surrounds and incorporates the structural foundation mass of the house so that heat stored in the mass is available to the house, not lost to the outside environment.

When energy costs were low, insulation was not a concern. Now, heating and cooling an uninsulated home can be a major expense. So, even though good insulation is expensive, the energy savings offset the initial cost in a short period of time.

How do you go about determining the insulation requirements for a house like this?

The heating requirements for buildings in different climates are expressed in "Degree Days." [A Degree Day is the difference in degrees Fahrenheit from 65° F added up for each day of the year.—Ed.] In the U.S., the heating requirements vary from 1200 Degree Days in the warmest areas to over 10,000 in the far north. If you know the Degree Days in an area you can calculate the amount of insulation needed to balance the building's heat loss with the available solar energy. The quality of the insulation is expressed in R-values — a term that quantifies the amount of resistance a material has to heat flow.

The R-values required by the California Energy Commission for new construction are very adequate for walls and ceilings. These regulations, however, do not address the need to incorporate the structural mass of the foundation into the house, so I recommend using almost the same R-value for insulation placed on the exterior of "below grade" foundation walls and about half the R-value of the wall insulation under the foundation floor slab.

So once you get the right R-value for your insulation, you're in business?

Unfortunately, no, because the theoretical R-values apply only to insulation installed in an entirely empty wall cavity but when you have a cavity filled with plumbing, wiring, electrical boxes, and framing members, you won't meet the theoretical insulation requirements for the whole wall. So in addition to the insulation inside the walls, I install a continuous layer of rigid insulation on the outside of the entire building and cover it with a vapor barrier.

And that's the envelope?

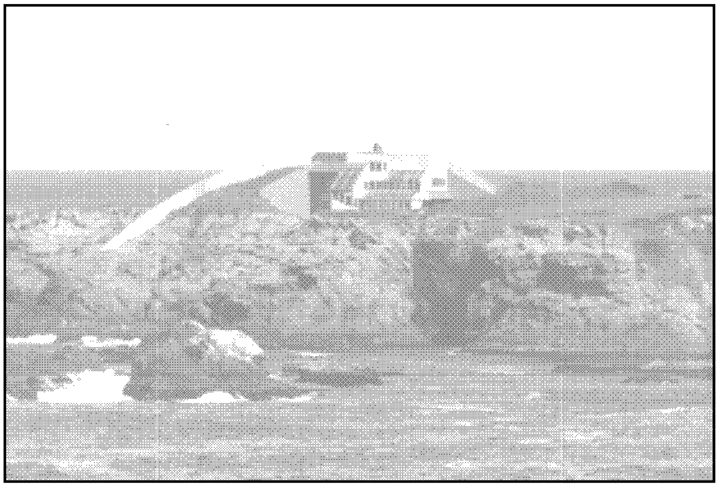
Almost. Doors and windows are penetrations of the insulating envelope that have to be carefully considered. The main entry should be located on the most protected side of the house. In addition, all exterior doors should have some intermediate space between them and heated interior spaces — a kind of baffle, such as an enclosed porch, entry hall or solarium. There should be a second door into the heated living space to eliminate direct exposure to wide-ranging, outdoor temperatures.

All windows should be double-glazed, which provides twice the R-value of single-glazed glass. If the budget permits, Heat Mirror™ windows have an additional thin film suspended between the double-glazing to increase the R-value more than four times that of single-glazing. In more severe climates some kind of moveable insulation or sealed drapes should cover the windows at night.

Mass

Now, tell me about "mass."

O.K., but I call it "integrated mass," because houses built on or below grade with a floor slab have plenty of mass in



Above: The home, built below grade and bermed, stays warm by the cool California coast.
Photo by Steve Heckeroth

their foundations without adding water containers or rock storage bins.

When you build on or below grade you are taking advantage of the earth's ability to moderate the outside air temperature and block air infiltration. The further you dig into the earth, the closer the temperature will approach a constant — about 60 degrees in this area. The part of the house below grade only needs to be heated against a moderate constant instead of heating against the wildly fluctuating temperatures at the surface.

Your solution here?

Right, but, in addition, the house has been bermed on the north and west sides to increase the earth connection and deflect the prevailing winds. So, when I use the expression integrated mass I'm talking about many things working together: integrating enough mass into the structure of the house to compensate for heat loss during cold sunless periods, integrating the foundation into the insulating envelope, maximizing the earth's ability to moderate the temperature, and channeling the sun's energy into the mass, either directly or indirectly.

Channeling the Sun's Energy

You'd better explain what you mean by "channeling" the sun's energy, Steve.

As I said earlier, about three times as much solar radiation falls on an average house in this area over a year's time, as is used by the house's occupants. The job of the solar architect is to maximize and channel the available supply of the sun's energy to satisfy as many energy requirements as possible. The simplest solar solution is usually the best, and in this house we relied primarily on passive solar design. Passive design does not depend on the use of pumps, blowers, and electric controls associated with active systems.

All effective passive systems depend on glass, or other translucent materials. They allow short-wave, solar radiation to enter a building or solar collector and prohibit the long-wave, heat radiation, from escaping.

There are several ways of getting the sun's energy to heat a house using passive design: direct gain, thermal storage walls, attached sun spaces, and convection loops.

You have direct gain any time solar radiation passes through a window and warms a surface in a living space. In this house, there's almost 400 square feet of south-facing windows in just the living room and the family room. You want the solar radiation coming through the windows to warm as much mass as possible. Dark surfaces reflect less, therefore, absorb more heat. If you have a dark tiled floor, the floor will be able to absorb heat all day and radiate heat into the room at night.

This house is at 40 degrees North latitude which means that the sun varies from a high of 73 degrees above the horizon, at noon in the summer to a low of 27 degrees above the horizon, at noon in the winter. This works to our advantage because the low winter sun can penetrate deep into a room when the heat is needed the most. When the sun is high in the summer it is easy to construct an overhang to shade some or all of the windows when overheating may be a problem. Here, we built a roof to shade the summer sun and on that roof we will attach the photovoltaic panels in order to satisfy the need for electricity.

Tell me a little about thermal storage walls.

They're also known as Trombe walls, named after a Frenchman who experimented with them. Usually they are dark masonry walls placed between the glass and the living space. The thickness varies depending on the desired heat lag. Trombe walls take up very little floor space and, as mass, collect more direct sunlight in the winter due to the low entry-angle of the sun. We constructed a Trombe wall here, between the greenhouse and that part of the living space which is used at night.

The attachment of sun spaces does pretty much the same thing. Is that correct?

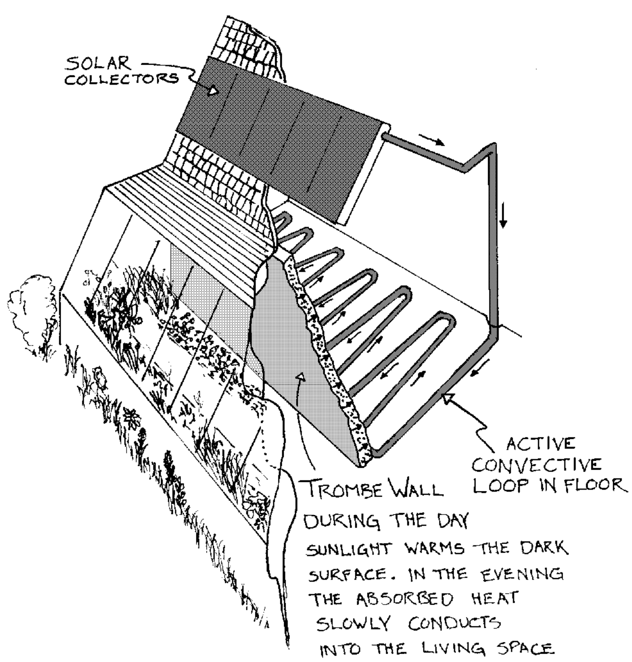
No, it's not the same thing, but it's another good solution for getting the sun's energy to help heat the house. Essentially, they're glass rooms built on the south side of a house and function best when they are thermally isolated from the living space. They warm up quickly with the first sunlight even on cold mornings. To get the heat from the sun space to the living area all you need to do is open a window, door, or a vent. There are four sun spaces here: two small balconies connected to the bedrooms, a greenhouse, and dining room, called the sunset room, on the southwest corner of the house.

And you said that you also incorporated convection loops as part of the heating plan.

Yes, they're just another way of distributing the energy collected from the sun. A typical installation includes a black metal absorber (a solar collector), under glass. When liquid is used as the transfer medium, as we've done here, the pipes are thermally connected to the black metal absorbers. As the heat transfers from the metal to the liquid, the liquid rises, creating a siphon which then pulls cooler liquid through the absorbers where it is heated. This kind of convection loop is called "thermosiphon." Thermosiphon systems are most often used for water heating. I've used the system for 15 years to heat all the water for my family.

And nobody at your place takes a bath during those long weeks in the winter when it rains?

When it's rainy and cold, we light the wood-burning stove. I have a stainless steel coil at the back of the fire box with



Putting it all together with passive solar design.
Diagram by Chris Greacen

a low inlet and a high outlet which is part of the same thermosiphon loop as the solar collectors. It's a backup, however, that we only use when we would have a fire anyway. Most of the time, the sun keeps the 80 gallon tank above the solar collectors full of hot water.

Is it an entirely maintenance-free setup?

Yes, for the most part. However, when you have water in a solar collector, freeze protection is very important. I installed two drip valves at the lowest point in the loop of our system and flush out the collectors and clean the valves once a year.

You've installed the same kind of system here?

Almost. There's a small, tankless, gas water-heater for backup because a wood fire has never been necessary for heating the house. We installed a second thermosiphon loop here for heating the floor. It's filled with glycol in order to protect the system from freezing. When the glycol in the floor heat tank reaches 100 degrees Fahrenheit, a 1/20 horsepower pump circulates the glycol through pipe that is embedded in the floor slab. The pump keeps the system from being purely passive but it allowed me to design a system that uses remote collectors to dump solar heat where it does the most good — in the floor mass.

I'm currently building a house on a south slope where it's possible to place the solar collectors below floor level which permits us to eliminate the tank pump and controls. The glycol will thermosiphon through the pipes in the floor slab all by itself whenever the sun comes out.

So in each case you have to evaluate both the location and the economics of installing any particular system?

I've tried to explain the different solar-heating systems in the order of complexity and cost. If you have a southern exposure with a view, go with a lot of direct gain. If you have the exposure, but the view isn't so good, go with a Trombe wall. If there's a little more money in the budget and you like lots of natural light, go with a sunspace. If you're on a south slope, use a convection loop.

If you don't have a south slope and the only part of the house that gets sun is the roof, then you can't be a "passive" purest, but don't give up. Active systems can be simple and elegant too. A photovoltaic pump can be used in just about any situation. The energy that makes a PV-powered pump operate comes from the sun. Whenever the sun shines on the PV panel, the pump comes on. The glycol starts circulating through the nearby solar collector picking up the sun's heat and carries it through the pipes in the floor slab. The heat, then, is transferred to the mass. Such a system is flexible enough to solar heat any building.

Energy Conservation

Then, after the building is solar heated, you mentioned that there are a number of energy-conservation approaches that you recommend. Can you tell me a little bit about some of them?

For heating, do everything you can to use the sun first. Only then, turn to wood or gas. In this house, the sun satisfies all of the space-heating requirements and 90% of the water-heating needs. The other 10% are taken care of by a propane, flash-heater.

The other big energy users are cooking-stoves and clothes dryers. Propane is much more efficient for both than electricity. And even more efficient for your clothes, is the sun. Hang them on a clothesline!

You seem to have a very, deep-seated hatred of electricity, Steve. You want to tell me how you feel about it? Take your time. Or would you rather talk to a professional?

For me it's almost criminal to use electricity for generating heat. The steps involved in producing electricity and getting it to your home make it too precious to use indiscriminately. So don't even use it for heat. Use it for running the refrigerators, stereo equipment, personal computers, and lights. Houses, like this one, can be designed so that no electric lights are necessary from dawn to dusk. Every living space in this house has a natural source of light. And at night the lights are the new fluorescent bulbs that require only 1/4 of the energy used by standard bulbs. Stereos and computers don't eat up too much electricity, but watch out for the refrigerator. Even the most efficient ones in mass production now use as much as 10 times more energy than is necessary.

You're kidding!

No. Some time in the '40s, a now obscure designer, decided that hiding the compressor and the heat dissipation coils under and behind the cold box was more important than efficiency. The heat given off by the compressor rose into the cold box. And the air circulation behind the refrigerator was not the best. No problem! They just put in a bigger, noisier compressor and a few extra coils. The designers were more concerned with the nice, round shape and creating an aura of magic than they were with door seals so lots of moisture entered the box and froze on the inside.

The designers got busy again in the '60s, and along with deciding that refrigerators should be square, they came up with the idea of electrically heating the inside walls of the "cold box" to melt the ice and then developed a system of trays, gutters and pipes to collect the water and electrically evaporate it. Of course, an even bigger, noisier compressor was needed.

Now we're in the '90s and ice water dispensers are mounted in the door — another hole where the marginal amount of insulation used to be and, yes, an even bigger compressor is needed.

I know that a much more efficient refrigerator can be built because a small company in northern California is doing it. They put a small, silent compressor on top of a well-insulated box and make a 19-cubic-foot refrigerator that uses about 150 kiloWatt-hours a year. A typical, mass-produced refrigerator of the same size uses about 1350 kW-hrs a year. If you multiply the difference (1200 kW-hrs) by, approximately, the 100 million refrigerators in this country, you can see that a lot of energy is being wasted needlessly.

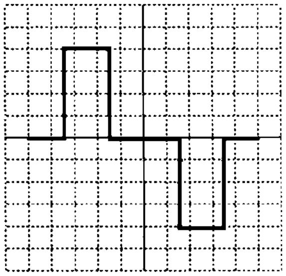
I'm beginning to understand why you were so interested in telling me about the electric-car garage before we started the interview. All part of overall energy conservation?

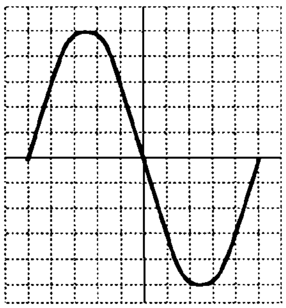
Right. It would be a terrible irony if one were to build an energy-efficient home and then put a "gas-hog" in the garage. The garage here is designed so that photovoltaic-panels will be installed on the roof to recharge the batteries of the electric-car that will eventually be parked here. Advances in photovoltaic design and efficiency are very promising. Soon you'll be able to roof your house with interlocking photovoltaic shingles and have more electricity than you can use.

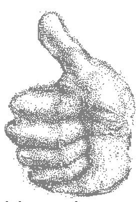
It's pretty clear that you're already looking ahead to some of your next projects. It's also clear that right now people can have 100% solar heating! I think you really have put it all together, Steve. Thanks for the interview.

Access

Architect: Steve Heckeroth, Solar Design & Construction, 30151 Navarro Ridge Rd., Albion, CA 95410 • 707-937-0338







Backcountry Phones

Don Loweburg

Photovoltaic technology has extended the limits of comfortable rural living, providing electricity to run our home and business. Last year we made another major shift in our lives when we installed a radiotelephone, the Optaphone+ system. Phone communication now allows us to realize our dream of having our business operate full time from our home in the central Sierras of California.

About a month after we purchased our Optaphone+, the local telephone company called and offered us telephone service using a new system they were initiating. There is an element of sardonic humor here. For several years, we and a number of neighbors, all remote, had been lobbying the local telephone company to provide this service. Cynthia and I got tired of waiting and took action; we bought the radiotelephone. It seems that when it rains it pours. Though we already had purchased our telephone system, we ended up benefitting when our company got the contract to install the solar power source required for the telephone systems our neighbors were having installed. Through my work with the local telephone company I learned how their system works, technically and administratively.

Three Types of Radiotelephone Systems

I encountered three types of systems: single users, 50 line systems for small communities, and systems over 100 lines. All three systems use radio transmission to provide a link between a “base” and a “subscriber”. The quality of the connection is adequate for FAX and telecommunication. The frequency or band depends on the specific geographic area, but usually is in the VHF (very high frequency 30 to 300 megahertz) or UHF (ultra high frequency 300 to 3000 megahertz) band. Unlike older systems, the mechanics of these radiotelephones are transparent to the sender and receiver. There is no push-to-talk or mobile operator involved. This is largely because these units are “duplex” meaning that the base and subscriber units transmit on different frequencies, allowing you to talk and listen at the same time. In contrast, “simplex” radiotelephones are like CB radios — they broadcast and receive on the same frequency. These require you to push a button to talk, and release the button to listen.

Optaphone+ for Individuals

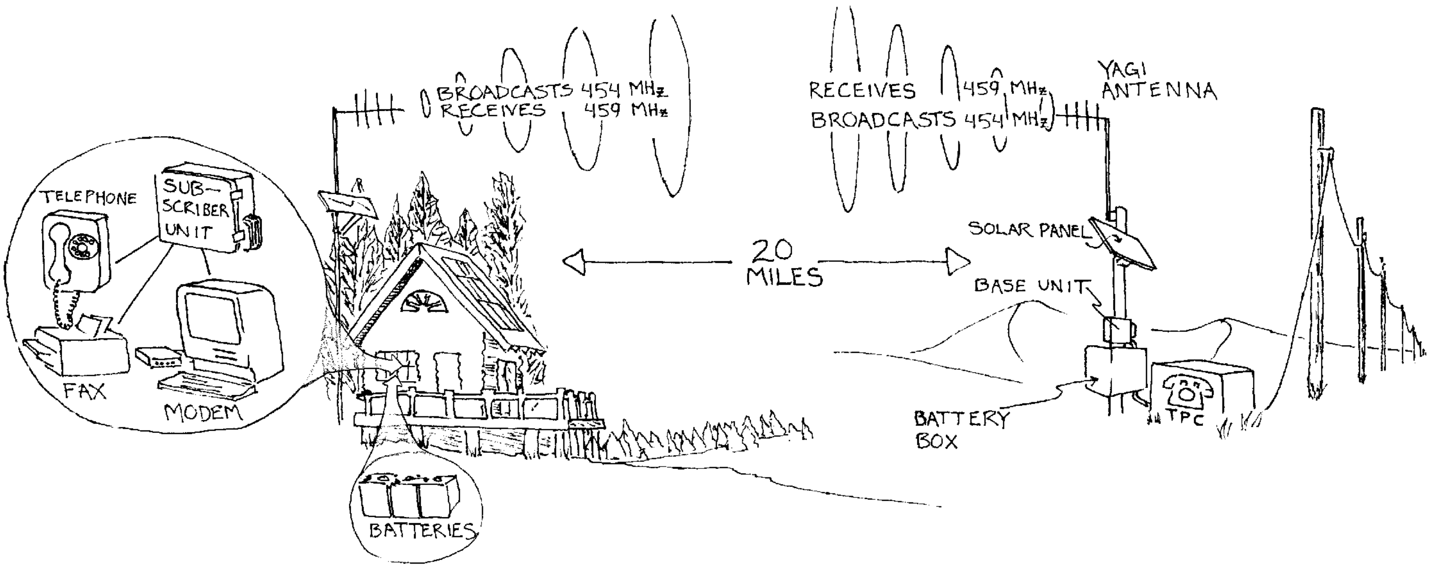
The Optaphone+ is a single user system. The “base” unit plugs into the telephone jack where the telephone would. The unit then transmits and receives using a yagi, beam-type, antenna. The “subscriber” unit is at the user’s remote site. It too is connected to an antenna and the user’s telephone plugs into a standard jack on the subscriber unit.

Radio waves propagate in straight lines at these high frequencies; a line of sight path is always best. If there are VHF frequencies available in your area, a line of sight path is not as critical, but for UHF, it is. The distance may be in excess of twenty miles, but it is best to check out the radio path’s quality before investing in the equipment.

When the telephone is not in use, both the base and subscriber are on standby and use very little power. If there is activity at either end, whether a ring-signal at the base or the phone off the hook at the subscriber, then both units activate and a connection is made. During this mode, both units will be transmitting and receiving. When the phone at the subscriber end is hung up, both units return to standby mode.

Since the owner is in fact operating a radio transmitter, a station license is required by the FCC (Federal Communications Commission). This is a simple administrative procedure and helps maintain order in frequency allocation. There would be problems if two users were using the same frequency (or channel) at the same time in the same neighborhood.

The Optaphone+ system is powered by a 12 Volt DC supply. This could be a photovoltaic source in many cases. The Optaphone was designed to use very little power and can easily be operated from a single 30 Watt photovoltaic module and a 60 Amp-hour battery. This modestly sized battery could provide up to 20 days backup. Low power consumption was a primary factor in our choice of the Optaphone+. Over a thousand lines nation wide are using the Optaphone+.



Above: A solar powered radio telephone provides telephone, FAX, and modem service to a remote location.
Diagram by Chris Greacen

The Community Optaphone Star
The Optaphone Star is a multi-user system that shares the low power requirements and basic technology of the single user system. The Star system is designed for modest sized communities (up to 96 subscribers) that require phone service. A single base unit can operate on several frequencies or channels at the same time, allowing up to six subscriber lines to be in operation. Typically there will be more subscribers than channels which requires a microprocessor, that acts as a traffic cop, to control the system. The advantages of this approach is a cost reduction per line. Optaphone Star systems are in service in Montana, Alaska, and Pennsylvania. Carlson Communications Inc., the manufatcurer of Optaphone, is working on a 96 subscriber system which will be able to carry 24 simultaneous conversations.

The Ultraphone for Larger Systems
Communities that require more lines would probably use another kind of system. Because of the higher cost and complexity, larger systems are installed by existing local phone companies that wish to extend service into unserved or unfiled territory (an area that no telephone company wishes to serve).

The Ultraphone produced by IMM of Pennsylvania is such a system. This is the system installed by the phone company in this area, Ponderosa Telephone Company, O'Neals, California. This is a digital system: conversations are broken up digitally and pieces of each are fed in order on a single channel. The IMM system can carry four lines on each radio channel or frequency, increasing total system capacity to over 100 lines. The subscriber units are often solar powered. Unfortunately, the IMM system is not very energy efficient, requiring 200 Watts of PV array and 200 Amp-hours at 24 VDC battery. The system has 10 days of backup. Though expensive, the customers of the phone company don't pay outright for the system. Instead they pay a modest monthly fee in addition to the normal phone service and long distance charges. The local phone company may often receive a low interest loan from the REA (Rural Electrification Administration) to finance the project.

Telephone Service for All
Radiotelephone technology has made it possible to extend phone service into previously unserved areas. If an individual has the resources to purchase their own Optaphone or similar system, this might be the best approach, at least the quickest.

Others may opt for a community approach. The first step would be for everyone in an unserved area to write to the telephone company to request service. Also, write the PUC (Public Utilities Commission) letting your need and request for service be known. It's important to be polite, but firm. There is no technical reason not to have telephone service. Let them know that you understand the REA has low interest loans available for this kind of project and you are aware of its existence in other areas. Communicate among those in your area participating in the project. Compare notes and make sure the authorities' responses are consistent. Remember, the PUC and the phone company have a mandate to survey our interests. Make sure they do. When you have dealings with these agencies, make sure every promise, action, or response has a time or date attached. Then consistently hold them to their promise. The process may take a while, but telephone service is usually available for citizens wherever they live.

Access

Don Loweburg, Offline Independent Energy Systems, 231 Main Street, North Fork, CA 93643 • 209-877-7080

Optaphone: Carlson Communications Inc., 655 Redwood Dr., Garberville, CA 95440 • 800-382-6006 • 707-923-2345

IMM Ultraphone: Inter Digital Communications, 3000 Horizon Dr. Ste. 130, King of Prussia, PA 19406 • 215-278-7800

Bright Lights, Bright Future

Bob-O Schultze

When Hornbrook Elementary School decided to upgrade the classroom lighting as a cost-cutting measure, they saved more than just money. By increasing the quality of lighting at the same time, they contributed toward the general well-being of the classroom environment as well.

The Situation

The main building, cafeteria, and classrooms of Hornbrook Elementary were built in the 1950s. Several extra classrooms and the gym were added in the early 1980s. While the newer classrooms had 4 foot tube fluorescent light fixtures using standard coil-core ballasts, the main building was fitted with incandescent lighting throughout. Each of the three older classrooms used nine single bulb fixtures, each sporting a 300 Watt mogul-base bulb. These behemoths measure 9 inches long and are over 4 inches in diameter. With all nine lights on, as they are during school hours, the lights consumed a total of 2.7 kiloWatts. Figuring the classrooms were in use for eight hours a day and five days a week, that's 324 kiloWatt-hours per week for the three rooms.

The school office used five of the same 300 Watt bulbs and fixtures which consumed 60 kW-hr per week. Other identified energy guzzling areas were the hallway with ten 100 Watt incandescent bulbs in various fixtures and five exit signs using two 40 Watt bulbs each. The hallway lights consumed 40 kW-hr a week and the exit signs consumed 16 kW-hr a week.

Lighting Criteria

Designing adequate lighting for the classroom or a workspace must take into account the quality as well as the quantity of light. Artificial lighting affects different people in different ways. Primary factors are the age and the seeing ability of the viewer, the glare, the length of time spent doing a given task, and the quantity (luminance) of light. As a rule, none of the primary factors except luminance can be controlled. As a result, more light and more power is usually used to compensate for the other conditions, rather than better quality of light or better fixture placement. While this approach works to one degree or another, it nearly always results in higher energy costs and an increase in the discomfort caused by glare.

At the Hornbrook school, luminance ran from 84 foot-candles at desk level in the classrooms to 5 foot-candles in the hallway. A foot-candle is the amount of light that falls on a square foot surface one foot away from a lit candle. The number of foot-candles needed in a room depends primarily on the task being performed.

Color Rendering

Color rendering, an important measure of the quality of light, is measured on a scale of 0-100. A color rendering index (CRI) of 100 is supposedly equal to the color of sunlight at noon on a clear day. People and objects viewed under lights with a high CRI appear to be more natural. High CRI also gives the impression of a higher level of light. This adds to its cost effectiveness and energy effectiveness.

Color Temperature

Color temperature is kind of misleading. It has nothing to do with the actual temperature of the lamp, but is a measure of the color appearance of light. It has a startling effect on a person's perception of his/her surroundings. Different color temperature is used to establish an atmosphere or change a mood. Color temperature is measured in degrees Kelvin and is described as warm, neutral, cool, or daylight. The color temperature chosen depends on the application. For example, an intimate restaurant might chose a color in the warm range (2300–3400°K) to set an intimate and personal mood, whereas an office area or a classroom would benefit from a cool range (3800–4500°K) which projects an appearance of neatness and efficiency.

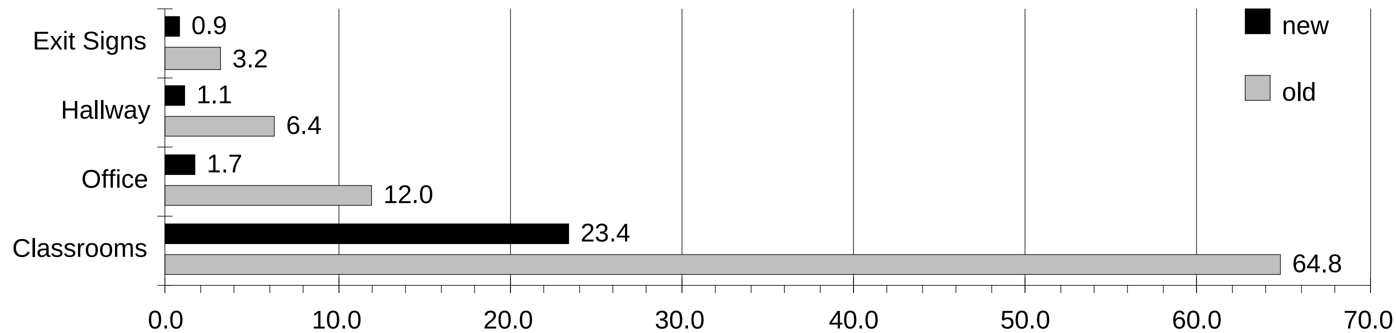
Other Considerations

A certain percentage of people are also affected by the flicker or pulsing of 60 Hz alternating current, especially from fluorescent lighting using standard coil-core ballasts. Using electronically-ballasted fluorescent lamps eliminates much of this type of problem.

Relamping the School

The nine single bulb fixtures in each classroom were removed and replaced with 13 of Philips' electronically ballasted, 4 foot 2-tube fluorescent fixtures. This decreased the energy use by 65%. Because of the much

School in Hornbrook, California saves electricity and money with efficient lighting



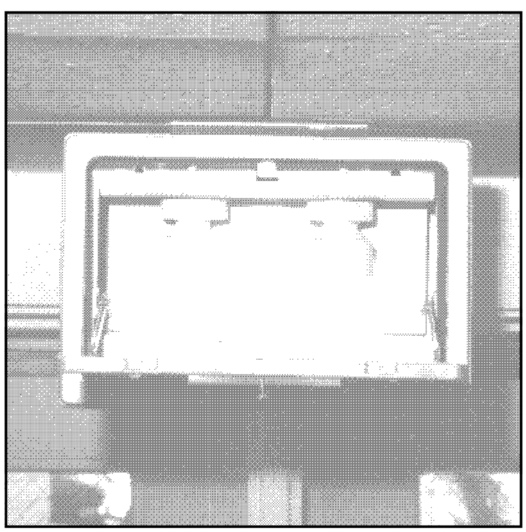
higher switching rate of the electronic ballasts (20–30 kHz), all flicker should be eliminated. The lamps have a CRI of 80 and a color temperature of 4100°K. These lamps were chosen to emphasize the clean and neat classroom atmosphere. The light level jumped from 84 to 104 foot-candles and seemed to be better diffused throughout the room.

The lights in the hallway and exit signs were replaced by 11 and 15 Watt Osram compact fluorescent lamps with built-in ballasts. To minimize the initial investment costs, these lamps were retrofitted into the existing fixtures. The energy usage dropped by 85%, but the light levels didn't change, and the cooler color rendition gave the appearance of more light.

The school office offered a good opportunity to combine naturally available light with efficient supplemental lighting. It also demonstrated a classic example of overlamping. The office has three large windows which more than adequately illuminate most of the workspace on a clear day. This area used five 300 Watt bulbs to supplement the natural light during early morning, evening, and overcast days. The space is rarely used during the evening and there is some natural light available every day regardless of the weather. The school was able to retrofit four of the existing fixtures in the high ceiling with reflector-type 15 Watt compact fluorescent bulbs. The remaining incandescent fixtures were further from the natural light source and were replaced by two 4 foot 2-tube fluorescent fixtures. That's an energy savings of 86%.

The Bottom Line

The total cost for relamping the classrooms, office, exit signs, and hallway was $5462.87. Hornbrook Elementary will realize a savings of $88.72 per month just on electricity costs at the present rate. Since there is no chance of rates going down in the foreseeable future, this figure can only get better. Each of the 100 and 300 Watt incandescent bulbs replaced has a life span of approximately 1000 hours. They cost $1.00 and $11.00 respectively. The 4 foot fluorescent tubes have a average



Left: An EXIT sign is lit all the time. This sign used to be lit by incandescent lamps.

Right: Inside the EXIT two compact flluorescent lights save thousands of watt-hours of energy yearly.

Photos by Mark Newell

life span of 20,000 hours and the compact fluorescent bulbs are rated at 10,000 hours. The school should witness a savings of approximately $540.00 per year just in incandescent bulb replacement costs during the life span of the fluorescent lamps. This figure doesn't include labor costs for the maintenance person. Given a nine and a half month school year, the initial investment will be paid back in just under four years.

Conclusion

The graph depicting the energy and dollars saved pretty much speaks for itself. In terms of dollars and cents, making the switch to energy-efficient lighting makes good sense, but that's just the beginning. Increasing the quality of light and life for our future generations has a value beyond money. It's priceless.

Access

Author: Bob-O Schultze, Electron Connection, POB 203, Hornbrook, CA 96044 • 1-800-945-7587

Hydrogen Basics

Amanda Potter and Mark Newell

Home Power is gearing up to use hydrogen fuel for cooking. We've been hoping to eliminate or at least reduce our propane use for a long time now and have been encouraged by the interest and enthusiasm in hydrogen that we've seen in our readers.

Hydrogen is not a source of energy; rather, it is a non-toxic means of storing and transporting energy. Any energy source can be stored in the form of hydrogen. Solar, wind and hydro power can be used to break down the molecular bonds which bind hydrogen in hydrocarbons and water. Hydrogen, unlike electricity, is efficiently transported over long distances (through pipelines, for example). It enables energy produced in areas where renewable energy resources are abundant to be safely transported to areas with high energy use. Part of hydrogen's virtue as an energy storage medium is the fact that energy stored in the form of hydrogen can be converted into different forms of usable energy without producing pollutants. Heat or electricity can be produced with water as the primary by-product.

Catalytic Combustion

Hydrogen can be recombined with oxygen to produce heat in the normal combustion process or it can be recombined in a fuel cell to produce electricity. In both cases the primary by-product is water. Burning hydrogen produces some nitrous oxides because of the high burning temperature. However, using a catalyst (such platinum or nickel) lowers the temperature and decreases the surface area of the reaction, which increases efficiency and reduces the nitrous oxides to a negligible amount. Pure catalytic combustion uses a catalyst to cause the hydrogen-oxygen recombination to occur without the input energy of a flame. There is a 100% efficient conversion of hydrogen to heat when temperatures are kept below 100 degrees Celsius or 212 degrees Fahrenheit.

Converting a propane stove to run on hydrogen is a fairly simple process. Low tech, inexpensive catalysts such as stainless steel wool (3% – 22 % nickel) work well and are easy to use. However, stainless steel wool is not as effective in eliminating nitrous oxides as more expensive catalysts. For more information on these operations see *Fuel from Water* by Michael Peavey. Also look in your local library under hydrogen.

The Electrolyzer

An electrolyzer is a device that uses electric current to lyse or split water (H_2O) into hydrogen and oxygen. (See Electrolyzer sidebar.) Electrolysis is currently the cheapest, simplest, and most efficient method of home scale hydrogen generation. Well-made and relatively inexpensive electrolyzer cells from Hydrogen Wind in Iowa are available. Each electrolyzer cell requires 2 Volts; the current determines how much hydrogen they produce. (see HP #22 and 26.)

How Much Hydrogen Would We Use?

We plan to use electrolyzers to produce hydrogen, but how much hydrogen do we need? Ideally we would like to supply the gas needs for the eight of us that live here on Agate Flat. That, however, is no small feat! In order to determine how much hydrogen we need to produce and store, we calculated how much hydrogen we would use on a daily basis. Here's how much hydrogen we would need to run the cookstove, our only gas appliance:

There are 82,000 British thermal units (BTU) per gallon of liquid propane. A 5 gallon tank of propane lasts us approximately twenty days. We therefore use:

$$\frac{82{,}000\,\text{BTU}}{\text{gal}} \times 5\,\text{gal} = 410{,}000\,\text{BTU every } 20 \text{ days}$$

$$\text{or } \frac{410{,}000\,\text{BTU}}{20\,\text{days}} = 20{,}500\,\text{BTU every day}$$

How much electricity do we need to run through electrolyzers to produce 20,500 BTU of hydrogen? We have a number for converting BTU into kilowatt-hours (kW-hr) of electricity but it assumes 100% efficiency. With the kind of electrolyzers we are looking at, we expect the efficiency to be about 50%.

$$1\,\text{BTU} = 2.9287 \times 10^{-4}\,\text{kW–hr}$$

$$\frac{20{,}500\,\text{BTU} \times \left(2.9287 \times 10^{-4} \frac{\text{kW–hr}}{\text{BTU}}\right)}{0.5\,\text{efficiency}} = 12.0\,\text{kW–hr}$$

This means we would need 12 kW-hr input to the electrolyzers each day to produce hydrogen for our daily

ELECTROLYZER PHYSICS

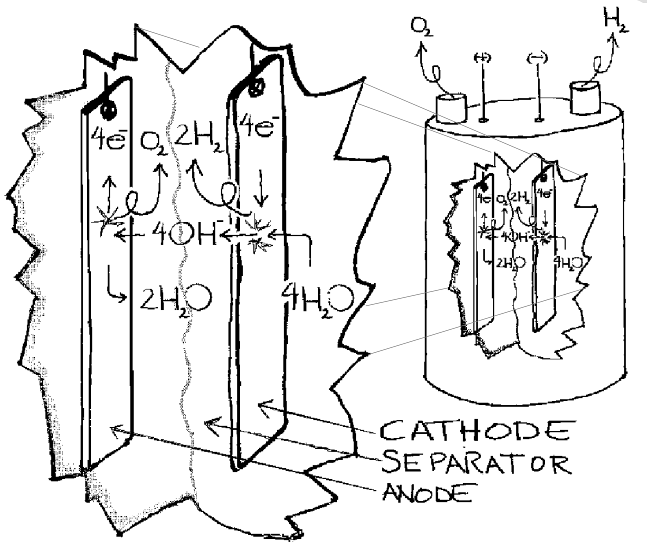
An electrolyzer is a device that uses direct current electricity to break the bonds holding together water, H_2O, into its components hydrogen, H, and oxygen, O.

An electrolyzer has three main components: an electrolyte, two electrodes and a separator. The electrolyte solution consists of distilled water and a salt, acid, or base, and is held in a chamber. The electrodes are pieces of metal which sit in the electrolyte and pass current through the electrolyte. The separator is a barrier that physically separates the electrodes from each other yet allows current to flow between them.

The Process

The following reactions occur when the electrolyte is a 30%solution of potassium hydroxide, KOH. If another electrolyte is used the results will be the same although the reactions will be different.

When DC electricity is connected to the two electrodes, current passes through the solution (H_2O and KOH), decomposing the chemical bonds of the H_2O molecules. Electrons enter into the chamber via the negative terminal, called a cathode, and cause a reaction. In this reaction four water molecules, $4H_2O$, are broken into eight positively charged hydrogen ions, $8H^+$, and four negatively charged oxygen ions, $4O^{2-}$. Since the four oxygen ions are unstable in this state, each one quickly re-attaches to one hydrogen ion, forming four hydroxyl ions, $4OH^-$. The four remaining hydrogen ions, $4H^+$, combine with four electrons at the cathode to form hydrogen gas, two molecules $2H_2$. This half reaction is:



$4e^- + 4H_2O \longrightarrow 4OH^- + 2H_2$

The negative hydroxyl ions that were generated at the cathode are attracted to the positive electrode, called the anode. The electrolyte increases the conductivity of the water, allowing the hydroxyl ions to be pulled to the anode. At the anode another reaction takes place in which the four hydroxyl ions give up four electrons and form oxygen gas, O_2, and two water molecules, $2H_2O$. These electrons leave the chamber via the anode to complete the circuit. The oxygen and hydrogen gas, kept separate by a barrier, bubble up through the electrolyte into separate pipes and off to their points of use or storage. This reaction looks like:

$4OH^- \longrightarrow O_2 + 2H_2O + 4e^-$

The overall result of the two reactions looks like this: $2H_2O \longrightarrow O_2 + 2H_2$

cooking needs. This is a lot of electricity! There are a lot of us up here now, but we are going to need to find more efficient ways of our cooking and heating hot water if we hope to power our entire stove with hydrogen. We are planning on installing a solar hot water heater. We presently use our solar oven almost every sunny day and we are planning on building a larger one to further cut down on our propane use.

A Realistic Approach

We can begin by supplementing our propane use with hydrogen. The next question is how much hydrogen we can produce. *Home Power* will soon be adding two trackers to test. With our additional loads, this will add about 1.5 kW-hr surplus power per day. We use the following conversion factors to determine how many cubic feet of hydrogen (at atmospheric pressure, 1 atm.) 1.5 kW-hr will produce and how much energy in BTU this amount of hydrogen will give us.

$$1\ \text{ft}^3\ H_2\ (\text{at } 1\ \text{atm}) = 0.791\ \text{kW–hr}$$

$$\text{or } 1\ \text{kW–hr} = 12.6\ \text{ft}^3\ H_2\ (1\ \text{atm})$$

$$1\ \text{ft}^3\ (1\ \text{atm}) = 270\ \text{BTU}$$

Using the above conversion factors,

$$\frac{1.5\ \text{kW–hr}}{\text{day}} \times \frac{12.6\ \text{ft}^3\ (1\ \text{atm})}{\text{kW–hr}} \times 0.5\ \text{eff} = \frac{9.45\ \text{ft}^3\ H_2\ (1\ \text{atm})}{\text{day}}$$

$$\frac{9.45\ \text{ft}^3\ H_2\ (1\ \text{atm})}{\text{day}} \times \frac{270\ \text{BTU}}{\text{ft}^3\ H_2\ (1\ \text{atm})} = \frac{2551.5\ \text{BTU}}{\text{day}}$$

We will be able to produce 9.45 cubic feet of hydrogen at atmospheric pressure (or 2550 BTU hydrogen) each day from our 1.5 kW-hr/day surplus energy. This will only run our cookstove burner (assuming 10,000 BTU/hour) for a little more than 15 minutes.

Storage

Now that we have the hydrogen, how do we save it until we need it? Hydrogen storage can be complicated and costly. Hydrogen can be stored as a liquid, in a metal hydride, or as a pressurized gas. Liquid hydrogen at -253°C requires costly and complex storage containers and the energy required to liquify hydrogen is 20–40% of the energy being stored. Certain metals like magnesium, titanium, and iron absorb hydrogen when cooled and release it when heated. In these metals, hydrogen remains a gas but is confined in the spaces between molecules in the metal. When the metal is "charged" with hydrogen, it is called a metal hydride. Metal hydrides are the safest way to store hydrogen, especially in transportation applications, but are also more costly and complex than pressurized gas. Hydrogen can be stored as a gas at high or low pressures. High pressure systems allow smaller tanks but require expensive compressors. We are considering relatively low pressure storage options because we would like to keep our storage system as simple as possible.

To determine the size of our storage container, we've converted cubic feet into gallons.

$$9.45\ \mathrm{ft}^3\ H_2\ (1\ \mathrm{atm}) \times \frac{7.5\ \mathrm{gal}}{\mathrm{ft}^3} = 70.88\ \mathrm{gal}\ H_2\ (1\ \mathrm{atm})$$

The Ideal Gas Law

When we talk about storage, we also need to talk about the pressure. The above equation assumes we are storing the hydrogen at just above atmospheric pressure. Hydrogen, stored as a gas, follows the ideal gas law, $P_iV_i=P_fV_f$. The law states that the initial pressure times the initial volume of a gas is equal to the final pressure times the final volume of the gas.

Pressure in the ideal gas law must include atmospheric pressure. When we inflate a tire to 35 pounds per square inch (psi), we are actually inflating it to 35 psi above atmospheric pressure. Atmospheric pressure is the pressure per square inch exerted on us by the atmosphere above us. It varies according to elevation and temperature but is about 14.5 psi. Anything less than that is a vacuum; anything more is pressurized. So, the tire we inflated would actually be at 35 + 14.5 psi or 49.5 psi. The tires walls only "feel" 35 psi because atmospheric pressure presses on it.

We have 70 gallons of hydrogen at just above atmospheric pressure, at say 0.25 psi above atmospheric, or 14.75 psi. If we choose to store the hydrogen at 50 psi above atmospheric pressure or, 64.5 psi we can determine the resulting volume by applying the ideal gas law:

$$P_i \times V_i = P_f \times V_f$$

$$V_f = \frac{P_i \times V_i}{P_f} = \frac{14.75\ \mathrm{psi} \times 70.88\ \mathrm{gal}\ H_2}{64.5\ \mathrm{psi}}$$

$$= 16.2\ \mathrm{gal}\ H_2\ \mathrm{at}\ 64.5\ \mathrm{psi}$$

The 70 gallons of hydrogen we produce can be stored in a 16 gallon storage tank at 64.5 psi. The advantage of the higher pressure is the low volume storage tank. Hydrogen at 64.5 psi could be stored in a propane tank. Propane tanks, however, are expensive and a compressor might be necessary to increase the pressure of the hydrogen. Since hydrogen storage becomes more expensive and complicated as we increase the amount of hydrogen stored, we decided to start our system with only one day's worth of storage. Our options are to either store 16 gallons of hydrogen in an empty 10–20 gallon propane tank at 64.5 psi or store the 70 gallons of hydrogen in two 55 gallon drums at slightly greater than atmospheric pressure (see HP#26).

Hydrogen For Home Power Users

Hydrogen offers many possibilities for home power users. Indefinite, long term storage becomes possible with hydrogen. Many home power systems produce more power than can be used during only one season. PV's produce surplus power in the summer; micro-hydro systems produce surplus power in the winter. Hydrogen allows for the storage of the surplus energy produced during one season to be used in another. Hydrogen can be combusted to produce heat for cooking or space heating with no pollutants. It gives home power producers the option of eliminating the last of their fossil fuels. Hydrogen can also be added directly into an existing propane supply. Hydrogen bonds with propane and can be used in a propane appliances year-round, without any modifications, to conserve propane (see HP#22).

In the foreseeable future, we may see fuel cells become a cost-effective method of producing electricity with stored hydrogen. Hydrogen could then be used as an alternative to batteries which require proper maintenance and employ toxic heavy metals which eventually need to be disposed of or recycled.

This exercise has given us a good idea of what it will take to replace all of our propane use with hydrogen. It's brought home the importance of conservation; our solar oven and solar hot water heater will determine if our transition will be possible. There is little information on "home scale, home budget" hydrogen systems. We welcome any advice or experience.

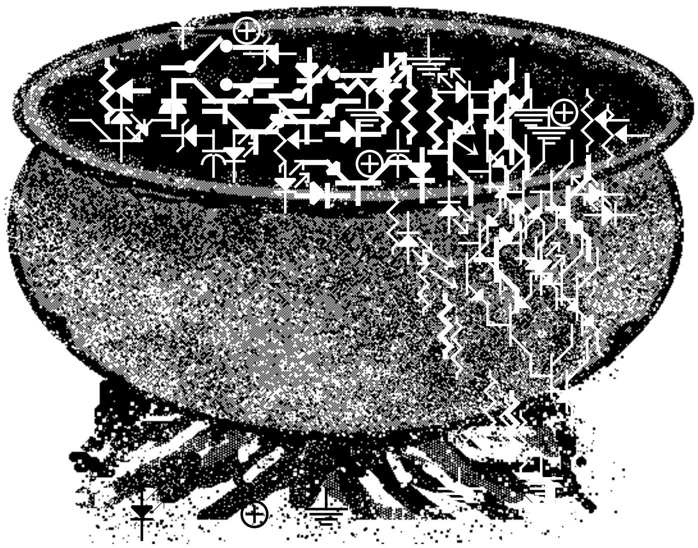
Access:

Mark Newell and Amanda Potter, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

Fuel From Water by Michael A. Peavey, (ISBN 0-945516) Merit Products, Inc., Box 694, Louisville, KT 40201. Also available from Alternative Energy Engineering (see ad on page 5 of this issue).

If you want to keep on groovin'
And to keep your HP movin'
Don't forget to check your label
Whenever you are fit and able

Homebrew



Array Direct Regulator

Chris Greacen

Want to run a radio or cassette player directly off your photovoltaic panel? You can get away with running some 12 Volt equipment “array direct” — that is with no battery. But if the equipment is electronic, plugging it directly into a twelve Volt panel can be risky business. The instant you hook your appliance to an illuminated PV panel, it’s at its open circuit voltage, as high as 21 Volts. This can fry electronics.

The circuits here can attach directly to the frame of a photovoltaic panel. At the flip of a switch, the panel’s voltage is regulated to anywhere between 5 and 15 Volts.

Low Power Simple Circuit

If your panel puts out less than 1.5 Amperes, you can use the circuit in Figure 1. The LM317 voltage regulator chip takes any incoming voltage up to 37 Volts, and puts out a steady adjustable voltage up to two volts less than the incoming voltage. The 317 does what it can to maintain a voltage drop of 1.25 Volts from Vout to Adj. You adjust the output voltage of the chip by adjusting the voltage of the adjust pin with the voltage divider formed by the 240Ω resistor and the 2kΩ potentiometer.

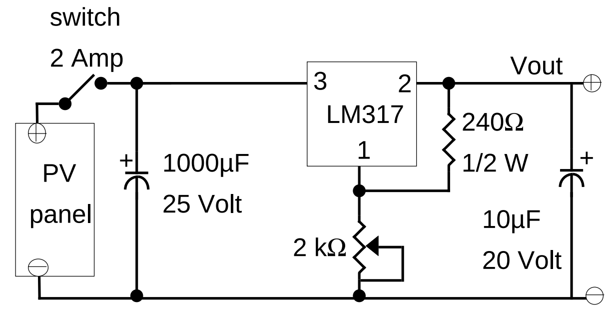


Figure 1: LM317 regulator good to 1.5 Amperes

Power Steering

Higher amperage versions of the LM317 are available: the LM350 (3A), the LM338 (5A), and the LM396 (10A). But another way to increase the amperage of this regulator is to use an “outboard transistor” (Figure 2). In this circuit the LM317 is limited to only 100mA — a very easy job for it. If the load draws more than 100mA, the voltage drop across the 6Ω resistor approaches 0.6 Volts, beginning to turn on the PNP transistor. Now when the 317 draws a little more current to supply the load a constant voltage, the PNP transistor turns more “on”. If the load draws less, then the 317 decreases its draw, which in turn, turns the transistor more “off”. The transistor works like power steering, with the 317 in the driver’s seat concerned with staying on the “constant voltage road.” This method has some advantages over the LM350 approach. Parts are cheaper, and power

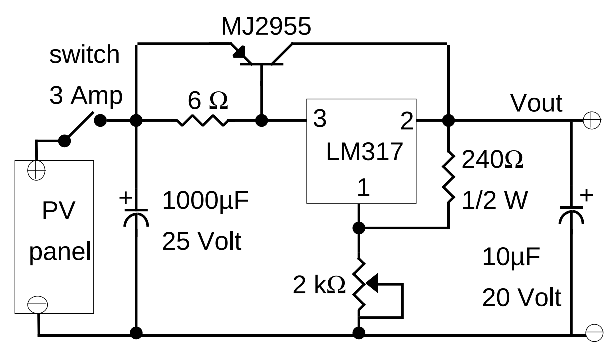
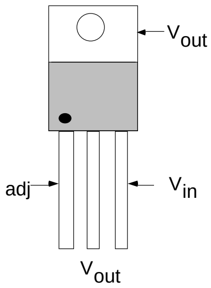
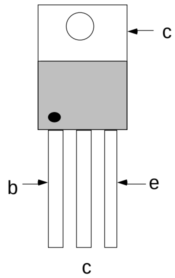


Figure 2: Array-direct regulator good to at least 10 Amps



front view LM317T
TO-220 package



front view MJ2955
TO-220 package

transistors have a much higher allowable chip operating temperature than the voltage regulators, so heat sinks don't need to be as good.

A big capacitor on the input works like a battery, storing up power for short-duration surges the load might draw. If your load surges are especially big — say you've got a single sideband ham radio which draws little power in receive mode, but draws more than your panel can put out on transmit — then use even more capacitors.

Building the Circuit
This circuit dissipates excess voltage as heat. For example, if the regulator is connected to a 16 Volt PV module and set to 10 Volts at three Amperes, the regulator dissipates 6 Volts. Six Volts times three Amperes is 18 Watts of power dissipated as heat. It's important to get rid of this heat. Heat sink the LM317 and MJ2955 on a piece of metal that can be cooled by air. Don't build the circuit inside the PV's junction box. If you put it together and find the chips too hot to touch, then you need a better heat sink.

Access
Author: Chris Greacen, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

Electric Car Conversion: What To Save & What To Scrap

Shari Prange

You've taken the plunge. Your smelly internal combustion donor car lies waiting to be transformed into a clean green electric machine. Before you can install the electric components you will have to remove a great deal of the original equipment. Which pieces you remove — or save — and how you do it can make a big difference in the final conversion.

Old is Good

There are three good reasons you're doing a conversion instead of building a whole car from scratch: time, money, and results. You don't want to spend the time or money to re-invent basic things like brakes, steering, and windows that roll up. Even if you were willing to do it, the results would probably not satisfy you.

When Detroit builds a car that is 70% new design and 30% off-the-shelf, it spends 3.1 million hours of engineering design time on that 70% of the car that's new. For optimum results in your home-built electric car, it makes sense to take advantage of as much of that engineering as possible.

A fourth good reason to convert is ecological. Every car that is scrapped is stripped for saleable parts. When it goes to the crusher, 30% of the car is non-recyclable "fluff" that ends up in landfills. That's on a metal-bodied car. Plastics or fiberglass are worse. So it makes good sense to "recycle" those dead cars and rehabilitate them into useful electrics.

Parts to Save and Sell

If the car runs, try to find a buyer for your engine before you remove it. The engine will be much easier to sell when it's in a car and running than when it's sitting on the floor oozing oil. The sale price might help pay for your conversion.

When you are ready to start disassembling, the first things to save are measurements. Measure the ride height (body to ground) at all four wheels. If the car can be driven, get it weighed — the whole car, and each axle separately. Measure the location of the transmission bellhousing to some mark on the engine bay. This information will help you reassemble as closely as possible to the original configuration.

Recyclables

The first things to recycle are all the fluids in the old car, except hydraulic fluids. Obviously, you don't need the engine oil anymore. The transmission oil should be drained too. When you re-install the transmission, fill it with a low-friction synthetic oil. Dispose of all the fluids carefully and properly. This is especially important with coolant. It is sweet and attracts small children and small animals — but it is a deadly poison.

Doctor the Donor

As you take the donor car apart, do so with a scalpel, not a machete. You might want to graft some of those pieces back together later. Remove all the wires at their connectors instead of cutting them, and label them with tape and a marker. You can reuse some of them.

Save all the original nuts and bolts in baggies, and label what they came from. These may allow you to reuse original holes or brackets. In fact, try to set aside a place to save all the internal combustion parts (except the engine) until the conversion is finished. You never know what you might find useful. For example, you might be able to use the original fuel line, or exhaust brackets to support battery cables beneath the car.

There are two metal tabs on the engine that are specifically for lifting it with an engine hoist. Save those tabs and adapt them to your electric motor, adaptor, and transmission when it is time to sling them into place.

Even if you are replacing the clutch, save the old parts until you are sure the new ones match. Save the flywheel and all the bolts associated with it. You will want to reuse them with your adaptor. These are special bolts, and will cost you time and money if you have to special order them through the dealer. Also save any locating dowels between the engine and transmission.

Clutch Features

This means, of course, that we are planning to reuse the clutch and transmission. The clutch is recommended for these reasons. First, it is a safety feature that allows you to instantly disconnect the motor from the wheels in an emergency, such as a runaway or lock-up condition. Second, it makes the car's performance much smoother.

Third, it saves energy. You can see this for yourself by starting an electric car from a stop with a clutch, and without a clutch, and watching the ammeter. The car without a clutch will draw more amps until the motor gets up to speed.

Transmission
Golf carts can get away with eliminating the transmission because they are very light and don't need to go very fast. In a passenger car, you need the gearing and torque multiplication for performance. The G-Van doesn't use a transmission, but it needs 215 volts to get it up to highway speeds.

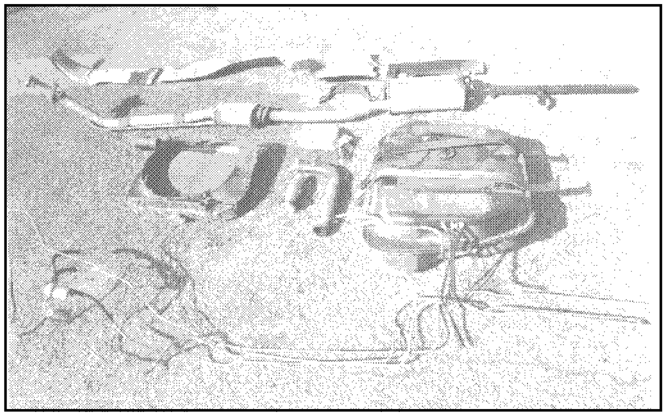
Batteries
Save the idea of 12 Volt accessories, but not the battery itself. If you do not have a DC/DC converter, you will want to replace the original battery with a heavy-duty deep cycle battery, especially if you do much night driving. A DC/DC converter is highly recommended as a constant source of voltage for lights, but it doesn't replace the battery. If the DC/DC converter should fail for some reason, it will do it at night ten miles from home. So if you do have a DC/DC converter, you will still want a 12 Volt battery, but you can use a very small one.

Don't eliminate the 12 Volt battery by tapping across two of your main pack batteries for accessories. This will cause uneven discharge of the pack, and decrease its lifespan.

Space
Save your passenger and cargo space. It's easy to just stuff the batteries into the back seat or truck bed, but with a little thought they can be maneuvered under the hood, behind the back seat, or under the truck bed. This will give you a more usable and more valuable vehicle.

The building of the electric conversion actually begins with the dismantling of the internal combustion car. If it's done right, the process of disassembly is an integral part of the process of assembly. It should be done thoughtfully, with the vision of the finished conversion always in mind.

Every journey begins with a single step. Be sure your foot is pointed in the right direction.



Above: In addition to the engine, these are the parts you remove from the internal cumbustion car. Photo by Shari Prange

Access
Author: Shari Prange, Electro Automotive, POB 1113, Felton, CA 95018 • 408-429-1989

rms Voltage: What Is It And Why Do We Care?

Chris Greacen

If you measure the voltage of a resting battery, the voltage stays put from one fraction of a second to the next. On the other hand, if you watch the voltage in an outlet of an American grid connected home, you'll see the voltage vary from +165 volts to -165 volts and back again, forming a sine wave sixty times a second.

Mr. Josephson's article, (page 22), looks a little at why anyone would want to transmit electricity by sloshing it back and forth like this. But with the decision to use ac (alternating current) power comes, among other things, the question "how do we measure the voltage?" We could say the voltage an American household line is 165 volts, since the peak of the sine wave reaches 165 volts. Or just as easily we could say the voltage is -165 volts, since that's as low as it goes. Maybe better yet, we could say the voltage on a regular household line is 330 volts since there's 330 volts difference between the peak and the trough of each wave. Of course, most of the time the voltage isn't at the positive or negative peak, it's increasing or decreasing somewhere in between. How about taking the average? The average is zero: every bulge above zero in the sinewave is matched exactly by a bulge below zero. If you add them up, you get zero. What, then, is "the voltage" of household ac current?

Usually the figure "110 volts ac" or "120 volts ac" or more precisely, "117 volts ac" (often written 117 vac) is used to describe household current. Why 117 vac? The 117 vac

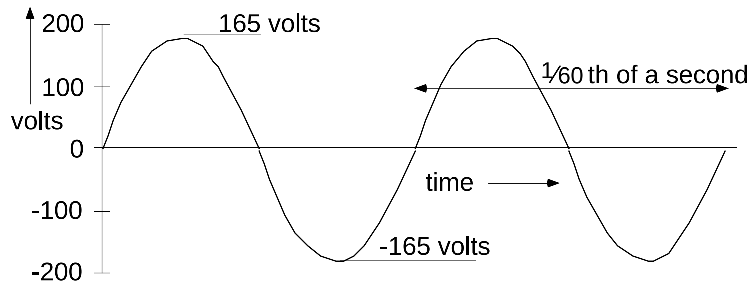


Figure 1: American household current: 60 Hz, 117 vac rms

refers to the "root mean square" or rms voltage of the waveform. What does "root mean square" mean?

The Effective Voltage

The simplest answer is that 117 vac rms is the "effective" voltage of the sinewave. Imagine two identical electrical resistance heaters (excuse this wattage wasting example). One heater is powered by regular household 117 vac rms current, and other one runs on direct current whose voltage you can adjust. The two heaters will put out exactly the same amount of heat, and draw the exact same power, only when the direct current voltage is adjusted to 117 Volts DC. (For you techies out there, we will assume ac loads are purely resistive.)

What is rms Really?

It's a bit cryptic, but the name contains it all: take the (square) *root* of the *mean* (or average) of the *square* of the waveform. Here's how it works. Let's pick an arbitrary wave form like Figure 2 (for a drawing of a modified sinewave inverter's waveform, see page 23).

Square

Square it. At each point on the graph, multiply the value times itself and plot the result (Figure 3). The deep negative dips are now strong positive ones since a negative number times a negative number is a positive number. Notice that the units on the vertical axis are now volts squared, not volts.

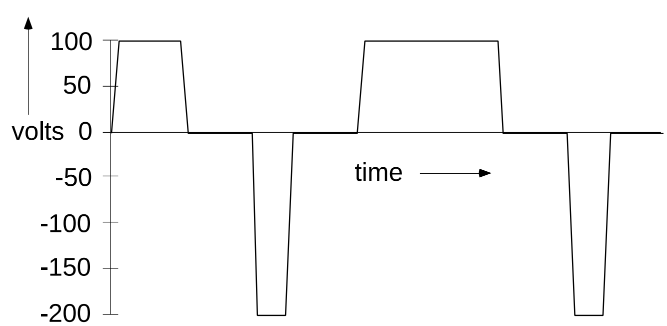


Figure 2: An arbitrary waveform

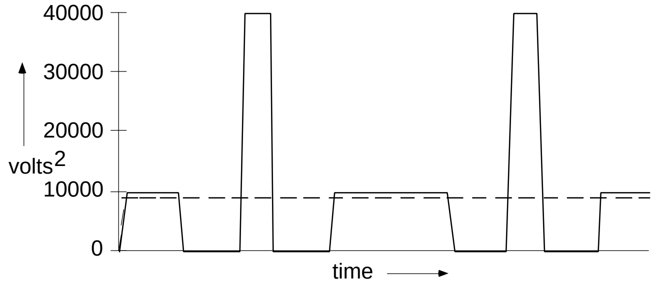


Figure 3:The arbitrary waveform squared, dotted line is the average of the squared waveform

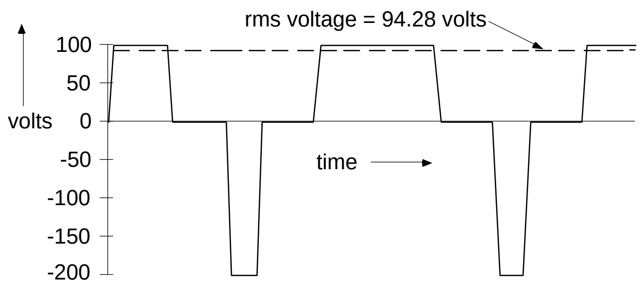


Figure 4: The original waveform. The dotted line (rms voltage) is the square root of the dotted line in Figure 3

Mean
Take the mean (average) value of this new wave (dotted line on Figure 3). As long as the original wave was not zero everywhere, the average of its square will always be greater than zero.

Root
Finally, take the square root of this average (Figure 4). Notice that units are back to volts. 94.28 vac is the rms voltage of this weird waveform. You can see that the rms value depends a lot on the *shape* of the waveform. For a perfect sine wave like Figure 1, the rms value is 1/(square root 2) of the peak value (117 = 165/(sqrt 2)). For square waves, the rms values is equal to the peak value.

See it to believe it
OK, so we've seen how you calculate the rms voltage for any weird waveform. But early in the article I stated dogmatically that the rms voltage (or current) is the effective voltage (or current). Want some evidence? Look at Figure 5 below. On the left is the voltage, current, and power waveforms of an appliance running on alternating current. On the right, the equivalent rms voltage, rms current, and their product, the average power. Notice the

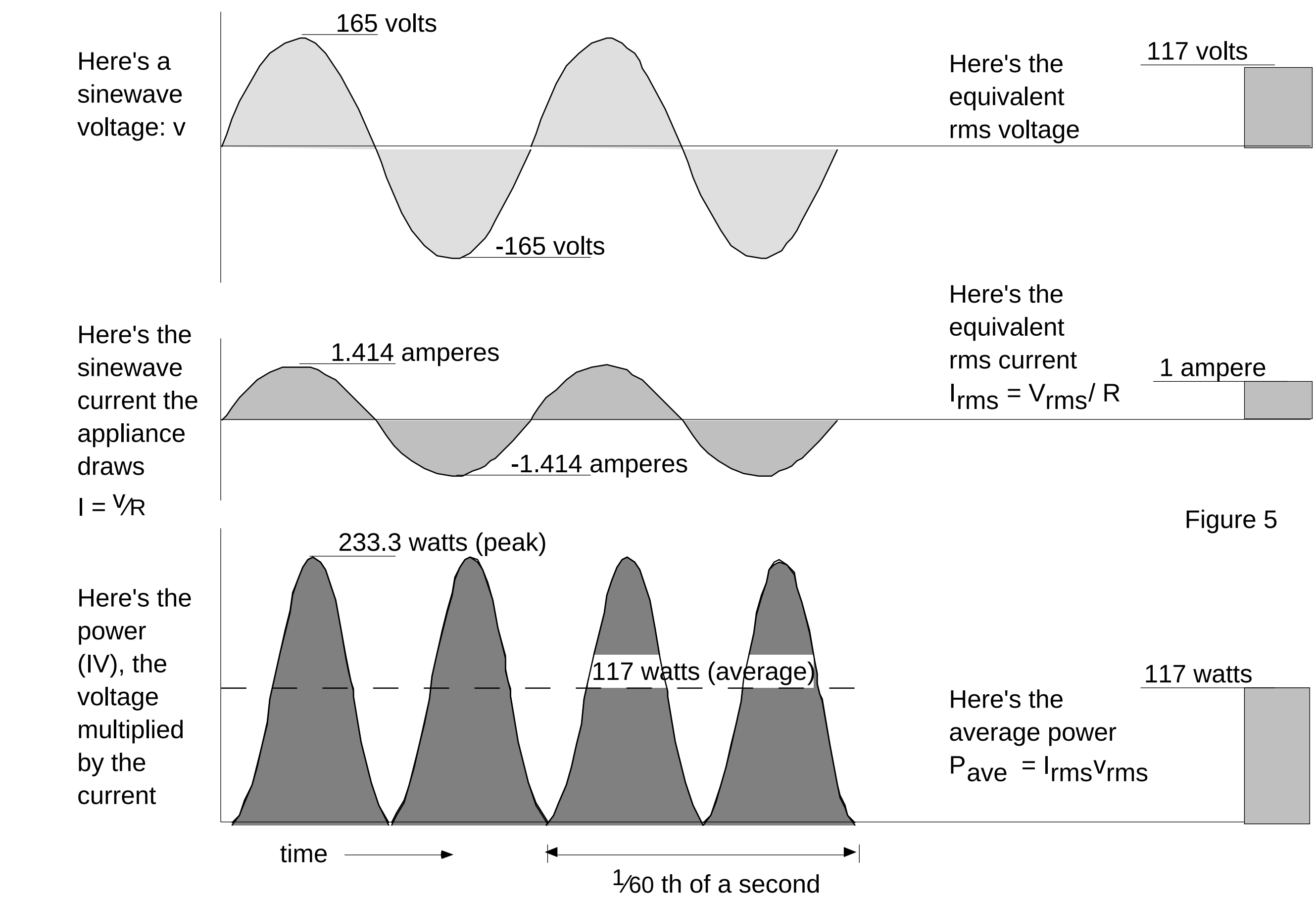


Figure 5

average power on the right is identical to the average of the power waveform on the left (the dotted line at 117 watts). The rms values let us use Ohm's law and Joule's law meaningfully with ac electricity without having to apply these laws to each instantaneous point in the alternating waveform. For DC electrcity, V = IR and P = IV. For ac electricity, $V_{rms} = I_{rms} R$, and $P_{ave} = I_{rms} V_{rms}$.

Various rms info

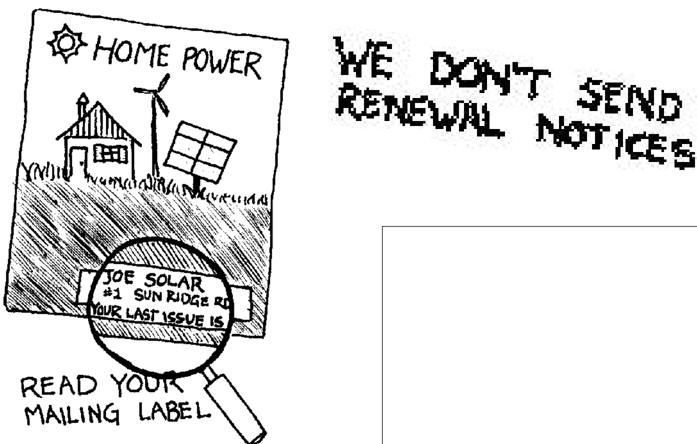
We noticed earlier that rms voltage depends a lot on the shape of the waveform, but it is possible to have two very different waveforms with the same peak and rms voltages. Power sinewaves are difficult to make electronically. A modified sinewave inverter's waveform is designed to have the same peak *and* rms voltages as utility supplied sinewave current.

As peak voltage drops under heavy loads, these modified sinewave inverters increase the width of each current pulse to preserve rms voltages. This keeps lights from going dim and computers from crashing, but is a little less effective at keeping motors happy.

It takes a lot of fancy electronics to measure rms voltages. Inexpensive multimeters just measure the average voltage, and divide by 1.1. (This technique is used in Amanda Potter's Homebrew article in this issue). This works for sinewaves, but is not necessarily accurate for other waveforms. If you really want to know an inverter's rms voltage, use a multimeter which measures "true rms", like the Fluke 87 or Beckmann 2020. In their electronic wizardry, they square the voltage, average it, and take the square root, just like we did graphically.

Access

Author: Chris Greacen, Home Power, POB 520 Ashland, OR 97520 • 916-475-3179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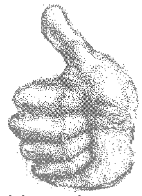
Things that Work!



Things that Work!
tested by Home Power

Beckman's 2020 Digital Multimeter

tested by Richard Perez, Chris Greacen, and Mark Newell

The digital multimeter (DMM) is our eyes into the invisible world of electricity — without it we're flying blind. The DMM is the measurement and troubleshooting tool for home power producers. The new Beckman 2020 is a true rms reading DMM with all the features, including data recording, of instruments costing much more.

Beckman 2020 DMM functions and specs
This instrument reads true rms voltages and currents. This means that the Beckman 2020 will accurately measure both voltage and current output from inverters. The 2020 will measure ac voltage, ac current, DC voltage, DC current, frequency, duty cycle, capacitance, and resistance. This DMM also is outfitted for diode and transistor testing. The instrument will record maximum, minimum, maximum minus minimum, and average data. It will make positive and negative peak voltage measurements on all types of ac waveforms. Basic DC accuracy is rated at 0.02%, while ac accuracy is 2.0%.

The 2020 is an autoranging meter that only requires the user to select the desired function. The meter will then automatically select the proper range. The 2020 is equipped with a bar graph meter in addition to numerical readout. The 2020's liquid crystal display (LCD) has a very readable red backlight for operation in the dark. The display is equipped with annunciators for every conceivable function, from low battery warning, to the presence of dangerous voltage; it's all there on the display.

The Beckman 2020 is 7.5 inches (175 mm) tall by 3.5 inches (90 mm) wide by 1.3 inches (34 mm) deep. It weighs 20 ounces (568 grams). The 2020 is housed in a protective rubber-armoured case with flip-out stand and hang-up strap. The 2020 uses a standard 9 Volt (MN1604) transistor radio battery as a power source. Battery life is about 200 hours or less if you use the backlight often.

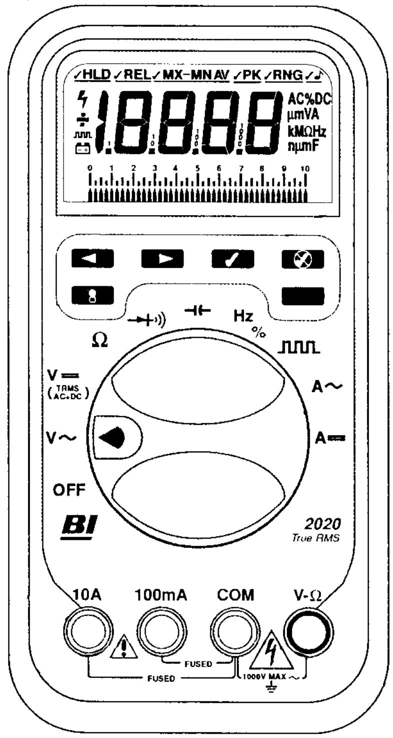
Using the Beckman 2020
We have been using three different Beckman 2020s. We are a beta test site for Beckman and evaluated their prototypes before testing their final production version for this article. Participation in this process has led us to really give the 2020 a full workout in a wide variety of situations.

The 2020 is very simple to use. Just select the function and the instrument does the rest. Once we were acquainted to the menu style operation of the 2020, accessing the various special functions, such as recording, was simple. The 2020 has standardized jacks on its front. All of our accessory probes (like temperature and clamp-on current probes) plugged into and ran on the 2020 with no problems.

Beckman 2020 performance
When it comes to instrumentation there are really two distinct criteria — function and accuracy. First an instrument must be able to perform a measurement. Then it must perform this measurement accurately. The function criteria comes first. For example, if a DMM does not read true rms voltage and current, then it cannot measure a modified sine wave inverter's output accurately regardless of its accuracy when measuring a sine wave.

It is inevitable that the Beckman 2020 will be compared with the Fluke 87 DMM. Fluke was first on the scene with these functions in an affordable DMM. In evaluating the performance of the Beckman 2020, we compared its functionality and measurements to those of three different Fluke 87 meters. Here is what we found.

The Beckman 2020 has several functions and capabilities that the Fluke 87 does not. For example, in record mode, the 2020 computes the maximum minus minimum value and stores it. The Fluke 87 does not have this function. The 2020 will automatically select 4 1/2 digit mode and maintain its 100 millisecond sample time in this mode. The Fluke 87 must have its 4 1/2 digit mode selected manually and its sample time drops to 1 second — ten times slower than the 2020. While this may seem trivial, it has greatly aided us in making measurements across shunts. Here very small DC voltages are present and the extra resolution and speed are pronounced. The data record function on the Fluke 87 runs for 36 hours then stops. The data record functions on the Beckman 2020 run until the battery is depleted, about 200 hours. The mechanics of running the 2020 are solid and reliable. The display is much larger and easier to read than the Flukes. The 2020's red backlight gives much better display illumination than the backlight in the Fluke.



In terms of accuracy, none of the three Flukes agree with either each other or the Beckman 2020. The differences in measurement between all these DMMs is trivial. When you reach accuracy levels of a fraction of a percent, it is impossible to tell who is more correct without calling in the National Bureau of Standards. The Beckman 2020 is plenty accurate enough for any type of home power measurements or troubleshooting, even on the professional level. The only radical disagreement between our Flukes and the 2020 was when making frequency measurements on very noisy power sources like alternators and LCBs. Here the Fluke was better able to dig out accurate data from a sea of noise.

The Beckman 2020 has a list price of $249.00 and the Fluke 87 has a list price of $325.00. Both carry a three year warranty.

Conclusions

The Beckman 2020 is a true rms reading DMM with high accuracy at a low price. It offers more features and faster speed with more resolution than instruments costing more. Now if could only make espresso…

Access

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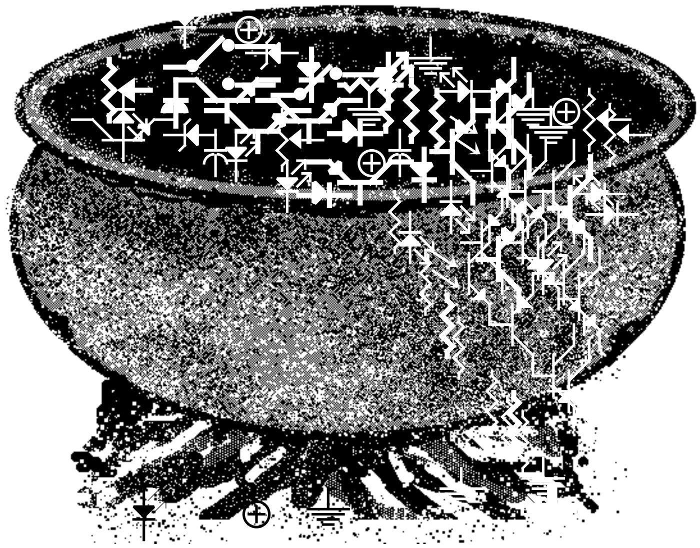


Low ac Voltage Detector

Amanda Potter and Chris Greacen

We recently received a letter from John Boles inquiring as to whether we have published a "brownout alarm" in any of our recent issues. He wrote that he had a friend who lives in a remote area who occasionally gets low ac voltage from the grid at his home. He would like to build a circuit that would disconnect his major appliances (refrigerator and freezer) when this happens to prevent future failure. We built this homebrew circuit in response to his letter.

The circuit sounds an alarm when the voltage gets too low. The circuit could be modified by replacing the buzzer with a relay which would turn off major appliances.

Convert ac Voltage to DC Voltage

Our first step was to convert the ac voltage into a constant DC voltage. We did this with a full-wave rectifier which charges a big capacitor through a 2.2 kΩ resistor. The output of the bridge rectifier, V_r, is shown in Figure 1. This voltage isn't very useful though; it must be smoothed out to generate a constant DC voltage. The RC combination does this. The capacitor is chosen so that RC >> 1 / f (where f is the ripple frequency, 120 Hz in our case). This relation ensures small ripple by making the time constant for discharging much longer than the time between recharging.

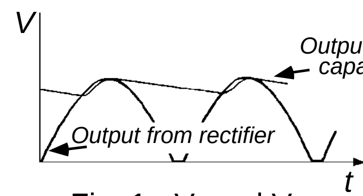


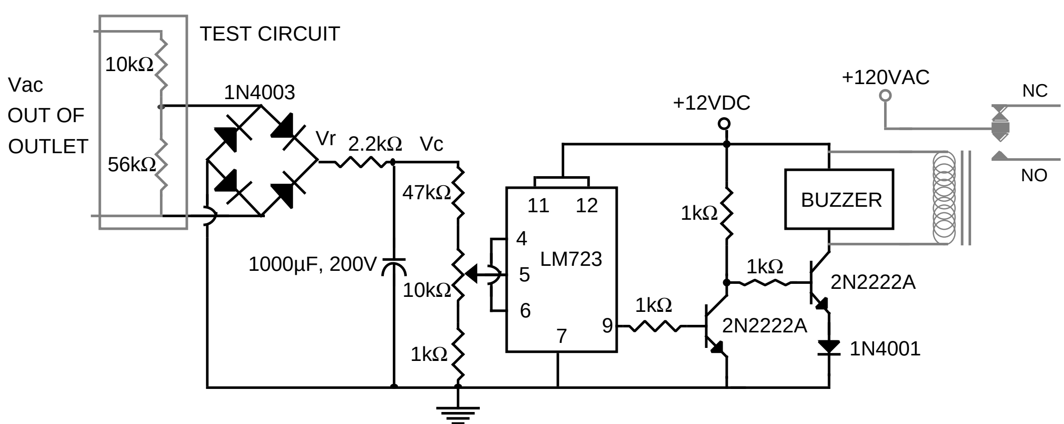
Fig. 1 - V_r and V_c

The output of the capacitor, V_c, also shown in Figure 1, is not V_{rms}; it is the average voltage. See Chris Greacen's article on rms voltage for a description of V_{rms}. For a sine wave, V_{rms} is 1.1 times larger than V_{avg}. See sidebar on the next page if you're interested in how this was calculated.

Most multimeters use this type of circuit to estimate V_{rms}; the voltage is then scaled up by a factor of 1.1. This scaling factor changes for non-sinusoidal waves, such as the waveform of modified sine wave inverters. This is the reason non true rms multimeters give false readings for modified sine wave inverters.

Detect The Voltage Level

An LM723 was used to detect the voltage level. As it is wired in our circuit, pin 9 of the LM723 will go high when the voltage at pin 5 goes above 7 Volts. The 47 kΩ



How is Average Voltage Different From RMS Voltage?

The answer is an interesting mathematical exercise.

(1) $V_{avg} = \mathrm{Ave}\left(\left|V_{peak}\sin(t)\right|\right)$

(2) $V_{rms} = \sqrt{\mathrm{Ave}\left(V_{peak}\sin^2(t)\right)}$

Equation (1) can be solved using beginning calculus.

(3) $V_{avg} = \mathrm{Ave}\left(\left|V_{peak}\sin(t)\right|\right) = \frac{1}{\pi}\int_0^{\pi} V_{peak}\sin(t)\,dt$

$$= \frac{1}{\pi} V_{peak}\left[-\cos(t)\right]_0^{\pi} = \frac{-1}{\pi} V_{peak}(-1-1)$$

$$= \frac{2}{\pi} V_{peak}$$

Equation (2) can be solved most easily using the following two equations.

(4) $\sin^2(t) + \cos^2(t) = 1$

(5) $\mathrm{Ave}\left(\sin^2(t)\right) = \mathrm{Ave}\left(\cos^2(t)\right)$

(6) $\mathrm{Ave}\left(\sin^2(t)\right) = \frac{1}{2}$

Substituting equation (6) into equation (2), we can solve for Vrms.

(7) $V_{rms} = \sqrt{\frac{1}{2}}\,V_{peak} = \frac{1}{\sqrt{2}}V_{peak}$

We can therefore conclude that :

(8) $V_{rms} = \frac{\pi}{2\sqrt{2}}V_{avg} = 1.11\,V_{avg}$

resister, the 10 kΩ potentiometer, and the 1 kΩ resister form an adjustable voltage divider which reduces V_{avg} to a level which the LM723 can deal with.

Turn The Buzzer On

The 2N2222A NPN transistors ensure that the buzzer turns on when the voltage level at pin 5 of the LM723 drops below 7 Volts. When the voltage level at pin 5 is above 7 Volts, pin 9 goes high which turns on the first transistor . Current flows from +12 VDC through the 1kΩ resistor and the transistor to ground. The voltage at the collector of the first transistor is thus at 0.6 Volts, the second transistor remains off and the buzzer will not sound. The diode was put in the circuit to ensure that 0.6 Volts is not enough to turn the second transistor on. When the voltage at pin 5 drops below 7 Volts, pin 9 goes low and the first transistor turns off. As a result, the voltage at the base of the second transistor gets high enough to turn the transistor on and the current flows from +12VDC through the buzzer, the transistor, and the diode to ground. This sounds the buzzer.

Set the Low Voltage Point

The final step was to set the potentiometer so that the buzzer would turn on at our "brownout" voltage. We chose 100 volts rms. We made a voltage divider which converted the 120 volts rms out of the outlet to 100v rms. The sum of the resistors was determined to be 60k ohms.

P = V2 / (R1 + R2); P = 0.25W, v = 120V

R1 + R2 = 60 k Ohms

We then changed the potentiometer until the buzzer just barely turned on. We used a multimeter to verify that the voltage at that point into the circuit was 100 volts rms. We used a 7 mA, 12 V pc-mountable piezo buzzer. A 130 mA coil current, 10A at 125 V_{ac} rated relay could also be used to turn off major appliances.

Access

Authors: Amanda Potter and Chris Greacen, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

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Electricity for Beginners: Resistors & Diodes

Chris Greacen

The last Electricity for Beginners article in *Home Power* #31 used a plumbing analogy to explain how current flows in parallel and series circuits. We looked at Kirchhoff's Laws which tell us how to predict how much current will flow in different legs of a circuit. Now let's look at the fun part — the pieces and parts that you can fit together to build circuits.

Playing with these electronic parts is to play with one of the pleasant successes of capitalism. These little pieces are cheap, and you can freely build whatever your mind can dream up. The only rules you need to follow are the rules of electrical physics. So, my electronic revolutionaries, lets get a closer look at two of these proletariat Lego™ blocks: the resistor and diode, and how we might put them together to build some circuits.

Some philosophy: an understanding of electronics is built up from lots of little understandings. Each of these components is explained starting with a plumbing model (compliments of our fictitious inventor, Dr. Klüge). Stop there if you want. This level of understanding will give you enough to often interpret what's going on in an already designed circuit. After the plumbing analogy I'll discuss some caveats — usually limitations to the device. An understanding of these restrictions is necessary for designing circuits that work or work reliably. Circuits are holistic systems — it is important to know who affects whom, how, when, and why.

Resistors

Resistors restrict the flow of electrical current. In the last issue we looked at a plumbing analogy for resistors: a section of narrow pipe or a pipe filled with gravel which restricts water flow, resulting in a loss of pressure or "head". A wide pipe, or a pipe with a small amount of coarse gravel is like a resistor with lower resistance. A narrow pipe, or a pipe with lots of fine gravel corresponds to a resistor with high resistance.

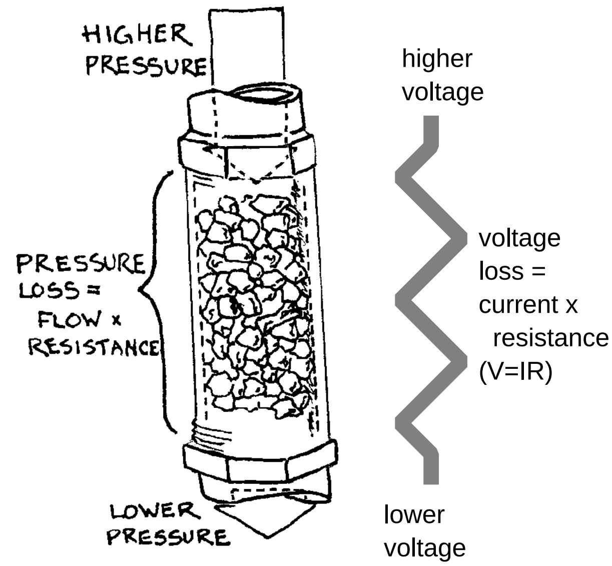


Figure 1: Think of a resistor as a section of pipe filled with gravel. The greater the voltage, the greater the flow of current through the resistor.

The greater the flow in the pipe, the greater the pressure loss from one side to the other. Mathematically, $V = IR$, the voltage drop (V, measured in volts) is equal to the current (I measured in amperes) times the resistance (R, measured in ohms). This is Ohm's law, formulated by the German Georg Simon Ohm in 1827. It's not exactly a law. Ohm's law works very well for resistors and wires, but for other things (like diodes) it's not true at all.

An ampere of current flowing through a one ohm resistor has a voltage drop of one volt. Voltage is named in honor of the Italian physicist Allessandro Giuseppe Antonio Anastasio Volta (1745-1827). The "I" for current comes from the French intensité. The Greek omega (Ω) is the symbol for ohms. Never thought basic electricity was so international, did you?

Joule's Heating Law

The voltage loss in a resistor causes heat. How much heat? The answer is given by Joule's law (the last law you'll have to look at in this article): $P = IV$. P is for power, measured in watts. For any component or appliance using DC electricity, Joule's law is always true. For ac electricity, Joule's law is true if I and V are measured at the same instant. One ampere of current at one volt will make one watt of heat. A car head light draws about 10 Amperes at 12 Volts, so it uses 10 x 12 = 120 Watts.

All electronic components make some heat. This Macintosh computer, from an energy perspective, is a glorified 40 Watt heater. Unfortunately, nearly all electronic components have degraded performance when they are hot, and if they get too hot, they die. Use Joule's law to figure out the heat a component will produce. Multiply the voltage drop across the component by the current through the component. Design your circuits so that they are comfortably below the maximum wattage ratings. Sometimes this is no problem, but often it determines what is practical and what is not.

Joule's law is often called the "I squared R law" since for resistors (and wire) you can substitute V=IR (Ohm's law) into P = IV to get P = I(IV) = I^2R. For more on wires and I^2R losses, see Elliot Josephson's article in this issue.

Diodes

On to more interesting components! Diodes are one way valves for electricity.

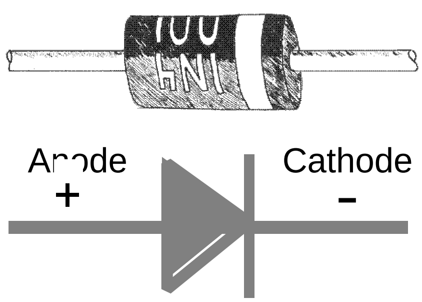


Figure 2a. Above, a typical diode, the 1N4001. Below: the symbol for a diode. The arrow always points in the direction of forward biased current flow.

Check out Dr. Klüge's plumbing diode, in Figure 2b below. If the voltage is higher on the anode (the side of the electrical symbol with arrow) than the cathode (the side with the vertical line), the diode lets the current flow through (Figure 2.b). In this case the diode is said to be "forward biased".

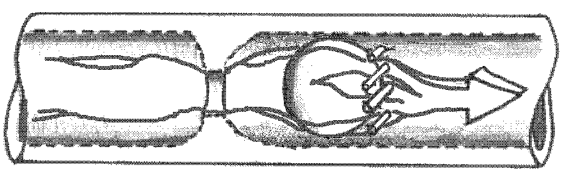


Figure 2b: The plumbing analogy of a forward-biased diode. Pressure higher on the left (the anode) opens the ball valve: current flows.

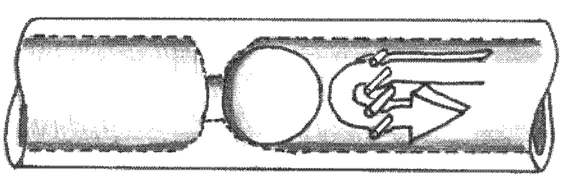


Figure 2c: A reversed-biased diode. Pressure higher on the right (the cathode) closes the valve: no current flows.

If the voltage is higher on the cathode than the anode then the "valve shuts" — current cannot flow (Figure 2.b). In this case we say the diode is "reverse biased". If you're curious what substances allow current to flow one way and not the other, see "How Photovoltaic Cells Work", Home Power #23.

Where would you use a diode? The current in a typical American home is alternating current (ac) (figure 3a). It sloshes back and forth sixty times a second. Computers and radios and many other consumer electronics need current that flows in only one direction, called direct current (dc). Diodes are used to "rectify" the ac current to a rough dc current. Capacitors, which I'll cover in a future article, are used to smooth this waveform.

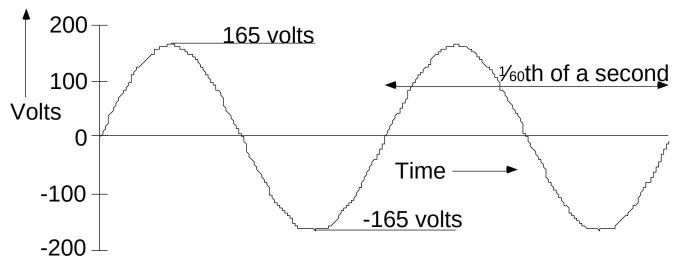


Figure 3a: The voltage of American household electricity forms a sinewave, repeating 60 times a second.

A single diode hooked up to an ac voltage lets only positive voltages through (figure 3b). Four diodes hooked together in a "full wave rectifier" let the positive voltages through, and bring the negative ac voltages positive

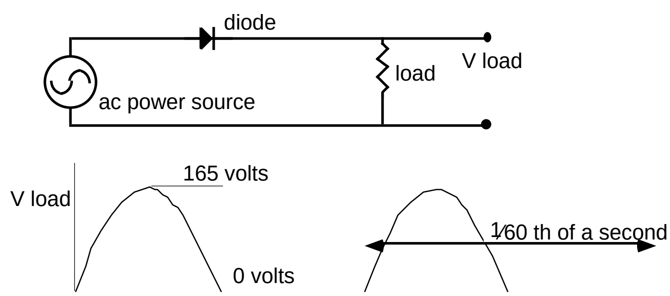


Figure 3b: A half-wave rectifier

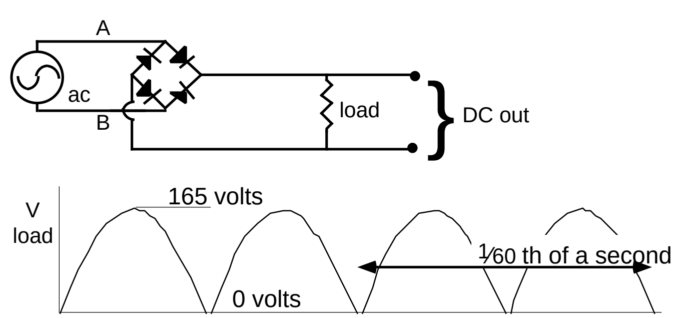


Figure 3c: A full-wave rectifier

(figure 3c). Pretty tricky, huh? Follow the circuit yourself to see how it works. Imagine a positive voltage on the top ac wire (A), and decide which diodes will conduct, then imagine the positive voltage on the bottom ac wire (B) and look at which diodes will conduct.

One very important thing about diodes is they don't obey Ohm's law (V=IR). The amount of current a resistor will conduct is proportional to the voltage applied. In other words, if you double the voltage across a resistor, you'll double the current going through it. This is not the case with diodes. One never speaks of the "resistance" of a diode. Your average diode conducts very little current until the (forward biased) voltage reaches about 0.5 Volts. Then, roughly speaking, the diode "turns on", and will conduct all the current that is applied.

Again, for a resistor, V = IR. For a forward biased diode, it's a good approximation to say that V ≈ 0.5 Volts, no matter how much current goes through it! Of course there's an upper limit on this current (one ampere for the 1N4001). If you exceed the limit you are penalized the cost of a new diode (about five cents for the 1N4001). How do you limit the current going through a diode? A common method is to put a resistor in series with it.

Also, diodes can only hold back a certain voltage. Above this peak inverse voltage (PIV) a reverse biased diode "breaks down" and starts conducting. The PIV for the 1N4001 above is 50 volts, but they're available with PIVs up to 1000 volts. Usually diodes are operated at reverse bias voltages much less than their PIVs.

LEDs

One particularly neat diode is the Light Emitting Diode or LED. When current flows in the diode (typically only 5 milliAmps to 20 milliAmps is necessary) they light up. They come in red, yellow, green, and (for a high price) blue. You've probably seen them in digital clocks with lit up numbers. LEDs have a voltage drop from 1.8 to 2.4 volts, depending on color. They're one of the most efficient light producers around. But, because of their monochromatic color, they don't make great house lighting. You can buy or make a set of them as low-voltage Christmas lights!

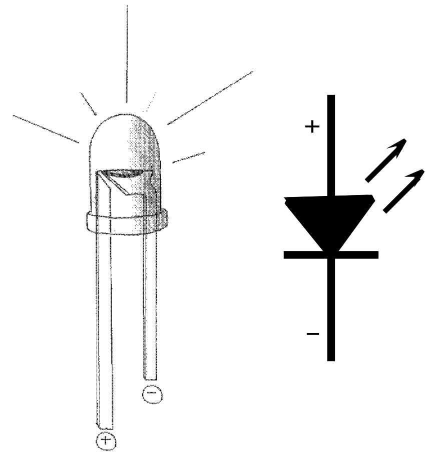
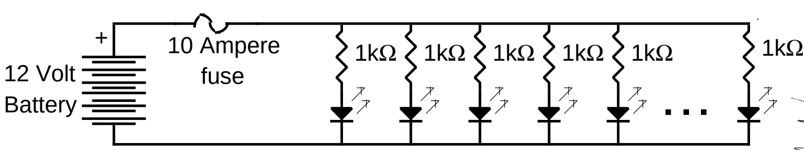


Figure 4: Left, a typical LED. The cathode (–) is usually the shortest lead. Right, the electronic symbol for a LED.

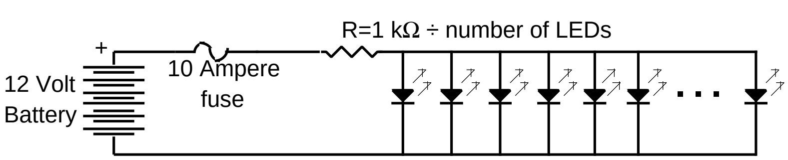
Solar Cells

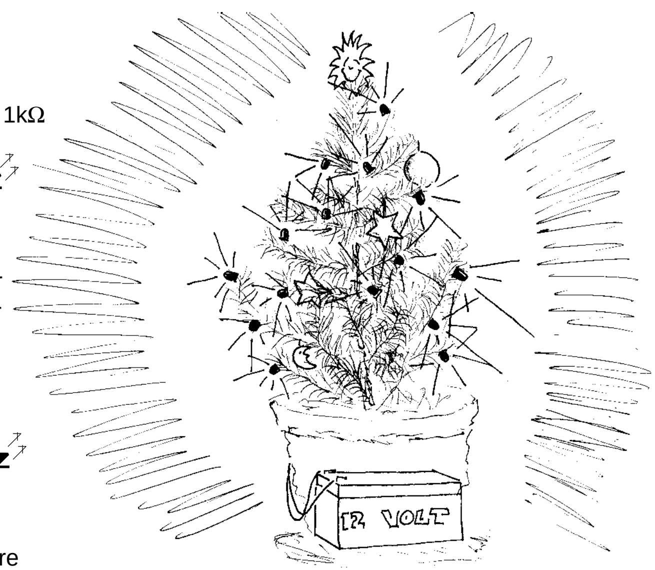
Photovoltaic solar cells (PVs) are big, flat diodes. There's still a 0.5 Volt drop across each cell, but sunlight does the work of pushing electrons up this 0.5 Volt drop to generate electricity. For an explanation of how they work, see "How Photovoltaic Cells Work", Home Power #23

Here's two equivalent circuits for a set of 12 Volt LED Chrismas Lights. In the top circuit, each LED has a 1kΩ (=1000 Ω) current limiting resistor.



In the bottom circuit, the current through all the LEDs is limited by a single resistor with resistance R a fraction of 1kΩ. If the LEDs are the same color (have the same voltage drop) the current in each will be the same in either circuit. If they're different colors, the difference is negligible.





Note: A more efficient method of wiring LEDs for Christmas lights is to wire strings of four LEDs in series with a 330Ω current limiting resistor.

Figure 5: LED Christmas lights

Zener Diodes

I said above that diodes are usually operated far away from their peak inverse voltage. An exception is the zener diode. Zeners are designed to break down under a reverse bias voltage. You can get them with breakdown (or “zener”) voltages anywhere from 3.3 to 75 volts. They work like pressure release valves, “letting off steam” when the voltage gets too high. Dr. Klüge has assembled a plumbing zener. Let’s see how it works. In figure 6a, the plumbing zener is forward biased. Pressure is lower on the bottom than the top, opening the right hand side ball valve. Current flows just like in a forward biased diode. This is no surprise — a zener is a diode, and forward biased diodes conduct.

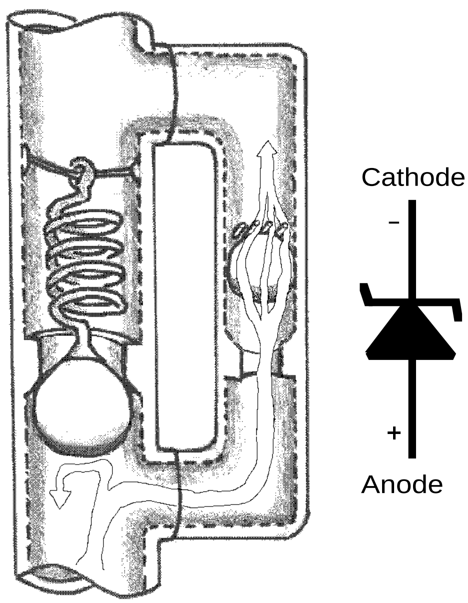


Figure 6a: Left:: the plumbing view of a forward biased zener diode. It acts just like a regular forward biased diode. Right:: the symbol for a zener. Notice the arrow still points in the direction of forward biased current flow.

For the next two figures, though, the plumbing zener is reverse biased. This is the way we normally use it. The voltage (think of it as pressure) is higher on the cathode than on the anode. In Figure 6b the voltage is not high enough to push the left ball open against the force of the spring. No current flows. In Figure 6c the zener “breaks down”. The pressure is high enough to open the spring, and current flows.

When a zener breaks down, it makes heat. Remember Joule’s law: P = IV. Here V is the zener voltage. I is the current conducted. You have to make sure that the zener won’t try to make more heat than it can dissipate. For

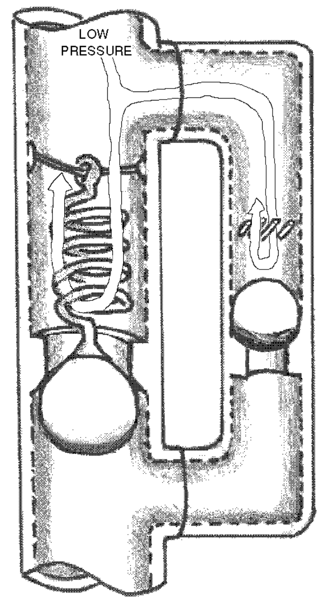


Figure 6b: Reversed biased zener with voltage below the zener voltage. No current flows.

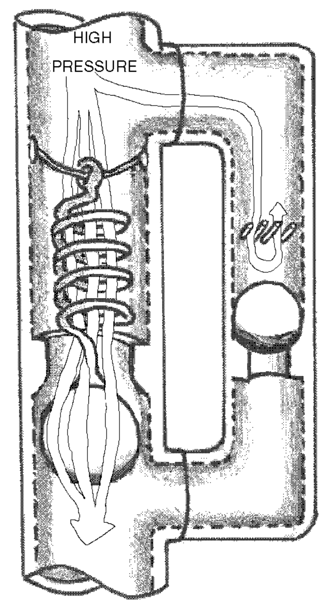


Figure 6c: Reversed biased zener diode with voltage above the zener voltage. The zener breaks down, current flows

example, a 1 Watt, 12 Volt zener diode can’t take more than 1/12 Ampere of current since 1/12 Amps x 12 Volts = 1 Watt.

For a very small PV (1 Watt) module, you might consider an appropriate 15 Volt zener as a single component voltage regulator for charging a small battery or powering a small over-voltage sensetive 12 Volt appliance “array direct”. If the battery’s voltage under charge reaches 15 Volts the zener shunts the current from the positive wire to the negative (or ground) wire. See figure 7. Warning: try this on a larger than a 1 watt panel and you’ll blow up the zener. You can get larger zeners, but they’re hard to find. Besides for bigger panels, there’s better ways using

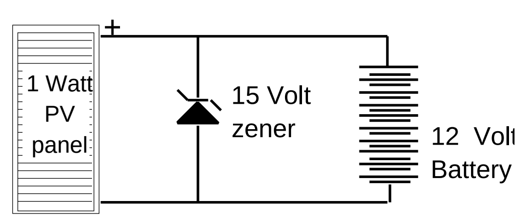


Figure 7: An unadjustable regulator for a 1 watt panel. When the voltage rises above 15 Volts, the zener starts to conduct.

transistors or integrated circuits; see the Home Brew in this issue.

Advertisement: Transistors Home Power #33
Resistors and diodes are interesting in their own right, but if you need to, consider this a prelude to next issue's look at transistors. Transistors are the basic building block of any of today's circuits which either amplify something, or have to make some decision.

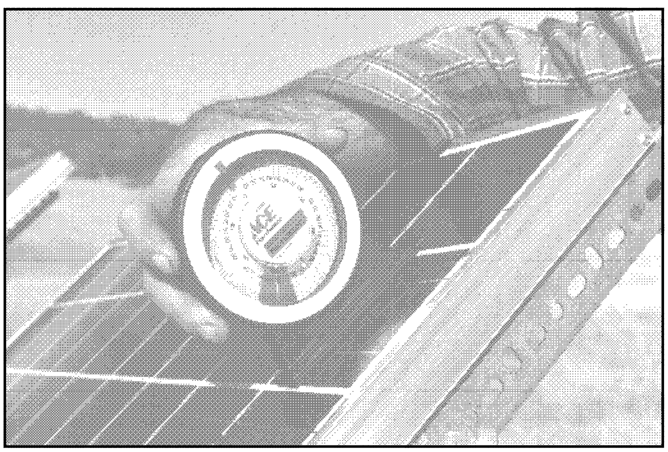
Access:
Author: Chris Greacen, c/o Home Power Magazine, POB 520 Ashland, OR, 97520 • 916-475-3179

Tech Notes:

PV Angle Indicator

Bob-O Schultze

Optimizing the output of PVs requires adjusting the elevation of the modules as the seasons change and the sun becomes higher or lower in the sky. Performing this simple adjustment just 4 times yearly at the solstices and equinoxes can add about 10% to your modules yearly output. Did I say simple? NOT! Anyone who has tried to juggle wrenches, bolts, and a framing square or triangle while supporting the array with your head, shoulder, teeth, or other handy appendage, knows what a pain this can be. You can, and should, make some indelible marks on your array support legs to indicate that your PVs angle is equal to your latitude (spring and fall), +15° (winter) and -15° (summer). But how to get those settings accurately in the first place?



Above: setting the PV angle. Photo by Mark Newell

I found a tool in my local Ace® hardware store that makes it easy. It's called a Magnetic Base Protractor. I've seen them in other stores called a Pitch Angle Indicator. It is used to check the pitch angle of a roof. I don't know much about roofing, but I know a dandy PV angle indicator when I see one! Slap this baby onto a magnetic part of your rack or tape it to your aluminum module frame and you've got an accurate, no-hands way to set your array to the correct elevation. At $8.95, it's a good deal.

Access

Author: Bob-O Schultze, Electron Connection, POB 203, Hornbrook, CA 96044 • 1-800-945-7587

Surge and Lightning Protection for the Stand-alone PV System

John Wiles

Do you have a lightning rod on or near your house? Do you live in a high-incidence lightning area? Are you concerned with the safety of your family and your investment in a renewable energy system? Photovoltaic (PV) arrays need to receive full sunshine and not be shaded by nearby objects. They are generally mounted in the open and are frequently the highest object in the immediate area. With wiring, metal module frames, and metal mounting racks and supports, they look a lot like lightning rods. They frequently act like lightning rods by serving as dissipation points for electrostatic charge and strike points when the charge build-up exceeds the breakdown voltage of the air between the array and the clouds above.

Article 280 of the National Electrical Code (NEC) deals in general with surge arrestors. Chapter 8 of the NEC covering communications systems also mentions surge arrestors. Since PV systems are a relatively new power source, there is little available guidance in the NEC concerning surge protection of such systems. This Code Corner will address some of the techniques that have been used to suppress surges in PV and other renewable energy systems.

NEC Requirements

The NEC requires that all exposed metal surfaces be grounded regardless of the nominal system voltage. Systems with PV open-circuit voltages below 50 Volts are not required to have one of the current-carrying conductors grounded. Any system with ac voltages at 120 volts must have the neutral grounded. Some inverters do not isolate the ac and DC sides; grounding the ac neutral will also ground the DC negative. Other inverters have the case (which must be grounded) connected to the negative input which grounds the negative current-carrying conductor.

Direct Strikes

Direct and nearby lightning strikes can damage inverters, charge controllers, batteries, and other components in renewable energy systems and in homes. There are no guarantees on methods of preventing lightning damage. There are good engineering practices that can be applied that reduce the probability of damage from lightning strikes. They have been used for years by radio and TV stations, ham radio operators, remote communication systems, utility companies, and others. More protection is provided by combinations of these systems. The cost increases as the degree of protection increases. Again, there are no guarantees.

Lightning wants to travel from charged clouds to charged earth or visa versa. The strike occurs when the potential difference between the cloud and the earth exceeds the dielectric strength of the intervening air. Normally non-conductive objects, such as trees and houses, can serve as conductors to channel the charges and shorten the distance between the cloud and earth. If the charge is dissipated before the potential increases to the breakdown voltage, the lightning strike does not happen. A tall, metallic structure that is well grounded will usually protect an area around its base that has a diameter equal to 1/3 the height of the pole or structure. This indicates that a tall, grounded, metal pole directly behind the north side of a PV array may protect the array frame from direct strikes.

Induced Surges

Indirect strikes near the PV system will induce surges in conductors of the RE system and conductors coming into the house. Direct or close strikes on telephone and power lines even miles away may put large surges on the lines leading to the house. The techniques outlined below will reduce the effects of lightning induced surges on the PV system.

Ground all Metal Structures
The NEC requirement can be extended. A separate conductor (as large as possible, but not less than number 10 AWG) should be fastened to each metallic module frame with a self-threading, stainless-steel screw. The other end of these conductors should be connected to a single point on the array frame or rack — again with another self-threading, stainless-steel screw or with a stainless-steel bolt in a drilled and tapped hole. From this point, number 4-6 AWG or larger copper conductor should be run directly to the nearest earth where it is connected to the longest, deepest ground rod that can be afforded. Eight feet is the minimum length recommended. Use a UL-listed clamp to make the connection. If a steel well casing is available, drill and tap the casing and use this as the ground rod.

In dry areas, several ground rods spaced 20-50 feet apart in a radial configuration, all bonded to the central rod can be effective. Buried copper water plumbing can also improve the grounding system. Pipe or copper wire can be buried in trenches 12-18 inches deep in a radial grid. All grounding members should be connected or bonded to the central ground rod with heavy, bare conductors buried under ground. Direct-burial, UL-listed grounding clamps or welding should be used for all connections. Soldering should never be used.

The NEC requires (on systems that must be grounded) that the conductor from the grounded current-carrying conductor (usually the negative lead) to the main ground rod be unspliced and be as large as the largest conductor in the system. It is probably a good idea to tie the required equipment grounding conductors to the grounding system at the point where this large conductor connects to the negative conductor.

Limit Surge Transmission with Inductors
After a surge is impressed on an electrical conductor, the transmission of the surge may be attenuated or restricted by placing an inductor on the line. Running the conductors from the PV array to the house in grounded metal conduit will provide inductance on the lines. This will shield them from much of the initial surge pickup and slow down the surges that do get through. At a location near the entrance of the house, the conductors from the array can be coiled in a loop about 6-12 inches in diameter forming an inductor. Five to ten turns should be used in the loop, and the conductors should be tightly held together. When used with conduit, this coil can be placed in a metal box, with conduit coming into and out of the box.

Disconnect the Array
All systems should have a PV disconnect switch (NEC requirement). If there are no conductors from the array connected to the rest of the system, then there is little likelihood that surges on the array wiring will get into the house. This disconnect switch will have two poles on ungrounded systems and one pole on grounded systems. This switch can be left open when lightning storms are nearby. The 1/4 to 1/2 inch gap in the switch will provide some protection from surges when open, but a large surge will jump the gap.

A better solution is to mount a cord-connected plug-and-socket assembly either near the base of the array frame or near the house entry point. Use some sort of unique three-conductor plug and socket that is rated to carry the current and voltage involved (possibly a 30 or 50-amp, 240-volt range or a dryer plug-and-socket set). If the system uses a blocking diode in or near the charge controller, the socket should connect to the array wiring and the plug to the house wiring . If the system has no blocking diode, a socket should also be wired to the house wiring and a jumper with two plugs should be used to connect the two sockets. The house-side socket should always be disconnected first and connected last. In this case when the plug is inserted into the array socket, the other plug has exposed contacts that are at the array voltage. The idea is to unplug the array when storms are near to create at least a 3-4 foot gap between the array wiring and the house wiring.

Absorb the Surges
Surge arrestors are available in a number of sizes—generally the larger, the better. Surge arrestors can be connected at both ends of the array-to-controller wiring to bleed surges to ground or absorb them internally. Small quarter-sized units (metal oxide varistors—MOV) can be mounted at module junction boxes and inside electronic equipment, such as inverters and charge controllers. They should have a clamping voltage slightly above the maximum PV open-circuit voltage. They are available from electronic parts distributors or mail order firms like DigiKey.

Large units (the size of a frozen orange juice can), which can absorb far more energy from surges, can be mounted on the conductors entering the house or controller box. These units are used to protect 120/240-volt service entrances on residences and deep well pumps. They contain silicon oxide and are sometimes known as silicon oxide varistors. Although rated at voltages higher than the typical 12, 24, 36, or 48-volt PV system, they can be used to absorb those really large surges. They are available from many electric supply houses or from Delta Lightning Arrestors. Delta has a good unit - the model LA 302 which is rated at 300 volts, 60,000 amps and 1500 Joules. These units should be connected positive to negative, positive to ground, and negative to ground. In the smaller MOV two-wire units, three separate devices must be used. The larger units, such as the ones from Delta, have three wires. One is connected to the positive conductor, one to the negative conductor, and one to ground.

Provide a High-Voltage Path to Ground

Close and direct hits can impose very high voltages on the array conductors. Some of this voltage will be absorbed by the surge arrestors. A spark gap can provide a path for the higher voltage surges to get to ground. Mick Sagrillo, in his excellent article on Lightning Protection in *Home Power* #24, presented an easy, low-cost method of making spark gaps using spark plugs. One of these spark gaps should be placed on both the positive and negative conductors near the bottom of the array rack or pole with a very short connection to ground. The gap can be as small as possible since it only needs to present an open circuit to PV voltages in the range of 22-44 Volts.

Utility and Phone Lines

If the RE user also has grid power (as a back-up, of course) or hard-wired telephone service, surge suppression must also be placed on these lines. The large surge arrestors described above can be used on the utility power lines and special telephone arrestors are available from Radio Shack and others.

Well Grounded Systems Last Longer and Work Better

The communications and computer industries are finding that surges and poor commercial power quality demand that all systems be grounded to a common point. Data corruption on computers, modems, and faxes and noise on telephone lines has frequently been traced to poor grounds or separate grounds for each system. Proper procedures vary from site to site and are beyond the scope of this article, but using a common grounding system can usually minimize many problems. Those trying to use telephone products that need external power have special problems which the local electronic technician can solve using isolated power supplies. Radio and TV antenna lead-ins should also be connected to appropriate lightning arrestors or ground.

Charge Controller Design

Charge controllers that use relays (either mechanical or mercury displacement) that are physically separated from the electronics control package are generally less susceptible to surges than controllers that have solid-state switching devices in a single package. The relays are pretty tough and it is relatively easy to add surge protection to the remote electronics package.

Summary

There is little that can be done to protect a renewable energy system from a direct strike. The probability of a direct strike can be reduced however and systems can be reasonably protected from surges induced by nearby lightning strikes.

Access

Author: John Wiles, SWTDI/NMSU, PO Box 30001/Dept 3 SOL, Las Cruces, NM 88003 • 505-646-6105

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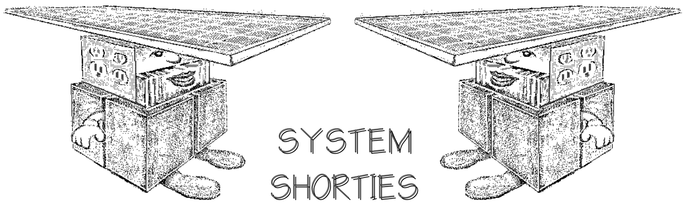
Delta Lightning Arrestors, PO Box 1084, Big Spring, TX 79721, 915-267-1000

DigiKey Corp., PO Box 677, Thief River Falls, MN 56701-0677, 800-344-4539



Solar Boy Scouts

Rod Wheeler WA6ITC

For the last three years I have been teaching Electricity & Electronics Merit Badges at summer camp. In previous years the facilities at Camp Emerald Bay on Catalina Island provided grid power to my teaching facility.

This year I spent three weeks at Holcomb Valley Scout Ranch near Big Bear City, California. The teaching facilities there were basically the same except the closest grid power was 400 feet away. Much too far for an extension cord. The only answer was PV.

Going Solar

I had an old Hoxan 40 Watt panel that could be used and I had just purchased a PowerStar 1300 watt inverter for a future project. All I needed was a battery and the problem would be solved.

A quick trip to the local battery store netted a 105 Amp-hr. deep cycle marine battery. An ASC-8 regulator does its job too.

Being Prepared

So before heading to camp I assembled the cables: 25 feet of #8 from the panel to the ASC-8 charger and a foot of #14 to the battery. The PowerStar inverter used two 30 inch, #2 battery cables. 12 VDC distribution is via a DC power cord to my Kenwood T5-4405 High Frequency Amateur Radio. The 120 vac is distributed through a 6 outlet power strip with circuit breaker.

The panel elevation is adjusted with a 3 foot piece of Jeffrey pine I found laying on the ground. Likewise manual Azimuth adjusting is used.

Using Solar Power

The 120 vac provides power for soldering irons, a model railroad demonstration, lights in the tent and a neon sign transformer for a Jacobs Ladder display. The ham radio was powered by the battery. Although none of the Scouts were Hams I demonstrated the Radio setup by making contacts from South America, New York and Midway Island.

Solar Scouting

Some 100 scouts received either the electricity or electronics merit badge during the three week stay. The solar power system provided a model for the electricity merit badge and power for the soldering irons for the electronic merit badge.

The camp hosted some 750 scouts and scouters those three weeks. Most stopped by to see exactly what the panel was powering. It seemed that everyone knew what the solar panel was. When I explained how it was being used, most could not believe how simple it was. It was a great opportunity to expose something new to them. They never realized how clear and direct the technology is to make power from the sun.

Next year I plan on being at the camp for five weeks with the same setup. I am still getting positive comments on the merit badge classes. The overall response from kids and adults was excellent. I will be checking on the possibility of a Renewable Energy merit badge in the future.

Access

Rod Wheeler, WA6ITC, 428 G. N. Golden Springs,
Diamond Bar, CA 91765

National Energy Bills and Strategies

Michael Welch

Hello, again, revolutionary readers of radical renewable rhetoric. I'd like to thank those of you who have taken the time to write your letters of support for this column. The feedback is desirable and necessary. In fact, if you have any column ideas or hot leads on fitting stories, be sure to let me know. I can't promise to print or mention every one, but I will look into any appropriate information sent.

I was originally hoping to concentrate this month's column on government and utility incentives related to renewable energy, but I was disappointed to find that there's just not that much out there. I uncovered a scattering of small R.E. programs, and there are more related to conservation and efficiency, but I'm going to have to dig a lot deeper in hopes of finding those few special programs available that you as individuals and businesses can take advantage of. This lack of appropriate programs is where you can make a difference. Please contact your state and federal representatives and bureaucrats as well as utility representatives to encourage them to provide as much incentive as possible for folks to enter the renewable energy world.

The New Energy Bill

I did find that the new Energy Bill will be providing some incentives for renewable energy. One incentive for end users is an income tax exemption for rebates from utilities for purchasing energy saving equipment. Previously, any rebate was considered taxable by the feds. Another plus for individuals is a tax credit for those of you who convert your vehicles to alternative fuels, including electric car conversions. This particular program also provides large tax incentives to companies that convert their fuel delivery systems to provide alternative fuels. Most of these incentives will be going into place within 18 months of the Prez signing the bill.

The Energy Bill will also provide a 1.5 cent per kWh production tax credit for wind and biomass.and a 10% business tax credit for solar or geothermal, and tax exemptions for commercial utility rebates. I uncovered no new research & development grants available in this bill.

National Energy Strategy Revisited

The Department of Energy (DOE) is the bureaucracy that is supposed to oversee energy policy and administer Federal laws and regulations regarding energy they've also been entrusted to manage all aspects of nuclear bomb production. The DOE is an agency whose highest heads are appointed by the President, so one would assume that agency staff is predisposed to an energy policy that is slanted toward the political wants and needs of the current administration. It was the DOE that developed Bush's National Energy Strategy and made recommendations to the Prez about how much should be spent on what in the DOE budget.

An internal DOE memo has been made public that shows that even the DOE initially tried to emphasize efficiency and renewables and de-emphasize funding for environmentally destructive energy sources. But that was before the politicians became involved. The memo was entitled "Spring Planning Process" and was obtained by Representative Howard Wolpe of Michigan, a leader with the potential for Good-Guy status.

A DOE cover letter attached to the "Spring Planning Process" tells the story. It says, "Altogether, this package reflects the results of a considerable effort to develop, *on its merits*, program planning priorities in tune with the NES [National Energy Strategy]. Political sensitivities can be applied later, but you need to know, first, what seems to be right based on the merits, determined in accordance with criteria carefully selected and applied as uniformly as humanly possible across all relevant program elements." [emphasis in original].

"Political sensitivities can be applied later?" That means here are our recommendations, and they're right and good, and you political types will muck it up now that we're done. Here's what Representative Wolpe had to say, "After comparing the recommendations made in this internal DOE analysis with the president's own budget proposal, it is crystal clear that the public interest continues to be shunted aside in favor of special interests."

The DOE's original criteria tried to work objectively in ranking program areas by the following criteria: potential energy contribution, environmental impact, economic growth, and technical and market risk. In the program area of Oil Vulnerability, designed to reduce America's oil addiction, the DOE's policy office recommended increasing funding for 1) improvements in fuel economy, 2) R&D on batteries, hybrid vehicles, fuel cells and both hydrogen and flexible fuel vehicles, and 3) residential, commercial and industrial efficiency and conservation. Of course, once Bush got hold of it, it was a mere shell of its former self. Despite the recommended increase, the final presidential version showed a $185 million decrease in request for funds. This from a man who says he wants to protect America from the foreign oil producers.

In the program area of Electricity, the programs ranked highest for increased funding included improving utility demand efficiency, developing renewable energy resources, and advanced R&D for alternative fuels. The policy office reached the conclusion that 12 of the 23 programs in this area should be de-emphasized. The programs to be de-emphasized included all of the DOE's various nuclear energy programs. The memo called for a 22% cut in these 12 programs, but low and behold, the final product showed a 22% increase in these programs.

George Bush signed into law in early October our country's comprehensive Energy Bill (see HP #30 for more information). Over the summer, energy bills with different provisions came out of both the House & Senate and went to a conference committee for final resolution. They finished with it and sent it on to the Prez for his approval.

This final version of the Energy Bill took still another unseemly turn. Senator J. Bennett Johnston (Dem. LA) and Representative George Miller (Dem. CA) slipped language into the bill which removed the EPA from regulating the future Yucca Mountain High Level Radioactive Waste Repository in Nevada. What this means is the radioactivity exposure standards by which the federal government regulate nuclear waste are being lowered for this one site just so work can continue.

In spite of a majority of public opinion to the contrary, Senator Johnston does all he can to help the nuclear industry. One might say, "Big deal, everyone is entitled to their opinion," except for one thing: Johnston is Chair of the Senate Energy & Natural Resources Committee. In essence, he is the most powerful person in government working on energy issues. No wonder this dinosaur called nuclear energy is still breathing.

On the other hand, there was some news in the OK to GOOD range that came out of the final version of the bill. It included wording that partly affirms states' authority in dealing with a form of radioactive waste called Below Regulatory Concern (BRC). Without this language, the Nuclear Regulatory Commission was prepared to allow nuclear waste producers to dispose of this new category of waste in community landfills, and even recycle it into common items like jewelry and cooking pots! Though language should have been much stronger, it has to be considered a victory. Congratulations and thanks are due to the many concerned people who relentlessly fought this irresponsible policy.

On Different Note

In the course of this search, I discovered a couple of resources that you might be interested in. The first is the National Appropriate Technology Assistance Service (NATAS). This is a wonderful program that "is an information and technical assistance source" and "has two main roles: to help people investigate or implement appropriate technologies, and to help innovators solve problems they have commercializing energy saving products and services." I just had to test them out, so I called their toll-free number (800-428-2525 or in Montana 800-428-1718) and asked for information on school curriculums that have been developed to teach kids about solar energy. They took my request, and an information specialist called back to get more specifics. Two weeks later, Redwood Alliance received a package of material three inches thick, all related to my specific request! In my opinion, this service is one of the most important that the government could possibly offer our renewable energy community!

The other resource I discovered is the Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS). Their name says it all. They have a long list of publications available on topics ranging from Electric Vehicles to Small- Scale Hydropower Systems and Wind Energy Reading List. I called them and got a state by state list of toll-free phone numbers for State Energy Offices. The CAREIRS number is 800-523-2929. They were pretty fast in sending stuff, but I discovered that many of their publications are unavailable because of inventory constraints.

By the way, the list of State Energy Offices' toll-free phone numbers is available for modem downloading in the General files section of the Home Power Communications System BBS by calling 707-822-8640 or by sending a pre-stamped and addressed envelope to Redwood Alliance.

Both NATAS and CAREIRS are funded by the

Department of Energy (DOE) and run by private contractors on DOE's behalf. Thank you! Thank you! Thank you!

Women In Power

On a slightly different subject, there is another type of energy in Washington: human energy. Maybe this is another place where we need an alternative—to the overabundance of testosterone running through the halls of Washington. What this world may need is more women in government. It's not an over generalization to say that most women have been taught to have a more nurturing attitude than most of the men that are America's power brokers in business and government. If there were a majority of women in Washington, is it possible that our government would care more than it does for the health and well-being of our planet and its inhabitants? Frankly, I think we should give it a try. I'm tired of the muscle-flexing that makes up world and national politics these days. Write and tell me what you think of this idea, and maybe I can devote more space to this subject.

Access

Author: Michael Welch, c/o Redwood Alliance, PO Box 293, Arcata, CA 95521

Sources

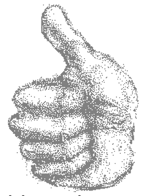
POWER LINE Magazine, Environmental Action Foundation, 6930 Carroll Ave. Suite 600, Takoma Park, MD 20912. A great magazine for energy activists! Get it!

US Public Interest Research Group (USPIRG), 215 Pennsylvania Ave. Washington, DC 20003. A great group, inspired by one of my heros, Ralph Nader. Join them!

Nuclear Information Resource Service (NIRS), 1424 16th St. NW Suite 601, Washington, DC 20036. A fine organization of overworked anti-nuke folks. Send them a check!

NATAS & CAREIRS, see body of article.

Things that Work!



Things that Work!
tested by Home Power

Sanderson's Rebuilt Kirbys

tested by Kathleen Jarschke-Schultze

Sanderson's Rebuilt Kirby vacuum cleaners have a classy style that only hints at their efficiency. These 1940s vintage vacuums were being scrapped for their aluminum bodies; Bill and Katcha Sanderson use their remote home to refurbish these well-made vacuums for sale. A look into the attachment kit "tool cabinet" and you know you have a workhorse of Clydesdale proportions. I have been using my Kirby for a year and a half under consistently rigorous conditions. In this case familiarity breeds content.

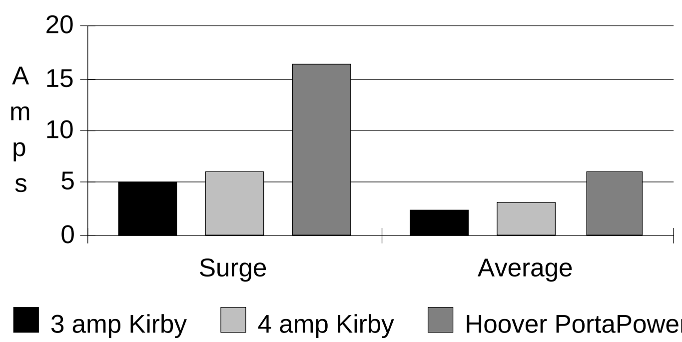
Shipping and Packaging
Most models are shipped UPS as mine was. It arrived packaged neatly in a cardboard box padded with wadded newspaper. There was a little assembly required. Instructions were provided so no problem was encountered attaching the various parts together. Home Power Central's was delivered by hand at SEER '92.

Size Wise
While the Kirby model I own draws 3 amps, Home Power's model is rated at 4 amps. Side by side they look like the same model. There are slight differences, mostly the newer replaced parts on the 4 amp model. Where the 3 amp model has a spot that rubs on couch edges when you vacuum close on the right hand side, the 4 amp vacuum has a replacement bag where that problem has been solved by using a wider plastic lip at the bottom of the bag. The overall size of the two machines is the same. Both models weigh the same, 16.5 pounds. Attachments are interchangeable.

Performance
For comparison I hauled out my Hoover PortaPower (I still use it to vacuum the car). This vacuum is so weak that I can't use the extension tube on it. It is much like working with a short handled hoe. The Kirbys, however, have a foot actuated control for adjusting the height of the vacuum head so you can fine tune the vacuum to the surface you are cleaning. In side by side tests the Kirbys picked up dirt three times faster than the Hoover did. I put 1/8 cup of dry dirt, for each vacuum, onto a woven wool oriental rug. Both Kirbys picked up the dirt and small pebbles completely in three swipes. The Hoover took longer (nine swipes); it did not pick up as much in a swipe and had trouble with the small pebbles. I thought the 4 amp model pushed and maneuvered easier than my 3 amp model. This could be a factor of age or just that Home Power's machine's parts are cleaner since it just came from the Sanderson's shop.

Power Consumption
I compared the power consumption of the 3 amp Kirby, the 4 amp Kirby, and my old Hoover PortaPower rated at 7.4 amps. The Hoover, the most inefficient of the three, gobbled up more power than dirt. A Fluke 87 meter was used for the testing. The chart below shows the results.

Vacuum power consumption in amperes at 120 vac



Attachments
The attachment kit for the Kirby is packaged tidily in a tool cabinet that hangs by two straps. The front opens up so you can hang the box on a chair and easily reach your preferred tool for whatever cleaning job you are doing.

The basic attachments are a long extension tube, crevice tool, utility brush nozzle, shoulder strap, curved extension tool, duster brush, blower coupler, massage cup, suction coupler, crystalator (for moth removal), lifter grip, flexible hose, duster, and buffer pad. When you need to carry the vacuum, the long handle on the vacuum comes off, the bag folds over and snap rings to the body. Then you can attach the shoulder strap to the body and carry it easily while using any of the attachments.

This list of optional attachments is dazzling. The Spray and Suds-O-Gun atomizes any liquid you would care to spray. It also shampoos furniture and rugs. The power polisher works on linoleum, cement, tile, or hardwood floors. Other attachments are the Handi-Butler, a sheeting buffing wheel for polishing sporting equipment and household metals, and a flannel buffing wheel for polishing precious metal jewelry, silver and chromium table and hollow-ware. There's a grinding wheel for sharpening knives and a wire brush wheel for cleaning dirt, rust, and scale from pans, tools, and sporting equipment. Finally, there is a lambswool polishing pad for polishing waxed surfaces on wood, metal or leather...automobiles, shoes, suitcases and furniture. If you can obtain this attachment, go for it. This attachment is the most versatile but also the rarest to find complete.

Idiosyncrasies

I have had to perform some routine maintenance on my Kirby. The frequency you have to remove and clean your roller bar is directly related to how many people in your family have long hair. If anyone flosses their teeth in the living room make sure they keep track of the floss. Any string-like objects will wrap themselves around the roller bar and eventually keep it from turning freely. I first became aware of this when the motor changed pitch and a burnt hair smell filled the room I was vacuuming. Since I am the one with long hair I do regular roller checks now so it has not been a problem since.

The plaid bag of the vacuum has a side zipper. It opens a deep pocket that goes nowhere. Before emptying the dirt you need to unzip the pocket, reach your hand in there and feel around for the plastic bar attached to the bottom of the pocket. Grasp firmly and use this bar to scrape the insides of the bag in downward strokes to get as much dirt out of the bag as possible. I am always surprised at the amount of dirt I can accumulate in the bag.

Both Kirbys have the Sani-emtor. This plastic tray collects dirt and can be easily unlatched to empty and dispose of the dirt. This means no throw away vacuum bags. There is an option that includes converting the pocket-dump bag to a cloth bag which uses standard disposable paper bags for people who want that emptying method.

Conclusion

After more than a year of use I am still enamored of my rebuilt Kirby. I have had several people tell me that after reading my comments a year and a half ago they either got Kirbys or the replacements parts from the Sanderson's and are now happily vacuuming with an efficient working machine.

The 3 amp model is $175.00 and the 4 amp model is $150.00. The original tool sets are hard to come by, so they are offered (used/serviceable) as available for an additional $25. The cost for a new replacement set of genuine Kirby tools is $75. Katcha and Bill are developing a home repair kit so that the cost of shipping your vacuum for repair would be saved.

Access

Author: Kathleen Jarschke-Schultze lives with a vacuum, not in one, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3401

Sanderson's Rebuilt Vacuums, 20295 Panoche Rd., Paicines, CA 95043 • 408-628-3362

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Me and My Panel

Therese Peffer

I did it. I decided to make my own power. I live in a trailer about a 100 foot extension cord length from Home Power Office & Power. The batteries are filled with electricity from photovoltaic panels and a wind generator — I can't complain about the source. But, well, sometimes the extension cord gets "borrowed", and there are "black outs" when Richard changes inverters (he counters that I haven't been paying my bill). I decided to create my own system to learn and to do a system for my folks.

The Plan

I decided to use a photovoltaic (PV) module to make electricity from the sun, and a battery to store it in, but what kind of PV module and what size battery?

First I made a list of the appliances I use and whether they use Direct Current (DC) or alternating current (ac). I also have a clock, but it is a wind-up model. Since my only ac loads right now are lights, I may buy a DC light instead of buying an inverter to change DC to ac current. I've seen DC compact fluorescents and halogen lights ranging from 11 to 50 Watts.

Then I looked at how much power or watts each appliance draws. The figure is usually stamped on the back or bottom of the appliance and often is not exact, but gives a fair estimate. Next, I listed how long I use each during the week. I also thought about expanding in the future. Our area is really dusty, so a small car vacuum would be nice. I've been thinking about getting a computer someday, too. I multiplied the wattage drawn by each appliance by the hours used per day to get an idea of how much power I need. Now I have an idea of how much electricity I need — about 100 Watt-hours per day. In the future, I may need over 212 Watt-hours.

Energy Consumption

Appliances	Watts drawn	Hours /day	Watt-hrs /day
compact fluorescent light (120 vac)	18	0.2	4
compact fluorescent light (120 vac)	15	3.5	53
radio/cassette player (ac or DC)	22	2.0	44
Maximum watts	31	***Total***	100
Maximum amps	3		
Future Appliances			
vacuum (12 VDC)	96	0.1	10
computer (120 vac)	38	1.5	57
hard drive (120 vac)	30	1.5	45
Maximum watts	96	**Future Total**	212
Maximum amps	8		

How much Storage?

The capacity of a battery — how much it can store — is rated in Ampere-hours. To figure out how big of a battery bank I need, I converted Watt-hours to Ampere-hours. Since power (Watts) equals voltage (Volts) times current (Amperes), I divided the number of Watt-hours by the Volts. I will use a 12 Volt battery, so I divide 100 Watt-hours by 12 Volts to get 8.3 Amp-hours.

Another concern is the usable capacity of the battery. Lead-acid batteries should not be fully discharged — you can't regularly use the full capacity. A 40 Amp-hour lead-acid battery cannot deliver 40 Amp-hours. If the battery is a deep-cycle battery (designed for deeper or fuller discharges), one should never use more than 80% of the capacity. For car batteries, only 20% of the capacity should be used — any more will decrease the life of the battery. I'll use a car battery a friend gave me for now, and maybe get a deep cycle or alkaline battery in the future. So I divided 8.3 Amp-hours by 30% to get 27.7 Amp-hours. I need a battery rated at least 27.7 Amp-hours; the car battery is rated 40 Amp-hours.

But what if the sun doesn't shine? We have stretches of cloudy days, about three in a row on average. Since I want to be able to turn on my lights during this period, I want to have a battery capacity of at least three days: 27.7 Amp-hours per day x 3 days = 83.3 Amp-hours. I don't have this capacity right now, but will make do with what I have. I will just watch my use on cloudy days until I get a different battery.

Figuring Energy Storage

Needs	Watt-hrs /day	Amp-hrs /day	Derating Factor		Rainy Days	Storage needed
current	100	8.3	car	30%	3	83 Amp-hrs
future	212	17.7	dp cycle	80%	3	66 Amp-hrs

Batteries are rated in Ampere-hours at certain charge/ discharge rates. For example, a battery may be rated 40 Amp-hours at a C/10 rate. A C/10 rate is the rate of charge or discharge. The rate of charge (in Amperes) is equal to the rated capacity of the battery (in Ampere-hours) divided by the cycle time (time to totally charge or discharge the battery in hours). In this case, C/10 equals 40 Amp-hours divided by 10 hours, or 4 Amps. If you discharge a battery at a higher amperage than its rating, you won't get the full capacity of the battery. If I plug in a load that draws more than 4 Amps, I would deplete the battery faster. If the load is only on for a few minutes, no big deal. I looked at my consumption chart to see how much current each appliance draws for how long. (Watts divided by Volts equals Amperes.) Currently, the maximum amps drawn is three Amps. The vacuum uses 8 Amps — a C/5 rate — but only for a few minutes. A C/10 rate would work for my current and future loads. The car battery can take a high discharge rate for a short time, so no problem there!

Choosing a panel

Next I wanted to buy a photovoltaic module. But which one? There are so many brands and sizes! I decided to buy a new panel; I want this to be a portable system, so greater power per size is a factor. Another factor is voltage. I may use Nickel-Cadmium or Nickel-Iron batteries someday; these alkaline batteries may be fully discharged. Generally, these batteries get up past 16 Volts under charge; lead acid batteries generally do not get past 15 Volts. Some voltage will be lost through wiring and a regulator (to prevent the PV from overcharging the battery), and also due to heat. We can get five months of 90° F weather here, and heat degrades the voltage output of most PVs (about 15–25% for every 25°C above 25°C (77°F)). Modules heat up to 50°C on a sunny day. I need a panel that has a high enough rated voltage to deliver a respectable current to fill nicad batteries. With a panel rated at 17 Volts, 15 Volts may reach the battery. Crystalline PV modules are made up of many cells wired in series; each cell produces about 0.5 Volts. So I need a module with at least 36 cells (36 x 0.5 V = 18 V). Modules with 33 cells are called self-regulating for a reason — the 13 Volts or so that reaches the battery cannot overcharge lead acid batteries and is not enough to fully charge nicads. Heat does not seem to affect amorphous silicone PVs, but currently these are more expensive per watt. Yes, another factor is price. I was willing to pay for a new module, but wanted the most watt per dollar!

I looked at the specifications of a few modules. Time for a lesson in alphabet soup! This is another area that has always confused me. I flipped through *Home Power* #24 to the article where Richard and Bob-O tested different photovoltaic modules. Let's see, I_{sc} is the short circuit current. If I directly connect the positive terminal of the module to the negative terminal, I create a short circuit pathway for the electrons set into motion when sun hits the panel. There is no load and very little voltage. Next is V_{oc}, the open circuit voltage. With full sun on my panel, this is the voltage difference from the positive to the negative terminal. No current is flowing. The panel's maximum power is labled P_{max}. The voltage (V_{pmax}) and current (I_{pmax}) at maximum power are also listed. The part of the "soup" important to me was P_{max} (maximum power), V_{pmax}, and I_{pmax}.

The final decision was fairly arbitrary. I called up my local dealer, Bob-O, and was told he dealt primarily in Solarex modules. Since the Solarex modules have 36 cells, produce 17.1 Volts at peak power, and were a fair price per watt, I opted for the Solarex MSX60 photovoltaic module. I decided to buy the 60 Watt panel instead of the 50 Watt, because I wanted plenty of power for future expansion. Maybe I'll run my toaster oven in my trailer....

The specifications for my particular module are I_{sc} = 3.86 Amps, V_{oc} = 21.4 Volts, P_{max} = 61 Watts, V_{pmax}= 17.2 Volts, and I_{pmax} = 3.55 Amps, rated at 1000 Watts-meter^2 (called solar insolation) at 25°C. Solarex provides real figures at 49°C and 800 Watts-meter^2 to account for the loss in power due to heat. For my panel, at 49°C, maximum power (P_{max}) drops to 44.4 Watts and the current at max power (I_{pmax}) is 2.91 Amps — voltage drops to 15.3 Volts!

The Frame

I had my panel! The next step was to find a place for it and mount it. I found a fairly clear place about 20 feet from the trailer. Using the Solar Pathfinder, a device that shows the sun's path across a particular spot over the course of the year, I found that my site will get 4.5 hours of sun in the winter and about 8 hours in the summer. The hours in a day are not equal in the eyes of PV's; photovoltaics produce the most power when perpendicular to the sun. My panel faces south on a stationary mount and will not track the east to west path of the sun. When looking for a site for the panel, the two hours just before and after solar noon are the most important. The 60 Watt panel will deliver the energy I need. In the winter, my panel will produce about 3.5 Amps times 4.5 hours of sun per day which equals 16 Amp-hours, or 189 Watt-hours. In the summertime, my panel will only produce 2.9 Amps due to heat but for 8 hours — 23.2 Amp-hours or 278 Watts. Great! I'll have plenty of power.

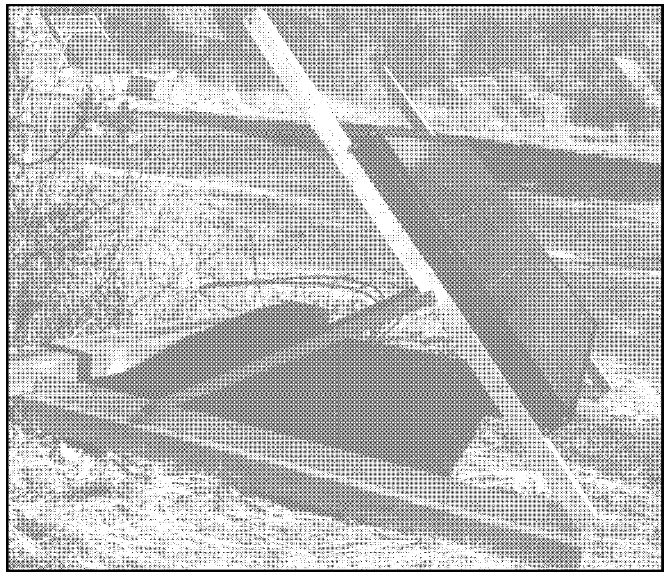
Energy Production

My Panel's Power	Amps	Hours /day	Amp-hrs /day	Watt-hrs /day
Winter time	3.5	4.5	16	189
Summer time	2.9	8.0	23	278.4

At first I looked at some perforated angle iron rack to mount the panel, but found out that we had some Echo Lite PV racks. I understand this company is out of business, but the racks work great! I had to modify the rack to fit the Solarex module (the module is about 20 inches by 44 inches long); I drilled two extra holes in the two-module rack holder. I screwed the bottom of the rack into two 3 foot long 2 by 4s, and that was it.

Shall I compare Thee to a Nose...

Photovoltaic modules perform best when perpendicular to the sun, just like your nose gets burnt from the sun before your arms or legs. Your nose is at an angle to catch more of the sun's rays. Unlike your nose, you can adjust your panels throughout the year to follow the sun's elevation in the sky: low in the winter and high in the summer. I have the panel set at 45° from horizontal for fall sun, but the rack is adjustable to three more angles: 60° for winter sun, 30° for summer sun, and 0° folds up for easier carrying.



Above: The mounted panel is set at a 45° angle. Note the extra holes to change the angle for winter and summer.

Photo by Therese Peffer

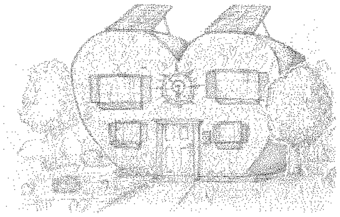
Next Time

Whew! In planning a system, I can see why using efficient appliances and shutting that light off when not in use is so important. I feel I've done and learned a lot, but I'm not finished yet! The next step is wiring, and building a homebrew regulator, which I'll write about next time.

Access

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

Home & Heart



Kathleen Jarschke-Schultze

Mainstream America has come to expect and depend on electrical appliances in the home and the kitchen. If it makes housework faster or easier, I am all for it. But what is the trade off in power usage? Self cleaning ovens and frostfree refrigerators are not efficient fuel-wise. Is saving time, and not power, the most important consideration? Not in the RE lifestyle!

Bicycle Grinder

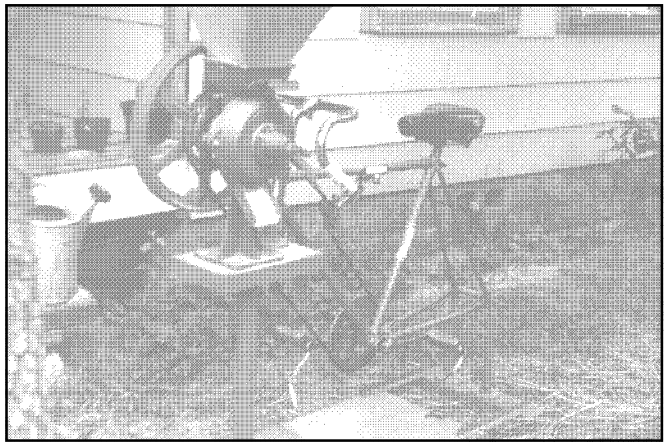
Bruce Johnson and Barbara Hagen of Spencer, OK have been using a bicycle powered grinder for 12 years. It sits on their front porch and gets frequent use. Bruce chose a a C.S. Bell #60 mill because of its sturdy construction, with a 1 inch diameter shaft and bearings. He bolted some bicycle sprockets to a large iron wheel which is attached to the shaft. This acts as a fly wheel. The mill is attached to a pedestal on a platform.

He removed the fork from an old bicycle and then attached the front of the bicycle to the base of the mill, using a short piece of pipe and a flange. The rear wheel of the bike is replaced by a stand. A lengthened chain from a 10 speed bicycle couples the pedals to the mill. An old derailleur is used on the slack side of the chain as a tensioner. The chain can be moved by hand to different sprockets for different drive ratios. They use the mill mainly for grinding whole wheat flour. A ratio of one to one works best. If it was a mill with smaller burrs you would probably want to gear it up some.

Flour to Bread

After the wheat is ground to flour, Barbara and Bruce use a hand crank dough mixer. It looks like a two gallon bucket with a dough hook attached to the crank. A five dollar flea market special, the mixer is young enough to have a nylon bearing. All of the ingredients go directly into the bucket. They usually make two loaves at a time. It takes about 30 minutes from when the wheat first goes into the mill until the dough is ready to rise.

Martin Holladay, of Sheffield, Vermont wrote to tell me, “The best book that deals with your question is Pedal Power edited by James C. McCullagh, and published by Rodale Press in 1977.” He also sent me excerpts of the book. It has a comprehensive set of instructions on building an Energy Cycle foot powered generator. Complete with parts lists and exploded views (I love those) and pictures, the Energy Cycle is designed to be adapted to a builder’s recycled materials. When assembled the foot generator can be adapted to almost any machine with cogs or wheels.



Above: a bike powered grinder.

Food Processor

Before HP #31 was even back from the printers, I received a hand crank food processor to test. Bob and Golda Maynard, of Energy Outfitters, saw a Kitchenmate™ manual rotary food processor at their local county fair. They were so impressed that they bought one. Now they sell them.

The Kitchenmate™ actually performs three functions. It is a rotary chopper, a rotary beater, and a salad spinner. The main bowl is only slightly smaller than my electric processor’s. I have used the beater to make salad dressings and a garlic mayonnaise or aioli. There is a well in the lid to pour your oil into so that it dribbles into the mixture slowly, freeing your hands for cranking the beater. It works very well. For homemade salsa or chopping onions (or garlic, or shallots) it works great. You have to coarsely chop the veggies first, but I have to do that with my electric model too. The salad spinner option is really kind of small for a family sized salad, but is perfect for washing and spin drying fresh herbs.

The unit is made of sturdy impact resistant plastic. It washes up very easily and doesn’t take up much space. Since the top locks on to the bowl, it is easy to handle without spilling or a lot of unnecessary movement. It has been worth the $19.95 price to me.

Lehman’s

Several readers have called or written to give me the access on a company called Lehman’s Hardware.

Apparently they have a whole catalog of non-electric appliances and tools, including a selection of mills and bread dough mixers. I am told they supply the Amish communities with products which fit into their simple lifestyle. I have sent for the catalog but have not received it yet. Again readers have assured me that Lehman's has always been a good company to deal with. I am eager to get their literature and see what they've got that I need (or want).

Access

Author: Kathleen Jarschke-Schultze, c/o Home Power Magazine, POB 520, Ashland, OR 97520 • 916-475-3401

Bruce Johnson & Barbara Hagen, 7605 N. Post Rd., Spencer, OK 73084 • 405-771-3551

Bob & Golda Maynard, Energy Outfitters, POB 1888, Cave Junction, OR 97523 • 503-592-6903

Lehman's Hardware, POB 41, 4779 Kidron Rd., Kidron, OH 44636 • 216-857-5441

HAPPENINGS

NATIONAL

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

Renewable Energies/Conservation Directory will be a listing of folks who have implemented conservation and renewables in their homes, and are willing to share their stories with others and at the same time help answer individual questions. Categories: 1) USERS: those employing a particular technology; 2) Providers: businesses who deal in renewables/conservation. Providers will be charged $25 to defray the cost of the directory; 3) Networkers: users or aspiring users interested in getting together to knock a few ideas around; 4) Homegrowns: those who are using a renewable system that they have built from scratch; 5) Owner-installed: those who purchased a system but installed it themselves; 6) Educators: those who know enough about a topic that they are willing to share their knowledge in a lecture, slide presentation, or forum with school or community groups (this is a most needed category!). If you're interested, send your name and address (phone optional) and category (s) to Julie Weier, Midwest Renewable Energy Assoc., POB 249, 116 Cross St., Amherst, WI 54406 • 715-824-5166

Elfin Permaculture is holding a number of workshops ranging from one day to three weeks in locations around the U.S. and Canada. Contact Cynthia Hemenway, 7781 Lenox Ave., Jacksonville, FL 32221

Audubon Solar Brigade If you pay an electric bill every month, let them know you'd like to see more utility solar power. The National Audubon Society's (NAS) Solar Brigade is an effort to coordinate a million people nationwide to demand 10% solar in ten years. Send a SASE to the NAS, 950 Third Ave, Dept. AB, New York, NY 10022 or call 212-759-6354 for more information, or to become a Solar Brigade leader. A roving video/slide show and free Audubon Technical Guide on energy efficiency are available by calling 212-546-9195.

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..Examples of free literature from CAIERS most recent mailing to us include "Hot Water Energy Conservation" and "Automatic and Programmable Thermostats". For more information contact CAREIRS, POB 8900, Silver Springs, MD 20907, or call 800-523-2929

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

CALIFORNIA

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

Now Forming—groups Of Alternative Energy Users/builders/homesteaders in Northern California to meet together to support each other, share information and skills, visit & help each others' projects, have presentations and hands-on workshops, and whatever. Call or write Patricia at Redwood Alliance, PO Box 293, Arcata, CA 95521 707-822-7884

COLORADO

SOLAR HOME WORKSHOPS will be held at the Solar Technology Institute (STI). These workshops are for owner builders and persons seeking careers as solar professionals. See ad on page 93. For a detailed description of SOLAR HOME PROGRAM WORKSHOPS, costs and scholarship information, write STI, POB 1115, Carbondale, CO 81623-1115 • 303-963-0715

DISTRICT OF COLUMBIA

SOLAR EMERGING: THE REALITY - April 22-28th, 1993, Washington DC. Three major solar energy conferences will be held jointly—The American Solar Energy Society (ASES) Solar 93 Conference, the SOLTECH 93 Conference, organized by the Solar Energy Industries Association (SEIA), and the American Society of Mechanical Engineers (ASME) International Solar Energy Conference. For more information, contact American Solar Energy Society, 2400 Central Ave G-1, Boulder, CO 80301 phone 303-443-3130, fax 303-443-3212; Solar Energy Industries Association, 777 N Capitol St NE Ste 805, Washington DC 20002, phone 202-408-0660, fax 202-408-8536; American Society of Mechanical Engineers, 345 E 47th St, New York, NY 10017, phone 212-705-7054, fax 212-705-7674.

FLORIDA

FSEC Photovoltaic System Design Workshop, Dec. 9-11, 1992 at the Florida Solar Energy Center (FSEC), 300 State Road 401, Cape Canaveral, FL 32920. The registration fee is $300; target audience; solar industry, engineers, government agency reps and interested individuals. Call JoAnn Stirling at 407-783-0300, ext. 116.

The Florida House Foundation is building two model homes incorporating passive solar architecture, energy and water efficient appliances, solar electricity and hot water, and edible landscaping. Contact The Florida House Foundation, POB 21583, Sarasota, FL 34276 • 813-924-6833

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

MASSACHUSETTS

NESEA-Over 50 cars, powered by the sun, will race from Boston, MA through New Hampshire, to Burlington, VT, May 23-29 1993, in the fifth annual American Tour de Sol, the solar and electric car championship. There will be free educational displays of these innovative non-polluting cars along the route. Contact: NE Sustainable Energy Assoc., 23 Ames St., Greenfield, MA 01301, (413) 774-6051

MICHIGAN

NORTHWEST ENERGY ALTERNATIVES of Northern Michigan is offering a workshop on solar powered homes. The workshop will focus on solar installations with opportunities for participants to actually construct photovoltaic systems, from panels to wire to batteries. The workshop will look at a variety of applications for solar technology and no one will leave before they have learned about system sizing and design. Each participant will size their dream or real home. At the end of the workshop tours of alternative homes will be offered. The program will stay focused on solar basics. This is the type of workshop for people who don't know an amp from a watt. The workshop will take place on December 5th in Travis City Michigan. For more information about this workshop please contact Maggie at 616-256-9262 or John at 616-256-8868.

NEVADA

Solar Electric Classes in Nevada taught at remote solar home site. Maximum of four students for more personal attention. Two day class choice on 4th weekend of Feb., March, & April or 3rd weekend in May 1993. Classes on weekdays & other 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

NORTH CAROLINA

PHOTOVOLTAIC DESIGN & INSTALLATION - the Solar Technology Institute's (STI) popular 2 week hands-on workshop (see ad in this issue) will be facilitated by GO SOLAR ENTERPRISES. Beginning March 8, participants will learn how-to specify and install PV systems. The workshop cost is $400 per week and is for those who want practical non-biased information from professional educators. No prior knowledge of solar or electricity is required. Everyone welcome! For more details write Joe

Flake at GO SOLAR ENTERPRISES, P O Box 422, Fairfield, NC 28137 or call 704-463-1405.

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).

The Homebuilt Dynamo

by Alfred T. Forbes

reviewed by Mark Newell

The Homebuilt Dynamo book presents complete details for what I consider to be the ultimate in homebrewed power projects—building my own low rpm (revolution per minute) generator. A low rpm generator is ideal for simple and efficient generation of electricity from sources that often are in the 100 to 800 rpm range such as wind, hydro or, as Alfred and Julia Forbes do for their daily electric needs, a bicycle. As Alfred says himself, “The Homebuilt Dynamo is not another ‘do-it-yourself’ book, it is simply a careful diary with photographs, detailed working drawings, and text of how I built myself a low speed, low voltage, three-phase permanent magnet alternator with internal rectifier diodes which makes it, in effect, a direct current generator. To avoid a long winded description, I have substituted the word ‘dynamo’.”

Alfred and his wife Julia were “New Zealand back to the landers” in 1967. They lived for three years with kerosene and oil lamps before tiring of smell and danger. The idea for the book was born because of the high cost of bringing power to their door. Deciding to make their own, Alfred was unable to find any books on building small dynamos and decided to document the learning and building process as he built his own.

The result is a 182 page journal filled with over 300 photographs, charts, and drawings detailing the construction of a 1 kiloWatt (28 Amps and 36 Volts DC) generator at 740 rpm. In building this generator, no casting, welding, or soldering is required as well as no previous knowledge of electrical machines. Construction requires nothing but hand tools.

It’s not, however, a project for the first time builder; if you have problems making a box out of wood and getting the corner to match up then I recommend practicing this first. Precision and patience are required in the cutting of materials and winding the coils. For the mechanically adept there is plenty of information, a source list for materials, and patient explanations of the underlying physics that make it a challenging, educational and rewarding project.

Alfred Forbes includes descriptions of how he built some of his tools and construction equipment—a precision-cutting diamond saw for cutting magnets to size, a high power magnetizer to magnetize ceramic magnets, a small precision sheet-metal, wire winding jigs, and several test instruments. The appendix contains details of tests made on the Homebuilt Dynamo and data for scaling up the dynamo to obtain large increases in output and efficiency. The only drawback I can find is the $65 price (including shipping from New Zealand) attached to this plethora of practical knowledge. Overall it is a great lesson of the art of self sufficiency—the patience, resourcefulness and determination needed. This is what home power is all about!

Access

The Homebuilt Dynamo, Alfred T. Forbes, ISBN 0 9597749 0 4 1987; 182pp. $50 ($65 postpaid) from Todd-Forbes Publishing, P.O. Box 3919, Auckland, New Zealand.

Reviewed by: Mark Newell, c/o Home Power, POB 520, Ashland, OR 97520 • 916-475-3179

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the Wizard Speaks…

Pyramids, Crystals, & Other Space-Distorting Matrices

With all the recent interest in pyramid power and crystals it is necessary to ask if there is any basis for their apparent effects. These effects are thought to be due to their geometric arrangement. Are there any scientifically recognized effects which depend on geometric arrangements? Two examples are superconductors and permanent magnets. In both cases the geometric arrangement of atoms and molecules is a significant factor. This implies that some of the phenomena of pyramids and crystals may be rationally explainable.

One set of ideas feasible for explaining these phenomena seems to be that of spacial curvature. The micro and macro distributions of mass and charge inherent in pyramidal and crystalline structures affect the spacial curvature in and around such structures. This effect may alter the electronic and electromagnetic paths in these areas enough to produce the perceived phenomena. The fact that these phenomena are often affected by the structure's orientation to the Earth's magnetic field lends credence to this idea.

Space-distorting matrices may be helpful in creating THE MAGIC BOX. The Magic Box would produce continuous and virtually unlimited power. It might do this via a dynamic space-distorting matrix whose topological properties twist space in just the right dynamic manner to produce a continuous source of power.

The most famous space-distorting matrix is of course the black hole. The brain is also a potent space-distorting organic crystal matrix. The geometric topologies of the brain tend to condense and focus five-dimensional space/time realities into our normal space/time continuum. It is quite possible that evolution is aiming at a state of technology without tools. Our bodies may eventually contain all the matrices necessary for survival and existence under any and all conditions. Shades of Childhood's End.

Change in the Air

Eric Westerhoff

There's a change in the air
You can see it everywhere
Chicago down to Houston
Boston to Bellaire

The answer's coming to a long lived prayer
Just how much can Gaia bear
Pollution once fast on the rise
Is about to meet its demise
In a world of people who care

Just wait and see what's gonna come
A little work has got to be done
Yesterday's Gomorrah is tomorrow's paradise
It'll be there because we opened our eyes
The people of the Earth are soon to become one

Air quality, rain forest and environmental groups
Our special kind of fighting troops
Have started changing the country's mood
Now we've got to consider the world's attitude
With all our resources do we need more proof

It isn't that hard when you know what to do
It's basically up to me and you
We'll need strong leadership and a dedicated following
The big rock moves easier once it starts rolling
If we work hard we can pull it through

It's gonna take time to mend our ways
So let's start today
Cultural habits are not going to die overnight
So let's take it slow to be sure it's done right
You'll have to do your part, what do you say

Clean fresh flowing water and aqua-blue sky
Recycled goods are right to live by
Teach the children that they are a link
Show them and society, we gotta think
And we can't let anything hamper our tries.

Eric Westerhoff
POB 3341
Breckenridge, CO 80424

Letters to Home Power

Selected & Entered by
Kathleen Jarschke-Schultze

A new reader speaks

Dear Home Power Crew: Enclosed is my subscription for your WONDERFUL publication. I "found" Home Power issue #30 in my local health foods store- But, let me begin at the beginning.

At the tender age of 15, I discovered the only major magazine dedicated to helping people be self-sufficient and to get "back to the land" (TMEN). Ever since, I have dreamed of living my life in the country, away from all the "gotta have It" of the big city. But, so far, my life hasn't turned out that way.

I married a man who works in the long-distance telecommunications industry. His jobs have kept us in the big city. But he makes a good salary, so I have been able to stay home for a good portion of the last eight years to raise our two children.

In early 1991, my dream started to gain some material reality. We purchased 21 acres of "unimproved" land in northwest Arkansas. This land is beautiful, with towering southern pines, plenty of nut bearing trees, two springs on the upper half (but no well), lots of wild game, and one lonely little power line to support an 18 foot trailer the owners had there for whenever they went hunting. The man we bought the land from told us there had been no one living on it for at least 30 years. It was just about perfect.

Shortly after purchasing our dream property, we heard about Earthships. So I ordered all the info I could and started dreaming big time. That lead me to Real Goods Trading Co. and their wonderful catalogs. The first time I looked at their Sourcebook, I was amazed at all the alternative energy products compiled into one source!

Now, I'm really not a big amps and volts kind of person. just recently got my registration for Massage Therapy. That's about as untechnical as you can get. But when I was looking at all the inverters and PV modules and batteries and so on, my palms started sweating and my heart beat faster. This was like love at first sight!

Then I picked up your publication. I read it from cover to cover, including the ads. My mind was churning out ideas about the application of alternative energy so fast, I felt like I might blow a cranial ventricle. I noticed there were no ads for resellers in Texas. I also noticed there are schools for alternative energy, but none in Texas. My husband called Jordan College in Michigan and asked if they have any correspondence courses. They don't and neither does anybody else, as far as I know. So, we will buy a couple of books about alternative energy and start learning on our own. We will teach ourselves how to build a system. That's much cheaper than attending a school, but we will miss out on the invaluable experience and knowledge of an instructor.

I am extremely excited about the growing alternative energy field, and its many, much needed, applications. It is my feeling that if the Clinton/Gore ticket is elected, then the alternative energy industry will grow much faster and easier than if either of the other "major" candidates are elected. There will be much more demand for solar and wind power, and my husband and I will help supply that demand!

We would like to talk to some of the manufacturers of photovoltaic modules to see what kind of a deal we can get on a large volume order. We are researching one of those brain blowing ideas, and want to have all the conversion data compiled to make a good presentation to the industry we are targeting. We will present them with the long-range money savings from using solar power and ask for a "test run" of a few sites and if they are pleased, then we can do mass installation.

Keep up the good work, and if you can help us out any by way of education, please let us know. Also, if any of your readers would like to communicate with us, we would welcome any input they are willing to share. Thanks, Jo Jo Doyle, 2905 Cotton Gum Rd., Garland, TX 75044 • 214-530-6167

Welcome, Jo Jo. You're on the right track for info. If you want the fast course, try Solar Technology Institute. Now is a very good time to get into renewable energy as a business. The technology is mature and just about to become commonplace. — Richard

AC Power Fields

Dear Home Power writers and readers; In a book on telephony I've seen a diagram of a "repeating coil" which provides DC isolation of a phone line and switches an isolated battery to provide power to the isolated line. Does anyone know where I could find one of these, or how I could build one?

I live beyond the end of the phone and power lines, so I have a 2 Watt UHF radio link which provides relatively normal phone service for my home and business, and a solar photovoltaic and battery system for power. Like the phone company, this phone link provides a "battery" voltage, which is negative with respect to earth ground, to run the phones in my house.

I have a Panasonic KX-Tl470 answering machine which runs fine from a 12V battery and works with the phone link except for one problem: It internally connects its power supply ground to the negative side of the phone line (the phone link is sophisticated enough to not be damaged by this connection, but it won't operate with the phone line effectively shorted.) Of course in normal AC power operation the Panasonic is isolated from earth by its wall transformer, and I could run it from an inverter, but one of the reasons my family and I live where we do is to avoid full-time exposure to AC power fields. We keep the inverter off as much as possible.

This question gets even harder when I realize how badly I need a fax machine - another temptation to run an inverter full time, as I have not seen any 12V fax machines. Has anyone hacked a fax machine to run on DC power, and did they find phone line ground problems?

Powering the answering machine from its own isolated battery works, but doing that properly enough to make it sufficiently reliable looks like it would cost more than the machine did. There used to be small isolated DC-to-DC converter modules (I only need 30 mA), but I can't find any now that I need one. A simple circuit to isolate the DC power supply might even be preferable to isolating the phone line. Does anyone know the best solution to this problem?

While I'm on the subject, I'm surprised there has not been more discussion in HP of the AC power field question. The big news in the last issue about the PowerStar inverters which provide full voltage full time points to a future where even remote, off-grid homes are enveloped in AC power fields full time. I don't know of any research, but I personally feel the radiation from square or modified sine wave inverter power is likely to be more dangerous than that from smooth sinewave grid power. Even though my inverter powers down to a low voltage test pulse when it sees no load, I'm more comfortable with it totally off. Does anyone out there have real information on the dangers of inverter power fields?

Some of the people beyond my place want to bring overhead grid power down the road, which loops around my home. My position has been that I would only give right-of-way to underground lines, partly for aesthetic reasons but mainly to avoid AC power fields. The neighbors are now insisting that earth does not provide shielding at ELF frequencies and that underground AC lines are as bad as overhead lines. That does not sound right to me, but again I have no real data. Does anyone?

Finally, a note in response to Carole Silon's struggle to get a mortgage with home power. I went loan hunting when I planned my PV powered home in 1984, and was refused by all the supposedly open, more alternative institutions. Believe it or not, I ended up with a completely normal mortgage from Bank of America! It turned out that only a bank big enough to carry their own loans full term could consider financing off-grid homes. Everyone else was dependent on being able to unload their loans on Fannie Mae or another government backed institution.

Unless there has been a change since 1984, it is this "secondary market" which enforces the requirement for grid connection. So while I agree our top priority is to get our home power systems running, we must also get busy changing the rules of the government bureaucracy before home power can be affordable to the non-do-it-yourselfer.

Unfortunately for people like Carole, when you go into a place like Bank of America and ask for a loan, it is up to you to convince the loan officer, who has probably never heard of home power, that what you propose to do is sound. Their primary concern is that your home will be readily resalable to an average person if you default on the loan. To that end, how many of our power systems would be operable by a stranger addicted to grid power.? How many are documented well enough to be efficiently repaired by even a skilled home power installer? We have a ways to go before we can expect bank financing of off-grid homes to become commonplace. Loren Amelang, Box 24, Philo, CA 95466 • 707-895-3837

Loren; It looks to me like a flying capacitor chip would give you the voltage isolation you need for your answering machine. If you need voltage inversion, it will do that too. The 7662 CMOS IC by Intersil takes 15 Volts input and returns -13 Volts at 30 mA. It will work for higher currents, up to 90 mA, but the output voltage decreases in magnitude. For higher currents, the LT1054 by LTC can give a regulated output up to 100 mA.

We have no hard info in 12 Volt FAXs. How about it readers? We can recommend a 120 vac FAX/Copier that uses plain paper, consumes less than 50 watts (about 4 watts on standby), and likes inverters —the Hewlett Packard FAX-310.

If anyone knows about AC electromagnetic fields in *buried lines, it is John Mills: 10475 Vineland Rd, Ben Lomond, CA 95005. Consider that the magnetic portion of the field is directly proportional to current. Since the PowerStar is producing very little to no current when idling, the field is correspondingly very low to nil. Burying the conductors in the earth will not greatly reduce the low frequency magnetic fields surrounding a 120 vac conductor.*

The issue of bank loans and reselling of renewable energy powered homes will become more and more important as this way of life grows. People I've talked to say that there isn't much of a history so far of reselling RE homes because the folks who build these systems are usually in for the long haul. It would be interesting to have an article by a sympathetic real estate or bank person on this subject.

Renewable energy systems are becoming more automated all the time. See for example the Tierradentro system on page 99 of this issue. Documentation of a system is still and always will be critical. If you roll yer own, then be sure to record what you have done. If you design and install for others, then the system schematic is part of the deal, don't leave it out! — Chris and Richard

Loan Block

Dear Home Power Folks; This past year we built a new house on our homestead. Our old one was small, drafty, and all salvaged materials. For SEVEN years we got our electricity exclusively from solar power (starting small, adding panels, batteries, and inverter). For our new house we planned on only adding four panels. The shock came when NO bank in the county would loan us the money to build our house (even though our twenty acres is paid off) unless we hooked up to the power grid. Even the biggest bank told us "solar power has not been shown to be economically feasible". What? We had never even paid an electric bill (our neighbors average over $100 a month). Eventually we tired of arguing and, needing the loan, we agreed to hook up. Our new dome home has two power systems - 12 volt solar for lights, fans, and water pump, grid power for power saws, TV, some lights (we use $6 a month worth of "their" electricity). We use LP gas for our Sabir refrigerator, Aquastar on-demand water heater, and stove.

The sadness we felt having to compromise our energy independence is now balanced by the joy of living in a new house. But, it's too bad that the majority of those in power still think of solar energy as something in the future, not possible today. I know banks are only thinking of resale and it would be harder for them to sell a defaulted house that wasn't conventional. But most people we've talked to would be happy to have a house with no electric bill and no blackouts during a storm. Oh, well - we'll keep hoping and educating. And you keep up your wonderful and informative magazine. We do appreciate it. Larry Behnke, POB 1311, High Springs, FL 32643

Hi Larry, You're not the only one who has had problems with financing a RE home. See the letter from.Loren Amelang in this issue. According to a local real-estate appraiser (who also owns a PV powered well pump), the problem is the "dinosaur" attitudes of the commercial banking institutions. It's a catch-22. Until the banks have data on a large number of successful loans to RE homes, they won't risk it, which means they won't get the data in the first place, etc. His suggestion is to find a private mortgage banker and convince him to carry your paper. This makes some sense. You can go one-on-one with the person who actually has the dough rather than some junior loan officer who has to follow strict bank policy. The downside is that you may have to pay a higher interest rate since you can't "shop" your loan around as well. -Bob-O

Batt Pairing

Dear Richard: I was doing some thinking (dangerous!) regarding the internal resistance of a battery bank made of 6V batteries connected in a series/parallel combination, to get the 12V and the proper current rating.

In doing so, I considered each battery to be an ideal one (no internal resistance) in series with a resistor Ri, which will take care of the fact that any battery has, indeed, an internal resistance.

Assuming that all the internal resistances have the same value, for each "pair" of 6V batteries we will have a 2Ri resistor. This value will be in parallel with the next pair, and so on.

If the bank consists of one 6V-pair, the equivalent Ri is a value equal to 2Ri, but if the bank is made up of several "pairs" follows:

2	6V-pair	Ri
3	6v-pair	2/3 Ri
4	6V-pair	1/2 Ri
5	6V-pair	0.4 Ri and so on.

Am I wrong? If I am right, a bad 6V battery (high Ri) will have a minor effect when it is one of a large bank, as the equivalent parallel resistance is always lower than the lowest value being paralleled. Sincerely yours, Hector L. Gasquet, 10909 Bill Collins Ct, El Paso, TX 79935

You're right Hector. Paralleling batteries — even batteries *with high internal resistance — can only decrease the resistance of the pack. This is how it looks from a technical, electrical standpoint. But there are some other things to think about before you mix bad batteries with good ones. Bad batteries have high self-discharge rates. Hooked in parallel with good batteries, they'll discharge the good batteries as well. Also bad batteries won't contribute much to the performance of the pack. When the pack is under charge, the good batteries can accept current at a lower voltage, so the voltage doesn't raise high enough to charge the bad batteries effectively. When discharging, the same resistance keeps the bad cells from contributing much current. All things considered, in many cases you're better off with separate packs. — Chris and Richard*

Nicad Charging

Hi Richard; We have met a couple of times, once down in the Bay Area and once when you gave a weekend solar seminar at Lawrence Schechter's residence at Alcyone in Hornbrook. I have some specific questions about the Trace inverter and nicad batteries. I currently have a Trace 2012SB, a set of M-409 247 amp/hour batteries, 4 Arco ASI 16-2000 solar panels and Cruising Equipment's amp/hour gauge.

I have used this solar system as a portable source for power tools at a remote building site. The system has performed admirably, running not only saws, drills and other tools, but even a small compressor for the nail gun.

I have recently set up the system in my home to record amp/hour readings and perform other tests. We have several computer systems and a shop full of wood working tools that the system will eventually have to power.

I bought most of the system components based on the favorable reviews given them in Home Power. HP has been and continues to be my main guide to energy independence. Thank you for being there. The one problem I currently face, that I do not believe that you have ever covered to any degree within your reviews, is with the Trace inverter. My Trace inverter with the battery charger option is not fully charging nicad batteries since the top voltage limit is below 15 volts. You have mentioned in your articles that the Trace will shut itself down at a battery voltage about 15.5 Volts, but in the charging section of the review in HP #25, you never come out and mention that the standby charger cannot fully charge nicads. My experience has been that I cannot restore more than 160 amp/hours into my 247 amp/hour set. And this amount is only obtained when I have all the settings on the charger set to maximum. Again in your article about STI in HP #26 you mention that they installed a Trace 2012SB in the system with the ED-160 as if to infer that this is a good match of charger to batteries. You mentioned that this was an excellent charger to do the job. But is it?

Once I started testing my batteries, charging and discharging them at the set 8 hour rates, I discovered that I was not getting more than 2/3 of the charge restored. I have the charger plugged into the grid for recharging. I called the good folks at Western Battery, where I had bought them. They mentioned that Trace was working on the problem, but that the Trace could never fully charge nicads since they require a voltage up around 16.5 Volts. There only suggestion was to purchase the high voltage charger from Todd Engineering. This was the only charger that could fully charge nicads. Unfortunately, I am reluctant to buy a second battery charger and would like to get some more information before I do.

Is my experience that the Trace charger can only charge nicads to 2/3 their capacity the general rule? Or am I missing something here? If it is the norm, it would be good for you to mention that in HP so that prospective buyers of the Trace could be warned not to get the battery charger option at this time if they plan on using the inverter with nicads.

Do you know if Trace will come out with a modification to their charger that will make it work well with nicads? I would hate to lose my investment on the battery charger but at the same time I also want to be able to fully charge my batteries. If no changes are in store within the near future, I may have to pull the charger and put it up for sale to pay for the Todd Engineering one. Anyway, before I do anything, I thought I would write to you and see if you could give me any advice. I would appreciate any information you could shed that might help me decide what to do with this problem. At this point I don't really know if the problem is just my ignorance of the parts of the system or whether the system is just not a good match. Since it will eventually become my only source of power and I will become very dependent on it for my work, I would like to clear out all the bugs before installation. Again, thanks for all you, Karen and the rest of the HP crew have done. Sincerely, Frederic J. Hoefnagel, 595 Ragsdale Rd., Trail, OR 97541 • 503-878-3107

Trace chargers are not ideal for Nicads, Fred, but they do work. I called up Bob-O Schultze who wrote the Things that Work! article in question, and found that he uses the

Trace 2012SB's charger to charge his Nicads. He says there are two models of the 2012SB. The older model has DIP switches behind a plexiglas cover. The new model has blue potentiometers (dials) on the face. On the older 2012SB, set the second bank of DIP switches with #2,3,4, and 5 turned on to set the charging voltage at the maximum: 15.7 VDC. This is all explained in pages 7 and 8 of the manual. If you have the new model, you can charge Nicads with the Trace's equalizing charge function. Set the EQ V setting to 16.1 VDC, the max charge amps to around 60, and the timer hours to five. Set the float voltage to its maximum: 13.5 VDC. Don't hesitate to call up the Trace folks.

Your ARCO 16-2000 PV panels are also a terrible match for your Nicads. Their Vpmax at 25°C is 15.5 Volts. At 50°C it drops to a pitiful 13.04 Volts in our tests (HP#24). Hell, the open circuit voltage Voc at 50°C is only 16.76 VDC. These panels will barely trickle charge Nicads. You'd be better off switching them to a series/parallel configuration half way through charging. - Chris

Hello, Frederic. Chris has covered your situation technically. There is one other solution to your PV /battery mismatch. Wire the modules in 24 Volt mode (i.e. series connect two modules). Then use an LCB to convert the extra voltage to current for the battery. — Richard

Cold Facts

Dear Richard, Karen and HP Crew; Would like to tell all of you a little story.

For over two years now, I've lived without a household refrigerator. During the preceding 6 years we lived with a series of ammonia absorption (gas) refrigerators. They were expensive to purchase and expensive to operate. While the manufacturers' specs say how little gas is used, as the machine ages the consumption of propane continually increases. I suspect this is due to the high operating pressures and the invariable leaks of the ammonia/hydrogen solution. Also, the flame burner inside the kitchen didn't make the insurance inspector very happy.

These 3 units all lasted about two years each. Then came the attempt to modify a 1.2 cubic ft. Coleman thermoelectric unit. It was super-insulated to about R-50 and kept in the coolest spot in the kitchen. A thermostat and additional muffin fan were added. The current draw at a warm 50° F chest temp. was 4 amps at about 50% duty cycle = 50 A hr/day. Since the nominal PV output is only 18 amp-hrs and in south west Michigan occluded skies, more like 10 amp-hrs, this type of small scale refrigeration also failed to perform.

Then came the third annual Midwest Renewable Energy Association energy fair, Brahmin Bless their Hearts. I met Dan Alway with his "Low-Keep" refrigerator display. After many questions to him on why I should use one, as compared to a Sun Frost or other units, I made the purchase of a 4 cubic ft., chest type, super-efficient refrigerator. We installed it in the kitchen in the middle of August. One of the nice features is the wood veneer counter top on the chest as it makes for a nice work area. The installed price of $795 sure helped too.

A 3-day test with a line chart recorder on a shunt and a VOM to average the compressor current (4.76 amps) on 30 minutes time, gave a rough calculation of 160 watt hours/day. The chest temp. remained below 40° F at the top of the chest, while two of the test days were in the mid-80's and very humid.

My battery capacity is about 300 amp-hrs (sorta small) of gel cells. Having the refrigerator for over a month now, the battery voltage has stayed around 12.50 - 12.80. Which is satisfactory for my system usage. It's nice to finally have my iced tea and sunlight too. Sincerely, Richard Orawiec, Steward, Oak Grove Sanctuary, RR1 Pullman, MI 49450 • 616-236-6179

Thanks for the info on the Low Keep frig, Richard. The power consumption you measured (160 watt hours daily) is just about 2/3 of what a single module produces on a sunny day. That's very efficient. — Richard

Reasonable Refrigerator

Greetings from Sunny Central Oregon, I want to let people know how easy it is to make a nice little 12 VDC.refrigerator from off the shelf parts. This unit does not compare to a Sunfrost in performance, but neither does it compare in cost.

Parts needed: Sanyo Cube refrigerator model# SR-4991W $84.99 to $109.99 at most discount stores. Danfoss compressor model BD-2 and controller model BD 102N3017 $185.00 to $240.00. Order from your local appliance repair shop or appliance parts wholesaler. 4 ea. 1 1/4 x 1/4 inch bolts, locknuts and flat washers.

Service needed: Take the parts to your local refrigerator repair shop. The repair person will need to drill new holes in the plate that holds the compressor. The existing thermostat works fine. Total labor should be two hours.

You now have a 1.7 cubic foot 12 VDC reefer for less than $400. The unit I built draws about 4 amps and runs about 10 to 15 minutes per hour. After adding extra insulation the run time dropped to about six minutes per hour.

If you have any questions, phone calls are welcome, no letters please, no time to write. Quintin D. Myers, 19344 Kiowa Rd., Bend, OR 97702 • 503-382-4633

Good work, Quintin, although I am in love with my Sun Frost RF-16, and would never part with it, you have certainly provided a low cost option. - Kathleen

At six minutes operating per hour (at 4 Amps) this frig consumes about 125 Watt-hours daily. — Richard

Light Intensifier

We live in Northern New Hampshire and rely on six Arco 55 panels and backup generator. Would like to see something on how to safely use reflector panels to boost output in winter when the sun is low and temperature is even lower. These panels are designed for full sun & heat of Arizona so some boost is needed at this location to get to that level in mid December. Would a temperature gauge or amp gauge be of more use in judging proper or 0/max boost? Would our cold North latitude be a better candidate for the light intensifier type panels than say Arizona? Possibly a variable set up for magnifying with feedback level control? Arthur E. Cook, RFD #1 Box 502 Tetu Rd, Stratford Hollow, NH 03590

Rock n Roll, Arthur! You bet, if your temps are low, then you can use mirrors or any reflector to boost PV current. Contact the fellows at Carrizo (800-776-6718), they have surplus reflectors for this purpose. Keep an eye on the temperature, and remove the reflectors if module temps rise above 75°C. — Richard

Hydro Hints

Dear Bob; As a micro-hydro power user of many years, I was interested in your article in issue #30 on the Model FT hydro unit. I wanted to point out a couple of things that might be of interest to you.

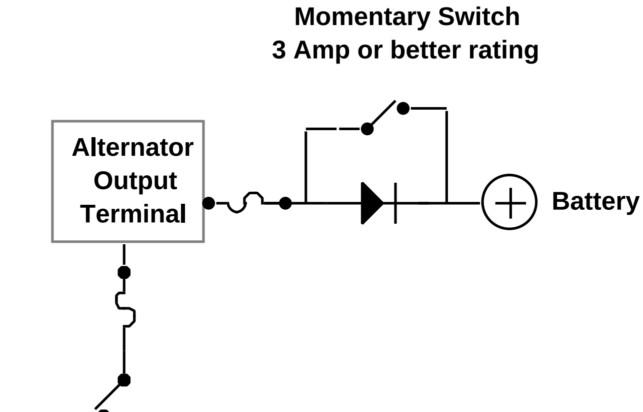
First, I don't think the diode in the diagram will prevent discharge of the battery pack when the wheel stops. As configured, it is forward biased all the time, even when the alternator stops generating power. In order to keep the battery from discharging. I think you need to put the diode between the battery and the alternator, with the anode connected to the battery. This way the diode becomes reverse biased if the voltage at the alternator terminal goes below battery voltage.

Second, you might want to point out to your readers that the rheostat is fine for determining the optimal field current, but once you know that you should put in fixed resistors. This is because after a year or so, depending on the conditions in the immediate vicinity of the rheostat, the sliding contact will corrode and cease making contact with the wire-wound resistor. This happened to me twice before I made the change.

After many years of living with my system (a Harris four nozzle), I have come to the conclusion that a voltage regulator is not necessary or even useful if you have a decent size battery pack. Of course, I am talking about lead acid batteries; I would not make this claim for nicads or other types (my battery bank is ten T-105 golf car batteries configured for 12 volts). But I find that a) if I am absent for extended periods of time, I simply turn off the water source (at the top of the pipe, by the way). and b) otherwise, my usage is pretty much balanced with the system's output (100 watts in my case), and the batteries just hum along fine day to day. In the rare event that my usage drops for a few days, the batteries seem to be able to take the slight overcharge without problems. I also like this because my batteries are almost always fully charged.

One more point, which doesn't get much air time with micro-hydro – the importance of a valve at the top of the pipe! Having the ability to conveniently shut off the water at the top is crucial in installations where freezing in winter can occur. 'Three of the four users in my area (Weed, California) lost their entire penstock during the hard freeze two winters ago. Mine was saved only by draining down the system prior to the freeze. If you do put a valve in at the top, you must also put a vent in just downstream from it. This is a "T" and short riser (the top should be taller than the top of the source water) which allows air into the pipe when the valve is shut. This is necessary in order to prevent the draining water from creating a vacuum behind it as it runs down the pipe, which can collapse the pipe. Sincerely, Ric Barline, 1420 Kahler Court, San Jose, CA 95132

Hi Ric, You're absolutely right about that diode. It's been one of those OOPSIEs that just won't go away. I reversed the text boxes on the schematic (see the correct version here) when I drew it and it slide right past the techo checkers. We actually discovered it before HP#30 was distributed, but too late to correct it. I wrote a correction for HP#31 which got stuffed into some cobwebby electronic folder somewhere and never made it into the issue. It was DEFINITELY going in this one and your letter is the perfect place. Thanks! I disagree with you about the fixed resistor AND the no-regulation plan. Obviously, you are in tune with your system and don't vary your usage much. Also, your water source must be very constant. Most systems aren't like that. It's more of the rule that people vary their charge rate with the seasons. During the winter, most folks have more water



to dedicate to their hydroplant and use more power due to the shorter days and staying inside during nasty weather. It's a whole lot easier to "peak" your alternator output after changing or shutting down nozzles with the rheostat than by changing out fixed resistors. The biggest problem that many hydro users have is overcharging. Eat your heart out, PVers! With a constant 24 hour, 365 day power source, a battery bank should be looked at as more of a "flywheel" than a sink. If your daily power usage closely resembles your daily hydro output, an alternator field regulator might work well. If you've got lots of extra power-especially during the winter runoff- a shunt regulator will let you throw the surplus at something useful, like a water heating element. Either system will let you keep your batts at a constant voltage level below the heavily gassing point (except if you decide to run a equalization charge). This will save on maintenance, messy batts, and will give longer battery life. Your top valve and "T" idea is GREAT! I'd certainly recommend for any system, both for freeze protection and ease of pipe repairs. Thanks for your inputs. - Bob-O

Rad Lights

Dear Home Power; Mr. Dave Lambert of Rainbow Power Company Ltd., N. S.W., Australia was kind enough to send along a report on ultra violet radiation emission from Tungsten Halogen desk lamps done by the Australian Radiation Laboratory. Their test results indicate that using BARE Tungsten Halogen bulbs for extended periods at desk lamp distance may expose the user's skin and eyes to potentially harmful levels of ultra violet radiation.

It is important to note that the Slyvania natural light halogen light bulb, and a number of others, have a glass enclosure around the halogen bulb which eliminates this problem. If you are using BARE tungsten halogen bulbs, a piece of window glass between you and it will reduce exposure by a factor of 300. Maintaining a four foot minimum distance between you and the bulb will also solve the problem.

My thanks to Mr. lambert and to the Australian Radiation Labs for sharing this information with us. Sincerely, Mr. John Mills, 10475 Vineland Rd., Ben Lomond, CA 95005

Grid Worker

Dear Home Power; First, I would like to take you up on your 'Winter Reading Special' as advertised in the Oct/Nov 1992 issue. The last six issues for $10.00!! You all get rid of something you don't need hanging around, I get something I will gladly let hang around for years.

Second, I am one of the bad guys who works for 'the Grid' here in Texas, and if any of your readers thinks you inflate or exaggerate the possibility of more brown outs and outright power outages in the future, let me say my 'insider' view supports your view 100%. The outages are coming, and while some will be slight, many will last for days at a time while the utility struggles to restore power in an overloaded system.

Third, although I live right in the middle of a suburb, and my view does not overlook a mountain, or stream or lake, I do still enjoy living here. (It is possible to enjoy living in a city, you just have to try a little harder). I think your magazine is really on the right track when it comes to giving the city slicker like me a push in the energy independent direction. Although it would be very difficult for me to produce all the power I need, you correctly stress that every watt saved or produced by my own means is one less 'the Grid' has to provide, or that I have to pay for. Every little bit really does count: A thousand people who consistently save 10 watts of power do more good than one person who saves thousands of watts.

Lastly, I want to tell you that I am very please to see that Home Power has made it to the newsstands here. I followed your magazine from almost the very first. You have come a long way and have improved all the time, while still presenting issues full of real stories from real people who are doing what they are teaching. Everyone who remembers the Mother Earth News of the old days will recognize and love the way you are doing things. Keep up the good work! Sincerely, James Melton, 2747 Wentworth, Grand Prairie, TX 75052 • 214-660-6614

Thanks for the flowers, James. — Richard

Q&A

Welder

I would like to know how to make a welder from a car or truck alternator or just from a deep cycle battery. We that use alternative energy usually don't have power enough to operate a transformer welder. Thank you so very much, Jim Carr, Rt #2 Box 475A, Rush, KY 41168

The MigMaster DC Welder is powered by 24 Volts DC (See Things that Work in issue #30). The manufacturer specified current consumption is 200 Amps - though this depends on the type of welding being done. "MIG" stands for "metal inert gas". A gas such as argon or carbon dioxide is injected at the welding tip to displace oxygen and cool the welding tip, allowing 100% duty cycle operation. It costs $249 for a basic unit or $599 for a toolbox model that comes with batteries and an electric drill for wire feeding. Distributor (Western U.S.): On Line Marketing, Inc., 12315 Mukiteo Speedway Blvd. Bld.1 , Ste. 2, Lynnwood, WA 98037 • 800-743-1403. —Amanda

Hi, Jim. You can weld with just about any battery with a voltage greater than 24 Volts and a capacity of greater than 100 Amp-hours. Control the current by using a heavy rheostat. A car alternator is far too small to be an effective welder on anything but light sheet metal. — Richard

Wire We Here

I plan to wire my new home 12V. Does it make sense to convert 120vac to 12VDC until I purchase the other equipment (PV, wind, etc.)? Would this be done by battery charger to batteries, then the batteries to DC load? What charger should I use? Is this possible? I welcome your advice. Chris McKay, POB 991, Maywood, NJ 07607

It is possible to convert your house to 12 VDC, but why would you want to? 12 Volt DC requires thick expensive wires, and 12 Volt appliances are more expensive, harder to get, and are poorer quality (in general) than regular 120 vac appliances. For this reason most renewable energy homes these days use inverters.

It's great to hear you're planning to make your (currently grid connected) house renewable energy powered. Starting with batteries and a charger is an option, and it would give you power during blackouts. Keep in mind, though, that a lead-acid battery's life is limited to about a decade. No sense sinking a lot of money into batteries if you won't be able then to afford solar panels for five years. There's something to be said for starting with a small complete system to power part of your house, and expanding as you learn. Also we're particularly interested in line intertie systems which feed into the grid. See Mick Sagrillo's article in this issue. — Chris

Traveling PCs

We publish a newsletter for people who travel with their computers and there seems to be a problem with running the computers directly from the generator and other problems concerned with the transformers being plugged into circuits fed by inverters. Can you shed any light on these topics? Judith L. Ashford, 919-D La Mesa Terrace, Sunnyvale, CA 94086

Old funky generators can put out nasty power, with unstable frequency and poorly regulated peak and rms voltages. Computer power supplies — especially "switching supplies" found in recent computers — are built to take fairly ugly power. The answer is to use an inverter. Inverters these days all have excellent frequency regulation, and the rms voltage regulation is good enough for computers. Besides, most generators are overkill for the power consumption of a computer. Generators are most efficient when they are well loaded. You'll burn less gas if you run the generator to charge the batteries, and then run your computer from an inverter. It's also a lot quieter!

We've had excellent success running computers (Apples, IBMs, etc.) from all inverters sold in our market. Laser printers are the only computer peripheral which don't digest inverter power. They use thyristors in their power supplies which burn up when fed the square shaped pulses of "modified sinewave" inverters.

Transformers resist the rapid changes in voltage which occur in the waveform of modified sinewave inverters. In our experience transformers fed inverter power just buzz loudly. A solution to inverter/transformer problems is to plug in a "line-tamer" or ferro-resonant transformer between the inverter and the troublesome transformer. Or try a long extension cord wrapped around a piece of iron pipe. These smooth out the waveform at the cost of additional power consumption. An excellent option is to buy a sinewave inverter — their power is just like downtown, only better. — Chris

Pump Problem

Dear HP Crew; Our system is inverted by a Trace 2524 SB, ACTC, DVM which is fed by an ample 745 Amp-hr (20 hr rate) battery. Our problem arises with our submersible pump. If the inverter is already on with at least a 150 watt load and the pump pressure switch contacts close, the system pumps as is normally expected. But if the inverter is in idle mode or active but with less than a 150 watt load, the breaker in the service panel clicks off. We contacted Steve Willey and proposed the problem to him as we heard that he had a solution for this problem. He promptly returned an answer stating that some pumps need full power available to them, the instant the contacts close, to start them. They can't wait for the Trace inverters to soft start, thus they surge off and on till the breaker blows. Steve has cured this problem on some pumps by installing a priority load that comes on when the pressure switch contacts close followed by a timer that runs for about 5 seconds and then starts the inverter before activating the pump. He said he had not heard of the partial preload requirement and thus was unsure if the switch he builds would help. So before I try to build another circuit with a load and timer in the pump circuit, I was wondering if any of you had any ideas. Clint & Karen, Box 94, 150 Mile House, British Columbia, Canada VOK 2GO • 604-296-4592

Inverters have a difficult time starting large inductive loads (such as pumps) from zero load. Steve's circuit which first activates a small resistive load gives the inverter time to get up to its rated current and voltage before the pump is turned on. The problem may be that without the resistive load, the motor of the pump is not receiving a high enough voltage. It may be acting like a short circuit and shutting off the breaker. The problem may also be due to the phase difference of the current and voltage. Current and voltage in purely resistive loads are in phase. The current leads the voltage by 90° in inductive loads. A load which is both resistive and inductive, such as a pump, will have the current and voltage out of phase between 0-90°. When the current and voltage are out of phase, the inverter needs to supply more current for a given voltage to give the same amount of power to the load (since P=IV, power equals current times voltage). This may also be the cause of the high current that is shutting off the breaker. The 150W resistive load helps bring the current and voltage back in phase - thus lowering the current supplied by the inverter. A capacitive load will work even better at bring the current and voltage back in phase. If you have a capacitor-start motor and it is above ground, the best solution would be to replace the capacitor with a lower value. Your problem may be due to one of these problems or a combination of the two. - Amanda

ABCs

A) In #30 page 107, you show a number of shunts. What do they look like and do they cause a voltage drop?

B) #22 page 29, What makes a fuel cell work? Is it heat? If so where is the energy for the heat coming from? Also, please show a picture of a fuel cell, it was vacant from the rack when picture was taken for #22.

C) If every home in the city had a PV system with batteries wouldn't all the batteries become another environmental problem? I would like to see more about synchronous inverters written about in #29 page 28.

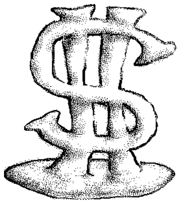
D) You have a fine magazine. I am learning a lot from the articles on systems people have built. I would like to see more pictures and diagrams though. Ken Kruller, 6355 137th NE #305, Redmond, WA 98052

A) A shunt has a known small resistance. The voltage drop measured across a shunt can be used to determine the current; current equals voltage divided by resistance (V=IR). Shunts come in all sizes from the size of a Bic lighter (ten Amps) to the size of a Twinkie (500 Amps).

B) A hydrogen fuel cell combines hydrogen and oxygen to form water; the resulting energy is released as electricity. An electrolyte (usually a solid polymer membrane) is located between the electrodes. Hydrogen is supplied to the fuel cell at the negative electrode (the anode); oxygen is supplied at the positive side (the cathode). The anode reaction is: H —> 2H+ + 2e-. Hydrogen dissociates in the presence of a catalyst (platinum is often used), forming hydrogen ions (protons) and giving up electrons to the anode. The hydrogen ions pass through the membrane to the cathode and react with oxygen to form water. Electrons can not pass through the solid polymer electrolyte. The electrons that are released at anode, flow through wires to an external load and then to the cathode where they become part of the cathode reaction which produces water. The cathode reaction is: 2H++2e-+1/2O2 —> H2O .The overall fuel cell reaction is: H2+1/2O2 —> H2O. See The Hydrogen World View by Dr. Roger Billings for more information.

C) Batteries could become a big environmental problem if every home used them as their primary source of energy storage. Lead and cadmium are toxic materials that must be properly recycled. Of the current battery technologies, nickel-iron batteries are the least toxic. Synchronous inverters are one solution to this problem (See "Utility Intertie Systems" in this issue). Hydrogen offers another, very clean option for energy storage (see hydrogen article in this issue). —Amanda

D) Hi, Ken. More pictures and more detailed schematics? See page 99 this issue. — Richard



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Sir Thomas Lipton — 1870

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Everything Grows!

Richard Perez

The difference between things alive and things dead is growth. This is the story of a PV project that grew in the Land Within, *Tierradentro.* It is the story of solar power in a remote Paez village in the Colombian Andes.

What a long strange trip it's been…

We didn't just wake up one morning and decide to travel all the way to Colombia, South America and install a PV system in the tiny village of Mosoco. The growth of such a plan takes time and patience. It all started over a year ago with a student of mine who attended the Advanced PV class at the Solar Technology Institute (STI) in September of 1991. This student's name is Jesus Eduardo Gómez, hereafter called by his nickname, "Bijou". Bijou had traveled all the way from his home of Cali, Colombia to learn hands-on solar technology at STI. One of the ideas he discussed with the group at STI was providing solar electric power for health center lighting and vaccine refrigeration in the remote villages of Colombia.

Bijou's ideas instantly sparked in the eyes of Ken Olson, Director of STI, Juan Livingstone of STI, Karen, and me. Ken had done on-site PV surveys in South America for the Pan American Health Organization (PAHO). Juan is Chilean and has done PV systems in South America. They know the need for PV power, and were overjoyed at the thought of returning to Colombia. Karen and I were fascinated by the project and joined up. Before we knew what was happening, we had a project.

Bijou had begun doing his homework before he came to STI in Colorado. He knew of a health center in a remote village named Mosoco in a Colombian province known as The Land Within or *Tierradentro.* This village has a population of about one thousand Paez indigenous Colombians. The health center was without electricity. Bijou, through consultation with Mauricio Puerta, a noted anthropologist and Colombian expert in indigenous peoples, decided that Mosoco was the place for a PV system.

Bijou, the STI Crew, and the Home Power Crew put their energies together and began to make our dream of solar power for Mosoco's health center a reality. We began designing, planning, securing the gear, and making shipping arrangements. Bijou handled all the arrangements in Colombia from the offices of his renewable energy business, Aprotec, in Cali. Ken and Juan worked from the STI office in Carbondale, Colorado. Karen and I worked from the Home Power office in Agate Flat, Oregon. A flurry of FAXs zipped between our machines as our jump off date of 3 October 1992 neared. We planned on having everything in Colombia and ready to go before any of the U.S. crew arrived. Or so the plan went…

Design by donation?

Let's get something straight about this project's financing. We had no support from either the U.S. or Colombian governments. We had no support from foundations or nongovernmental organizations (NGOs). We drew our support from people in the renewable energy field and from the makers of the equipment you see in Home Power. It worked like this…

Bijou, Ken, and I decided on a system design. We asked the makers of the equipment we specified to donate their products to this project. Most systems that are "designed by donation" are mismatched and function poorly. The *Tierradentro* System is different. In every case we got our first choice for equipment. The system's design and hardware are "state of the art."

Everyone who worked on the project did so for free. The fine folks of STI's hometown Carbondale, Colorado donated money to the project. All the STI and Home Power Crews paid their own expenses. Bijou and Mauricio Puerta, through his organization *Fundación Anthropológica de Tierradentro*, paid installation expenses and Colombian import duties.

This pilot project happened by the generosity of everyone involved. It was a labor of love.

The system's power consumption

The Mosoco health center wasn't even wired for electricity, so we had no real idea of electrical consumption. We worked with the floor plan of the building and decided that eleven lights were required. We concentrated on high illumination levels for the medical areas. Also included in the loads were a refrigerator for vaccines, a recharging station for flashlight sized nicads, and a TV/VCR combo. The need for the vaccine refrigerator is obvious. The nicad recharging stations will save many Mosoco residents from buying throw away flashlight and radio batteries. The television and video cassette recorder will be used for showing health and educational videos. And who knows, there maybe some fun and entertainment on the TV also.

The lighting equipment we used in Mosoco was 120 vac fluorescent. We used six new model Lights of America compact fluorescents donated by Real Goods Trading Co. The LOA compacts use a high frequency switching ballast and consume about 22 Watts (DC input into the inverter). These LOA models start instantly and run silently on modified sine wave inverter power. We also used five Magnaray 120 vac fluorescents donated by their maker Magnaray, Inc. These models have an excellent reflector and work well for ceiling mounts. They use a 9 watt Phillips tube, a coil/capacitor ballast, and consume about 11 Watts (DC input into the inverter). We decided to use 120 vac lighting for reason of price, performance, and to keep the system electrically standard for the users.

We had no data for the television display or VCR, so we assigned them average consumption values. The only DC loads powered directly from the battery are the refrigerator and nicad rechargers. The nicad rechargers would be able to fill up sixteen D sized nicad cells daily. The folks living in Mosoco spend a good deal of their disposable income on nonrechargable cells for their radios and flashlights. The use of rechargable cells will save them money and save their environment from the impact of thousands of throw-away flashlight cells.

We worked up the consumption estimate shown in the table and pie chart below. This consumption estimate of 2296 Watt-hours per day represents a calculated guess at what Mosoco's health center would consume. This is typical of PV systems designed for folks who have never before had electric power.

Designing the System

PV system design requires an intimate knowledge of local solar insolation and the system's users. We didn't have a clue how much solar radiation the town of Mosoco received. None of us *gringos* had ever even met a Paez, much less discussed his plans for electricity.

Here's what we did know. Mosoco is located at 2° 15' North latitude and 76° 08' West longitude. Mosoco's elevation is 2,775 Meters, or 9,104 feet, above sea level. We knew from Bijou that the area often has periods of overcast weather featuring many clouds — typical mountain living conditions.

We designed a 120 vac system. We considered effectiveness, reliability, maintainability, and compatibility. There are traveling dentists, with electrical equipment, who would stop at Mosoco if there was electricity. If there were lamp failures, we wanted locally available replacements — this means 120 vac powered lights. We wanted the health center to be able to use high powered, standardized medical equipment. All of this led us to design a system that uses 120 vac power for most of its output.

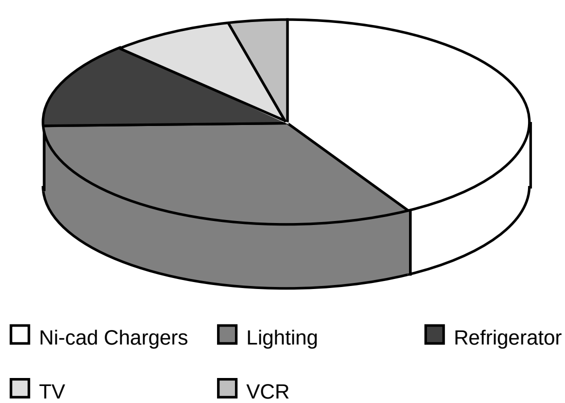
Power Sources

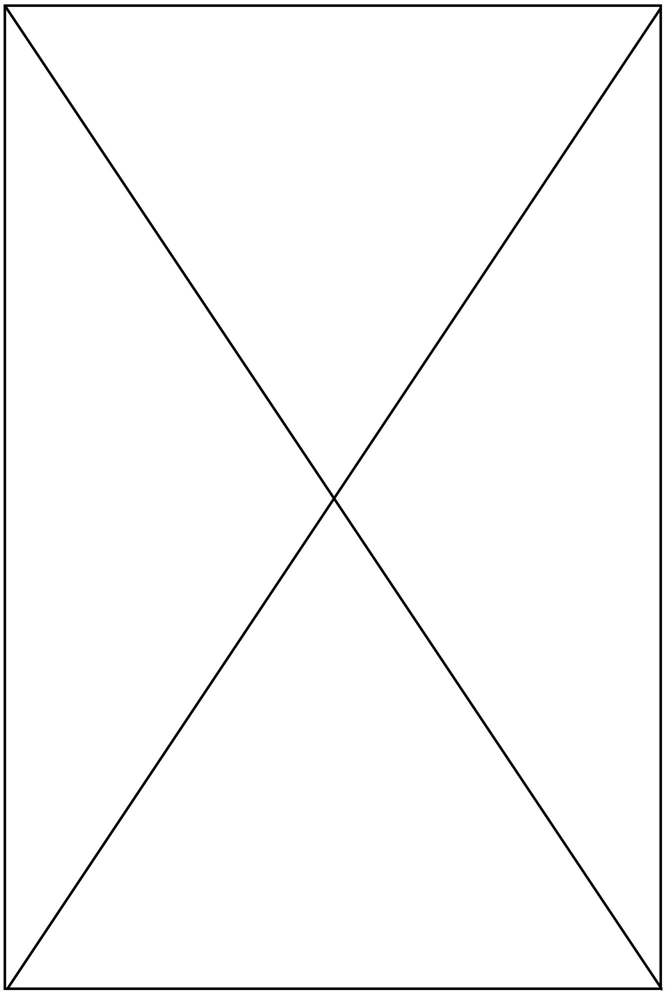
We chose twelve Kyocera J51 photovoltaic modules for the power source. Each PV module supplies 3 Amperes of current at 17 Volts DC and is rated at 51 Watts. Since we were dealing with a cloudy area, we derated the daily energy output of these modules by 40%. As it turned out later, the derating factor at Mosoco should have been about 25%. We actually measured very intense diffuse radiation even on very overcast days. I imagine that this has been experienced by others who have measured PV output power at the equator and at high altitudes. This array of 12 modules was configured for 12 Volt operation. We divided the modules into two subarrays of six panels each. Each subarray of six had its own set of two 8 gauge

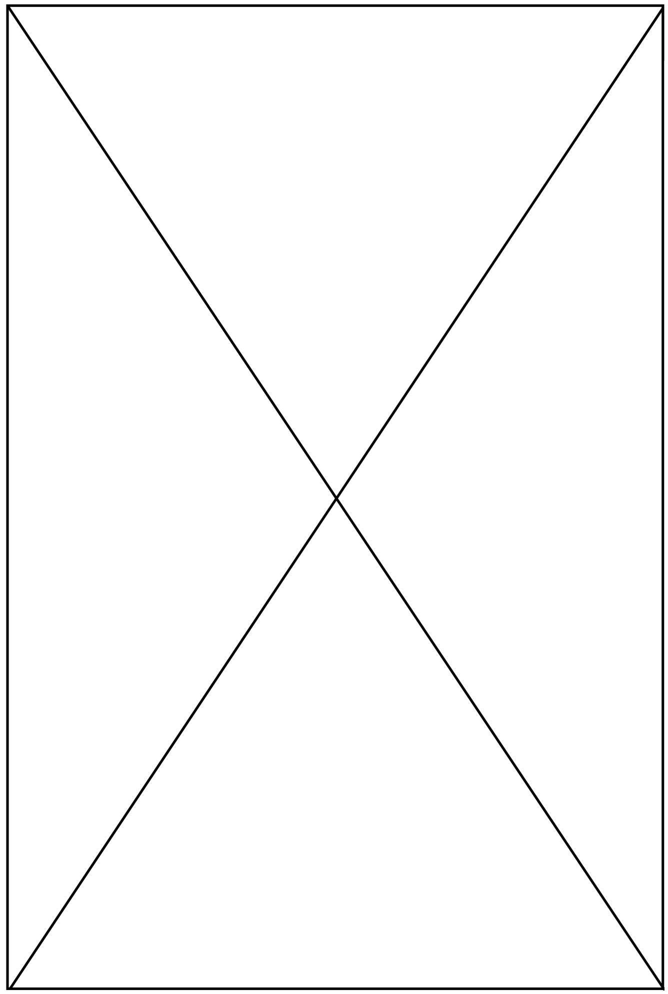
Mosoco Health Center Load Estimate

No.	Appliance	Run Watts	Hours /Day	Days /Week	W-hrs /Day	%
4	Ni-cad Rechargers	10	24	7	960	42%
6	LOA fluorescent Lights	22	4	7	528	23%
1	Vaccine Refrigerator	40	8	7	320	14%
5	Magnaray Lights	11	4	7	220	10%
1	Television Set	85	3	5	182	8%
1	Video Cassette Recorder	40	3	5	86	4%
	Power Consumption in Watt-hours per day				2296	

Mosoco Health Center Load Pie







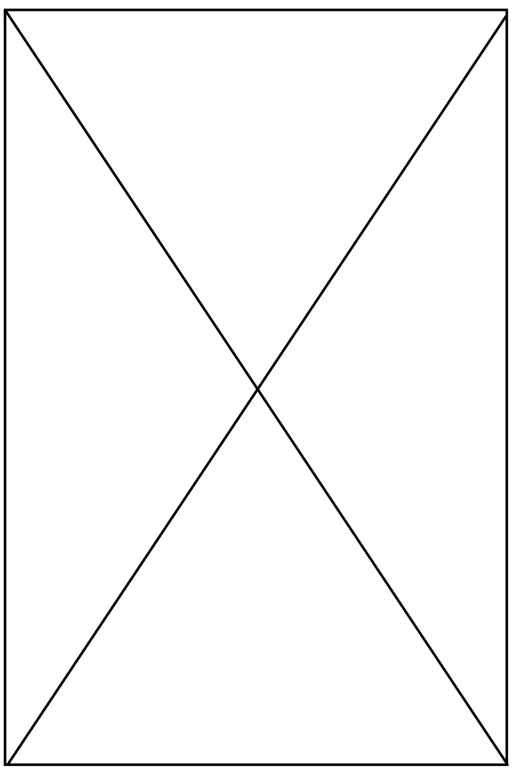
Top Left: Nevado del Huila (18,700 feet) on one of its rare appearances through the clouds.

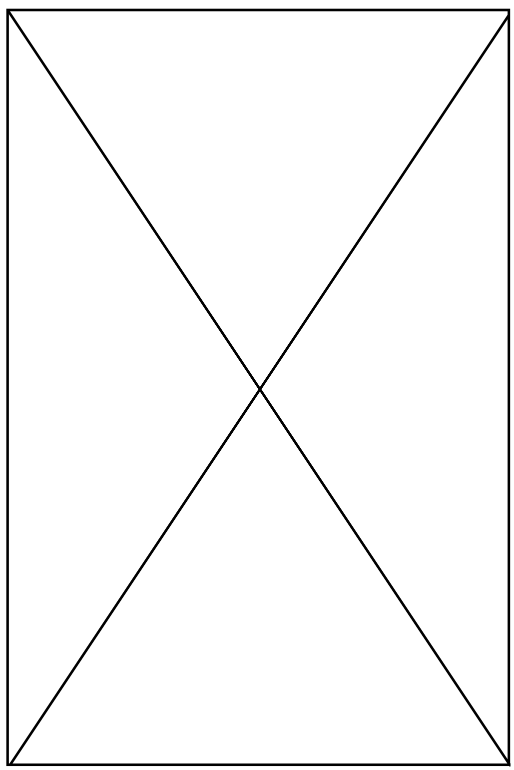
Top Right: The *Chiva.* These busses are the transpo of the Colombian Andes.

Right: The Paez meet PV in the back yard of Mosoco's health center.

Far Right: A view looking north from the roof of Mosoco's health center.

Photos by Karen & Richard Perez





copper wires connecting it to the Ananda Power Center. We did this to ensure low loss and reliability. All electrical connections between the module junction boxes and the Ananda Power Center were soldered.

Power Processing

This is a high tech system. We relied heavily on modern power processing equipment. We used a PowerStar UPG 1300 Watt inverter. This inverter converts 12 VDC power stored within the battery into 120 vac, 60 cycle modified sine wave power, like the Colombian standard in downtown Bogota. We used a Heliotrope CC-60C photovoltaic charge controller. This PV control allowed us the wide voltage operating window required by the alkaline battery, and also gave us room for array expansion in the future. We used a Cruising Equipment Ampere-hour +2 meter to give the system's users information about their battery's state of charge. One channel of this meter was connected as a net reading battery Ampere-hour meter. The other channel was configured as a cumulative Ampere-hour meter for the photovoltaic array. This second channel will give us data about the performance of the PV modules at Mosoco's health center.

The fellows at Ananda Power Technologies, Inc. packaged many of the system's power processors into a single box. Ananda made a special Power Center IV just for the *Tierradentro* project. This Power Center houses the inverter and the Ampere-hour meter. In addition it also provides DC rated circuit breakers for the two subarrays and all the 12 VDC powered loads. The Power Center also contains two 200 Ampere Class T current limiting fuses housed in a pull-out disconnect. The Power Center has fittings on its top designed to fit the Heliotrope PV controller. Using this Ananda Power Center IV made the job of installing a safe and reliable PV system in the remote Andes Mountains of South America a snap!

Power Storage

We had already learned that most South American PV systems fail in their battery. Many of these system failures don't start out in the battery, but they all finish there. A bad wire connecting the modules to the battery eventually finishes up as a discharged battery. A bad control eventually finishes up as a dead battery. Too much electrical consumption always finishes up as a dead battery. No matter what caused the system's demise, it eventually and inevitably killed the battery. We wanted a battery that would survive total and routine complete discharge. We specified nickel-iron cells because of their immunity to damage by routine and complete discharging.

We went to UtilityFree and asked for a donation of nickel-iron cells for the *Tierradentro* project. UtilityFree promised forty 150 Ampere-hour cells for the project. This would give the *Tierradentro* system a total storage capacity of 600 Ampere-hours at 12 Volts DC. This provides about three days of storage for the system. We were counting on the large array to provide at least half power on cloudy days.

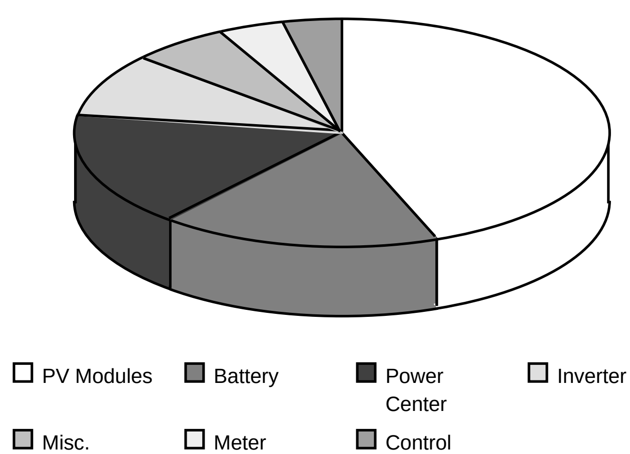
Appliances

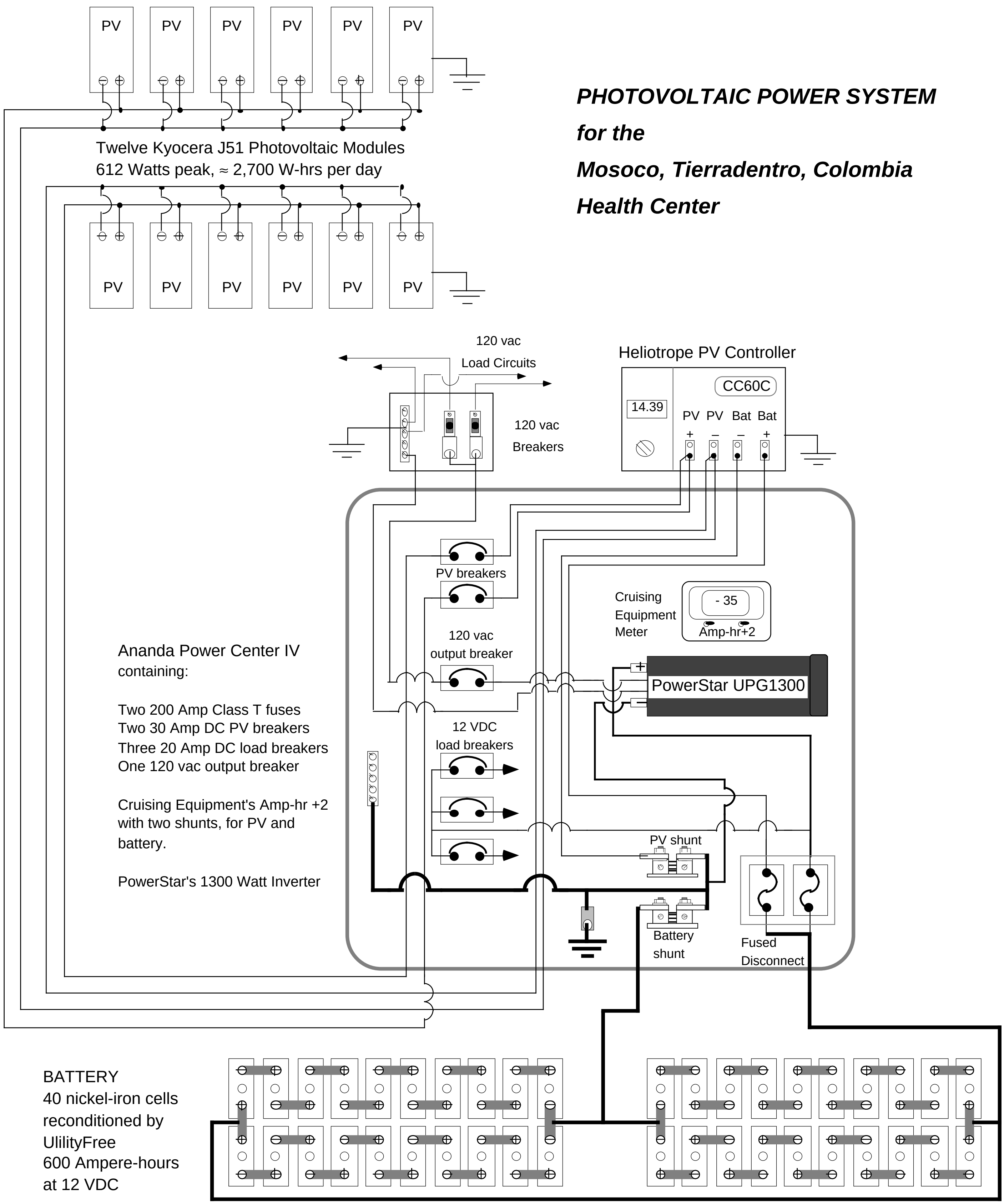
Part of the *Tierradentro* system's effectiveness would be determined by the system's appliances. We needed to use the most efficient appliances we could find. Real Goods and Magnaray donated the super efficient fluorescent lights. Real Goods also offered rechargable nicad batteries and chargers. The TV, VCR, and

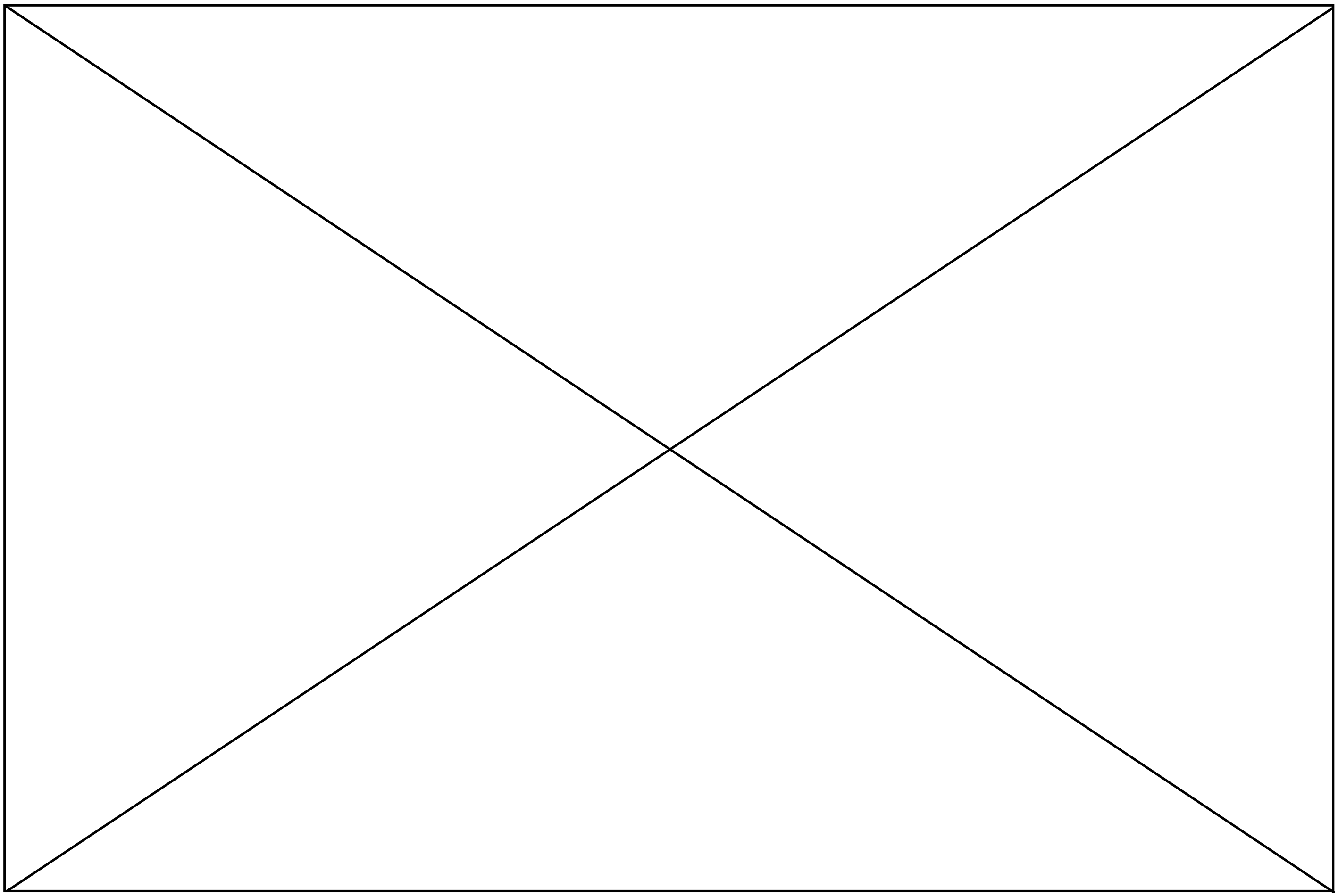
Mosoco Health Center PV System Hardware Cost

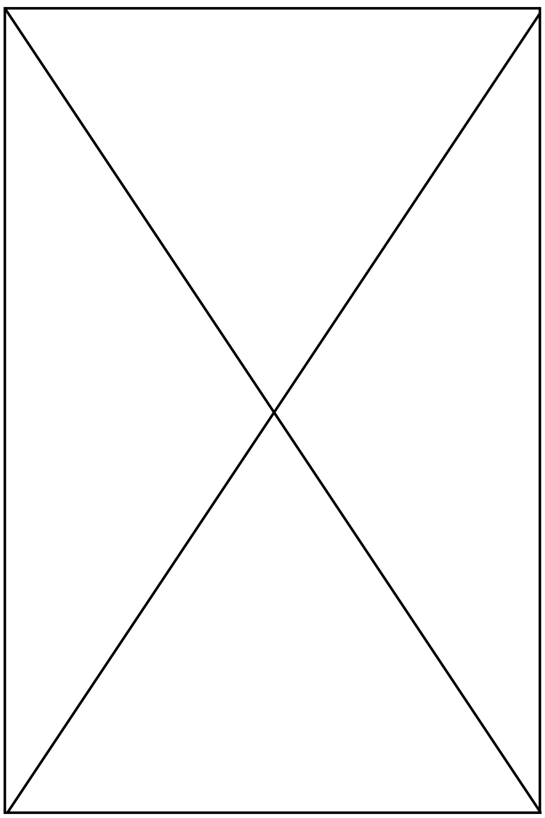
No.	Item	Unit Cost	Item Total	Item %
12	Kyocera J51 PV Modules	$365	$4,380	44.2%
24	Nickel-Iron Cells	$70	$1,680	17.0%
1	Ananda Power Center IV	$1,625	$1,625	16.4%
1	PowerStar UPG1300 Inverter	$899	$899	9.1%
1	Cruising Equip Amp-hr+2	$395	$395	4.0%
1	Heliotrope CC-60C Control	$340	$340	3.4%
1	Misc. 120 vac wiring	$185	$185	1.9%
2	PV Mounting Racks	$85	$170	1.7%
1	Misc. Hardware	$95	$95	1.0%
1	Mains Breaker Panel	$82	$82	0.8%
1	Distilled Water	$53	$53	0.5%
	Total System Hardware Cost		$9,904	

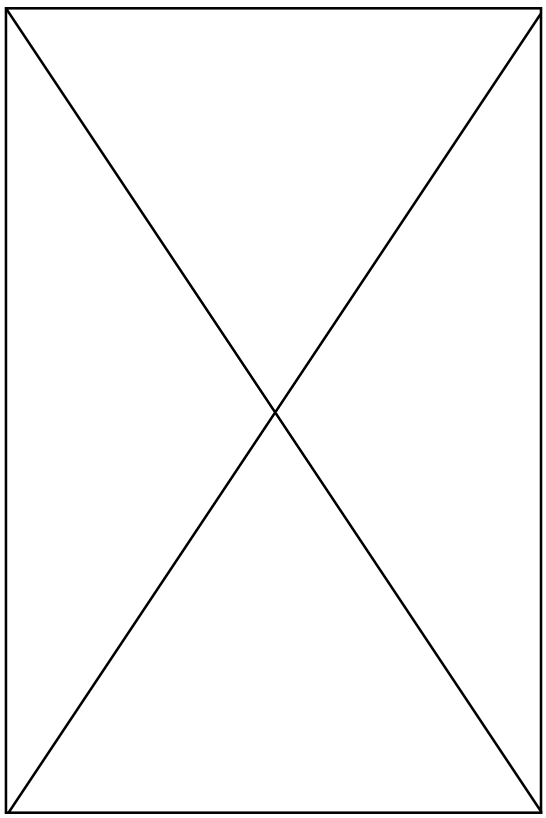
Mosoco PV System Hardware Cost Pie




PHOTOVOLTAIC POWER SYSTEM
for the
Mosoco, Tierradentro, Colombia
Health Center
PV
Twelve Kyocera J51 Photovoltaic Modules
612 Watts peak, ≈ 2,700 W-hrs per day
120 vac
Load Circuits
120 vac
Breakers
Heliotrope PV Controller
CC60C
14.39
PV PV Bat Bat
+ – – +
PV breakers
Cruising
Equipment
Meter
- 35
Amp-hr+2
120 vac
output breaker
PowerStar UPG1300
Ananda Power Center IV
containing:
Two 200 Amp Class T fuses
Two 30 Amp DC PV breakers
Three 20 Amp DC load breakers
One 120 vac output breaker
Cruising Equipment's Amp-hr +2
with two shunts, for PV and
battery.
PowerStar's 1300 Watt Inverter
12 VDC
load breakers
PV shunt
Battery
shunt
Fused
Disconnect
BATTERY
40 nickel-iron cells
reconditioned by
UlilityFree
600 Ampere-hours
at 12 VDC







Top: Jesus Eduardo Gómez and Luis Eduardo Pérez on the roof installing the Kyocera PV modules.

Far Left: Mauricio Puerta views the battery box containing nickel-iron cells.

Left: The Ananda Power Center with PowerStar inverter, Heilotrope control and Cruising Equip. Amp-hr+2 Meter.

Photos by Karen & Richard Perez

refrigerator were being provided in country and even Bijou didn't have their exact specs.

The flashlight battery recharging microenterprise or *microempressa* has long been Ken Olson's dream. During his extensive travels in South America, he noticed the large numbers of disposable cells used. Ken's idea is to establish PV-powered flashlight battery recharging stations. Individuals would own their rechargable nickel-cadmium, nickel hydride, or lead-acid cells. They would take the discharged cells to the recharging station and there they would be recharged overnight for a fee.

Installation

If this were a normal system installation, I would begin by throwing all the tools and hardware into the truck. But this system is in Colombia and everything had to fly in. As we neared departure date, things began going off schedule. UtilityFree was only able to supply half the nickel-iron cells and the remainder would have to follow later. Real Goods was unable to supply the rechargable flashlight batteries in time and they too would have to be shipped later. We shipped the three cartons of PV modules and the twenty-four nickel-iron cells via air freight and held our breath. At the last moment, the folks at Burns Milwaukee donated one of their SunOvens to the *Tierradentro* project. We shipped this SunOven also by air freight.

We packed all the gear we could possibly check as airline baggage. Juan repacked one suitcase three times before it went under the seventy pound limit. We hand carried the tools, the Ananda Power Center (with all goodies inside), the Heliotrope control, all the fluorescent lights, nuts&bolts, a video camcorder, plus all the clothing and gear we needed for three weeks in Colombia. We looked like a crew of overloaded solar gypsies.

On October 3, 1992, Ken, Juan, Karen and I got on an airplane and flew to Cali, Colombia to meet Bijou.

A week in Cali

Bijou met us at Cali's airport. We sailed through customs with no problems. We were cruising into Cali and were congratulating ourselves on our good luck when we hit a police roadblock. This was to be the first of many roadblocks we passed through in our three weeks in Colombia. The police bear a greater resemblance to army troops rather than American style police officers. They are heavily armed with submachine guns and assault rifles. They are interested in paramilitary activity and were looking for firearms. After a quick search of the truck, a fast frisk job, and an examination of our papers, we were on the road again. These stop and search routines became so common that I stopped counting them.

We spent the next six days in Cali doing two things. One, we purchased all the equipment we needed to wire the Mosoco health center for electricity. Two, we tried to locate the modules, the nickel-iron cells, and the SunOven. These items had been shipped two weeks earlier. We were assured by our U.S. side shipper that they had left Miami for Bogota. The customs folks in Bogota assured us that the load was due out mañana…

We spent hours on the phone trying to locate and move the modules; we raced around Cali buying electrical parts. The only way to get around Cali is to race. Colombia is 80% hydro powered, in a drought, and is now rationing electric power. All over the country, the electricity is shut off from three to eight hours each day. This includes the traffic signals. Couple the local high speed driving style with no traffic signals and it makes for exciting rides.

The daily power outages didn't affect the Aprotec office where we were based. Bijou had installed a PV system and ran the office on batteries and inverter when the grid was out. Bijou said that the majority of his business is grid-sourced uninterruptable power systems. All over Cali, businesses and homes ran thousands of gasoline powered generators on the sidewalks.

Shopping for electrical supplies in Cali is easy. All the vendors of parts are located on the same street. We planned on wiring the health center by Colombian standard technique — 14 gauge two conductor cable. We used locally made equipment such as keyless receptacles (ceramic bulb bases), cable, electrical boxes, switches, and a mains distribution panel. If I were to do it again, I would bring along some Scotch 33+ electrical tape and some Ersin 60% tin / 40% lead, rosin core solder. We were able to locate almost all the required 120 vac wiring stuff with no problem.

We needed about twelve gallons of distilled water to make electrolyte. The nickel-iron cells were shipped dry. The electrolyte was powdered and needed to be mixed with distilled water. Finding this much distilled water proved to be no small problem. Eventually a battery manufacturer, Roberto Leon Patacon of MAC S.A. in Cali, donated 125 bottles (each 500 ml.) of distilled water. We also got a tour of their lead-acid battery factory which was in the process of converting to brand new German machinery. The battery biz is booming in Colombia.

We fabricated the PV mounting racks out of locally available aluminum stock. This stock was 1/8 inch thick and had an "L" shaped cross section about two inches on a side. Bijou's garage at Aprotec slowly filled up with boxes of stuff.

We are very interested in developing the local infrastructure supporting renewable energy. We set aside time each day for meetings with people about using renewable energy. These people varied from industrialists like Manuel Mosquera Castro of *Industrias Purace S.A.*, to Maria Christina Alarcón, a nationwide TV reporter, to meetings with Carlos Dierolf of the PV program at *Universadad del Valle,* to Luis Eduardo Pérez, Aprotec's best employee. We found Colombians very interested in diversifying their energy production. The daily power outages made everyone want to listen to us instead of their neighbor's generator.

Meanwhile, the PV modules, the nickel-iron cells, and the SunOven had been located. They were still in Miami. After a few tense phone calls, we finally got them on an airplane into Bogota where Mauricio Puerta was waiting to push them through customs. Mauricio would then truck the shipment to Mosoco.

On 9 October, we loaded up the trucks and pulled out of Cali bound for Mosoco. Due to political unrest surrounding the 500th Columbus day holiday on 12 October, we decided to drive north almost to Bogota, then swing south and enter *Tierradentro* from the east. The Cali radio and TV stations were reporting indigenous groups and *guerrillas* blocking the roads into *Tierradentro* from the west. While we had the papers to pass through the indigenous peoples road blocks, we weren't equipped to deal with the *guerrillas.*

The trip to Mosoco

We drove north along a range of impossibly huge mountains. On a road called "La Linea" we crossed east over the mountains and spent the night in the town of Ibague. The next day we cleared town early to beat the National Bicycle Race which would shut down all roads out of Ibague at 7 in the morning. We then turned south and headed for *Tierradentro.* After a day's stop in Pisimbala, we arrived at Mosoco on the 500th anniversary of Columbus Day, 12 October 1992.

Mosoco

We were greeted in Mosoco by Roderigo Perdomo, the Secretario of the local *Cabildo.* The *Cabildo* is the local indigenous town government. Roderigo explained that Ernesto Mulcue, the *Gobernador* of Mosoco was out of town and would return in a few days. Though Ernesto was absent in Popáyan attending meetings about indigenous peoples' rights, we were welcomed by his wife Mariela and their family. We moved our sleeping bags into the unoccupied main room of the health center and set up shop.

The next day we started installing the equipment we had trucked in. We met with the local bricklayers and they began constructing a battery box on the outside east wall of the health center. We mounted the Ananda and the Heliotrope control inside on that very same wall. We began to wire the health center for 120 vac lighting and receptacles. This construction process went on for three days and on Friday, 16 October, we had installed all we had brought with us. We still lacked the PV modules and the nickel-iron cells.

We jumped into the truck and drove to the nearest large town called Popáyan. Here Ignacio Castro Bucheli and Victor Orozco of Fundación Mosquera Wallis lent us the use of their communications gear and we called up Mauricio in Bogota. Mauricio's mom answered the phone and told us that Mauricio had left Bogota hours ago with all the equipment in the back of his truck! There was much shouting and celebration that afternoon in Popáyan! We paused only for a shower and a bite to eat and then drove five hours back into the mountains, back to the town of Mosoco and the half completed PV system.

On Saturday morning about 10 AM, Mauricio Puerta arrived with the remainder of the equipment. He had driven at high speed and ran over a *guerrilla* road block to deliver the PV modules, the battery, and the SunOven to Mosoco. The customs duties charged were a staggering 1.8 million pesos or over $2,700 U.S. dollars. We were very happy to see him and his cargo.

We immediately set to work installing the rest of the gear. Bijou and Luis installed the arrays on the roof. Ken and I mixed electrolyte and filled the nickel-iron cells. Juan and Karen ran around with the camera to document the installation. The first thing we discovered is that the screw on caps for the nickel-iron cells had not been shipped. We had cells without caps. I'd been joking about all the throw away plastic bottles filled with distilled water we'd hauled to Mosoco. Well, these plastic bottles saved our butts because they fit snugly into the cell's filler neck. They made great temporary replacements for the missing filler caps. Check it out in the photo of the cells.

Karen immediately set up the Burns Milwaukee SunOven and began cooking. After a pot of rice and a few baked potatoes, the SunOven was a bigger hit than the PV electric system. Every time we put it out to cook, we gathered a large curious crowd. Karen left the SunOven under Mariela Mulcue's supervision. We're not too sure if PV electricity will catch on in Mosoco, but we know that solar cooking is already a popular success. The Paez are walking miles each day to collect firewood. The sight of their staple food, rice, cooked in about an hour was irresistible.

By 10 AM Sunday morning, we had the whole photovoltaic system up and operational. Even though the weather was overcast, the PV modules were still putting over half power into the battery.

Sunday afternoon we had an official ceremony to present the system to the people of Mosoco. That night many Paez gathered to see the lights at the health center. We had started explaining how to use the system the minute we arrived in Mosoco. All during the installation process we had scores of curious onlookers asking questions. We had been transferring the technology all along, but Sunday night was the evening of Mosoco's official acceptance of their new photoelectric system.

We had specifically trained Roderigo to operate and maintain the PV electric system. We hoped that no maintenance between Bijou's semiannual visits would be necessary. Bijou will return to the system within the next month to check that all is going well. The Aprotec Crew will also install the additional nickel-iron cells and cell caps when they are shipped by UtilityFree.

We waited to leave Mosoco until Monday, after the town's weekly market. We wanted to get back to the city and finalize arrangements that Bijou had made to meet with Colombia's First Lady.

Leaving Mosoco and saying goodbye to all our new friends was difficult. We want to thank the Paez of Mosoco who made us so very warmly welcome in their homes. We want especially to thank Mariela Mulcue who fed us many beautiful meals from her kitchen.

Everything grows

Tierradentro is a special place. Its equatorial, high altitude environment is unique. Everything grows there, even the fences. We commonly saw bits of trees that were whacked off and stuck into the ground as fences. These grew into "living fences". Every home, even the poorest, was a riot of floral color. I saw potted flowers and even trees permanently riding atop buses and trucks. The Paez people are among this world's luckiest to live in a land of such magnificent beauty.

On the way to Bogota

After leaving Mosoco we drove to Cali, and then flew to Bogota to meet with *la Presidencia de la Republica,* Anna Milena Muñoz de Gaviria. Señora Gaviria takes her duties as Colombian First Lady very seriously. She is active in rural health care and indigenous peoples' rights. We were pleased when she and her assistant, Maria Isabel Nieto

The Paez

Randy Udall

The Paez Indians live in southern Colombia in a mountainous land called Tierradentro—literally, " the land within." As befits a region with such a romantic name, their 200,000 acre homeland is isolated, rugged, remote, and scenic. Scattered throughout the mountains are 20 villages and 300 small settlements, home to approximately 45,000 people. The five largest villages have electricity; the rest are unlikely to ever be connected to an electrical grid, because the landscape is too rugged and the region too poor.

Like indigenous peoples the world over, the Paez are under siege. Although some virgin rainforest remains in their area, much of the land is deforested and the land is "tired." Infant mortality is high; average life expectancy is 35 years. Per capita income is less than $1000 a year. Seeking a better life, many young people have migrated to violence-plagued slums in Bogota, Cali, Medellin and other Colombian cities. Although their way of life is being eroded, the Paez have not lost their cultural integrity. They desperately want to break out of the cycle of poverty they find themselves trapped in. And they see renewable energy technologies as one tool to help them do it.

HIstorically the Paez have been subsistence farmers. Corn and beans were their staple crops until recently when violence associated with the cocaine and heroin trade began to change their lives. For the last twenty years, the people have been whipsawed between narcotics traffickers, guerrillas fighting the Colombian government, and the army. Some farmers began to grow poppies. Two years ago, however, the government and guerrillas declared a cease-fire. The coming of peace makes this a propitious moment for launching a development project in Tierradentro. The Paez are devising a comprehensive plan for economic improvement and are in the process of securing a $1 million loan from the Colombian government. They have asked STI to demonstrate how solar and renewable energy technologies can be used to power health care clinics, schools, a radio station, and various micro enterprises, including a silkworm project. The actions outlined here are the first steps in that process.

Jaramillo, were able to meet with us and discuss electrifying rural health centers. The *Tierradentro* crew left *la presidencia* feeling that future renewable energy projects would be supported by the First Lady.

Our special thanks go to Silvio and Lucita Gómez, Bijou's parents and Clara, Bijou's sister. Without their help the *Tierradentro* project would not have happened.

Back home

On 23 October, Ken, Juan, Karen, and I flew back to the United States. We left behind Bijou and Luis to carry on the day to day renewable energy business of Aprotec and of Colombia. We left the lights on in Mosoco's health center. We can't wait to return…

Access

Author: Richard Perez, c/o Home Power, POB 520, Ashland, Oregon 97520 USA • 916-475-3179

The *Tierradentro* Crew

Ken Olson and Juan Livingstone, Solar Technology Institute, POB 1115, Carbondale, Colorado 81623 USA • 303-963-0715 • FAX 303-963-3198

Jesus "Bijou" Gómez and Luis Pérez, Aprotec, Ave 9 A No. 9-47, Cali, Colombia • 68 80 26 • FAX 47 00 82

Richard and Karen Perez, c/o Home Power

Donors to the *Tierradentro* Project

Ananda Power Technologies, 14618 Tyler Foote Road, #143, Nevada City, CA 95959 • 916-292-3834 • FAX 916-292-3330

Burns Milwaukee, 4010 West Douglas Ave, Milwaukee, WI 53209 • 414-438-1234 • FAX 414-438-1604

Cruising Equipment, 6315 Seaview Ave N.W., Seattle, WA 98107 • 206-782-8100 • FAX 206-782-8100

Heliotrope General, 3733 Kenora Dr., Spring Valley, CA 92077 • 619-460-3930 • FAX 619-460-9211

Kyocera America, 8611 Balboa Ave., San Diego, CA 92123 • 619-576-2647

MAC S.A., Carrera la. 18-63, Cali, Colombia • 84 43 17

Magnaray Int'l., 2242 Whitfield Park Loop, Sarasota, FL 34243 • 813-755-2111 • FAX 813-751-5483

PowerStar Products, 10011 N Foothill Blvd, Cupertino, CA 95014 • 408-973-8502 • FAX 408-973-8573

Real Goods, 966 Mazzoni Street, Ukiah, CA 95482 • 707-468-9292 • FAX 707-468-0301

Solartek (Alfonso Lazcano), Ruiz #1703, 22800, Ensenada, Baja California, Mexico

Utility Free, POB 228, Basalt, CO 81621 • 303-928-0846 • 800-766-5550 • FAX 303-928-0847

Renewable Energies for the Paez Indians: *the software behind the hardware*

Ken Olson

The recent STI installation in Tierradentro, Columbia will improve health care and agricultural education for the Paez Indians. It is a pilot project. Hopefully, many more similar projects will follow.

The Leapfrog Project

Renewable energies can enable people like the Paez to "leapfrog" from their 19th century lifestyle directly into the 21st century. They have an opportunity to by-pass the fossil fuel era. They can improve their living conditions without harming the environment. What does it take to create such a project in a foreign land for a foreign culture? Let's look behind the scene.

Many Questions

How do we know PV technology and this application are appropriate for the Paez culture? How can they tell us? They don't know what the technologies are nor what can be done. How will the Paez understand and use the system? How will it be maintained and repaired? High technology is very foreign to the Paez culture. How do we know the system is appropriate for them? How will it be sustainable for the long term?

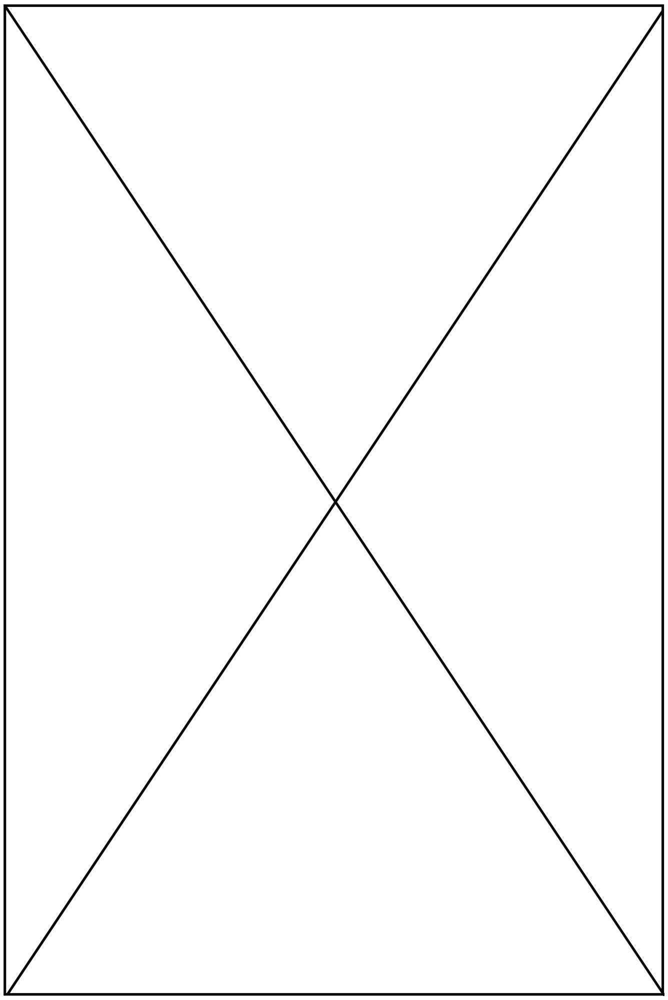
The Human Connection

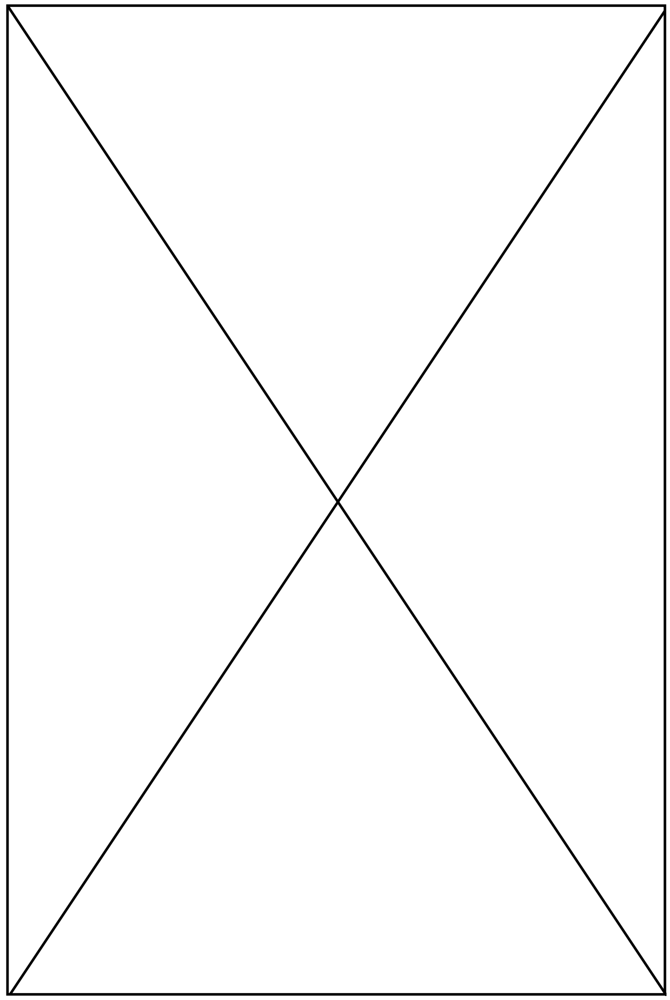
The hardware is reliable. It is the best the U.S. industry has to offer. It has the potential to perform reliably for many years with minimum maintenance/repair and zero operating expense. But will it?

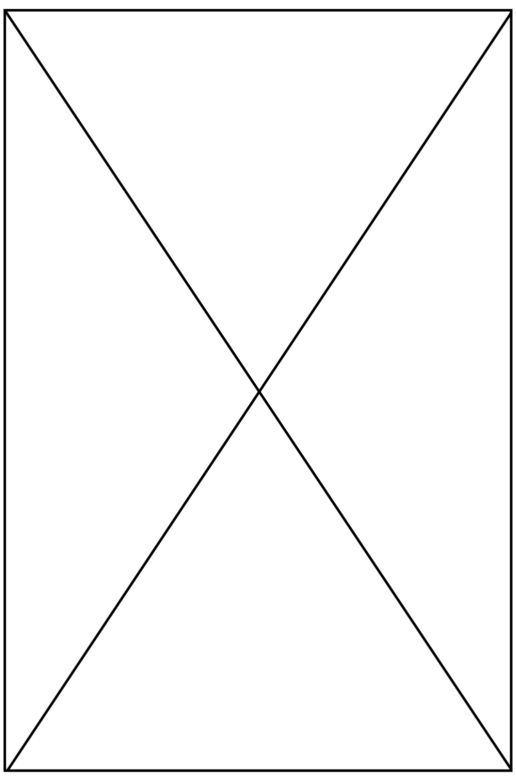
The most vulnerable connection is not in the hardware. It is in the soft, human connection between the technology and its users. This connection can sustain the system for long service life or render it useless within months. How the technology will ultimately serve the people depends upon this human connection.

The Software: A Model Process

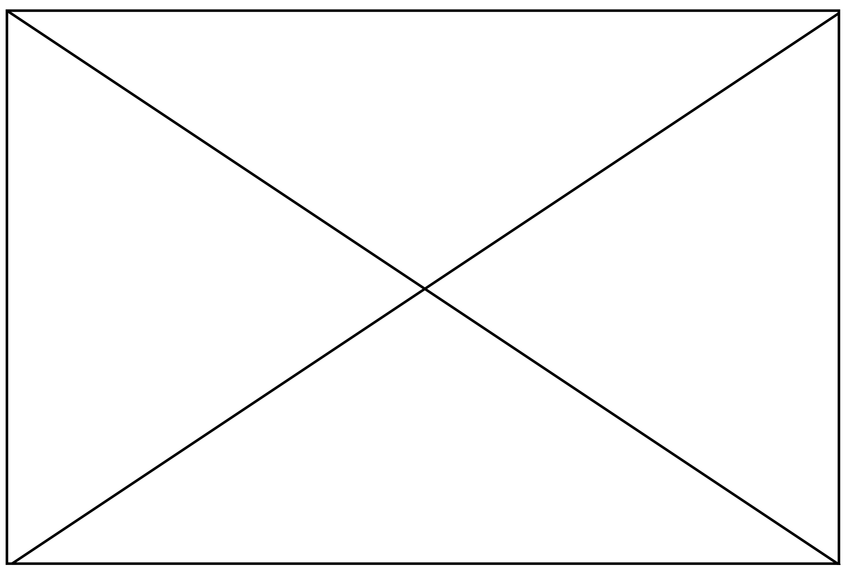
The installation in Tierradentro follows a development process which began one full year ago and will continue







Above Left: Ken Olson, Mauricio Puerta, Ernesto Muclue, and Roderigo Perdomo turn on the lights in Mosoco. Above Right: Kids are the same everywhere. Here soap bubbles provide the fun. Left: At least Home Power's photos are in Spanish… Below: The Mulcue family of Mosoco, Tierradentro, Colombia. Photos by Karen & Richard Perez and Ken Olson



for years to come. STI's purpose is to improve this process; to create a model process. It will become a blueprint to be replicated many times over in Tierradentro and beyond. The process integrates cultural awareness, needs assessment, technical design, financial resources, logistics, maintenance, and repair. Education of decision-makers, technicians, and users is essential. These are the elements of the software.

Intermediaries/Facilitators
Working in a foreign land and with a distinctly different culture requires one or more interfaces. The development process is so multi-faceted it requires a wide variety of human resources. Without each these people, the project in Tierradentro could not have happened.

The Paez Indians
Ernesto Mulcue is Governor of the Paez Reservation of Mosoco, Tierradentro, Columbia. The Paez are a well organized culture. Their government is autonomous from the Columbian government by agreement. The Paez are united in their struggle for social improvement. They are ready to embrace renewable energies. Ernesto Molcue's vision and leadership has played a formative role in Paez development. He officially received the PV system from STI on behalf of the Paez.

The Cultural Connection
Mauricio Puerta is an Anthropologist who has lived with the Paez for 20 years. He has been instrumental in giving direction to the Leapfrog Project. As an anthropologist with intimate understanding of the Paez, he helps to determine how renewable energies can best be incorporated into their culture. His personal connections to the highest levels of Paez Government, Colombian Government, media and financial resources gain support for the project's success and future replication.

Aprotec
Jesus "Bijou" Gomez is an engineer, STI Associate, and president of Aprotec, Inc., Cali, Colombia. Bijou is a graduate of STI's Photovoltaic, Micro Hydro, and Wind Power Programs. He is STI's chief liaison in Colombia. He facilitated establishment of STI's relationship with the Paez through Mauricio Puerta and gathered pertinent information and letters of endorsement for the project.

Bijou performed the in-country needs assessment leading to definition of the project and arranged all in-country logistics for the on-site installation. He provided on-site user training to the Paez. Aprotec will provide the critical follow-up work on-site to ensure the system continues to perform reliably and that the Paez understand its proper use.

Replicating the Process
Renewable energies can serve people for many applications. There are many different technologies available: sun, wind, water. Each project has its own character, culture, needs, resources, technology, and logistics.

By replicating the software, rather than the hardware, we can derive an infinite number of solutions; each being uniquely appropriate for its users and their particular needs.

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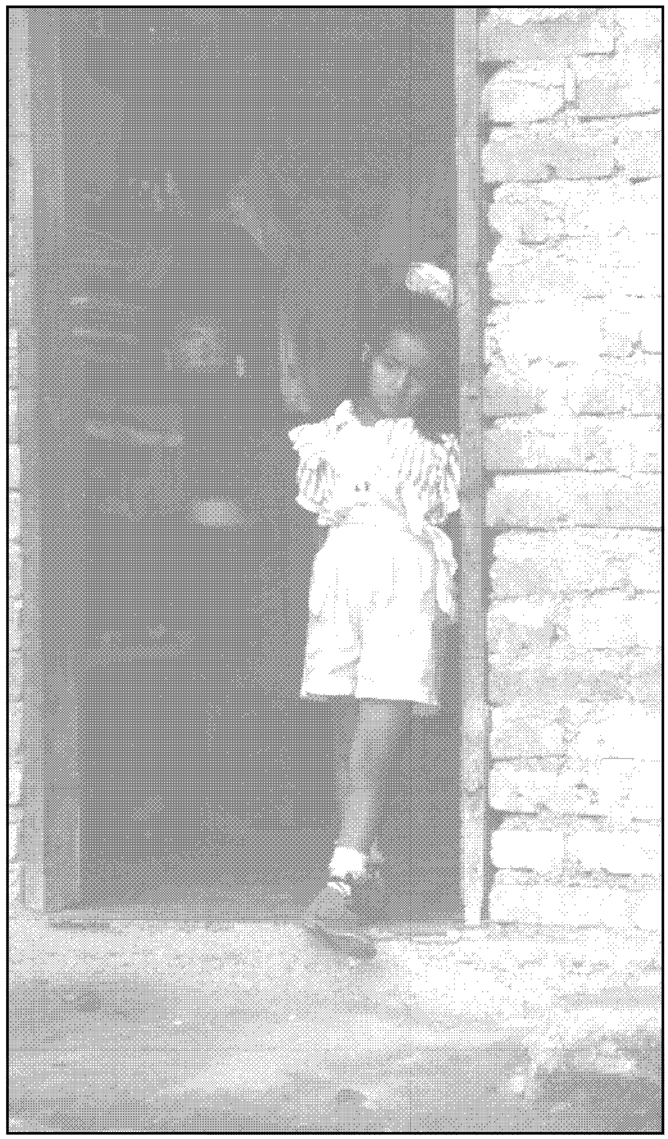

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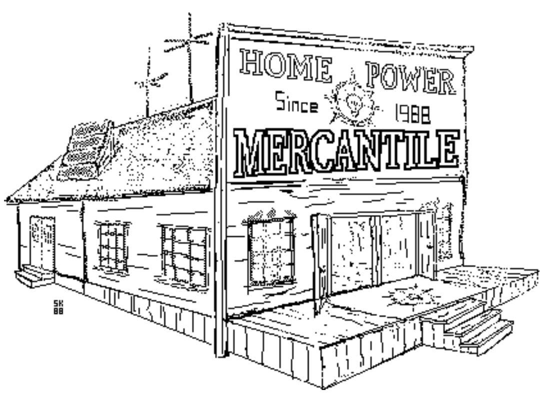

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