The Grand Experiment AKA MREF 2000

Tehri and Roak Parker

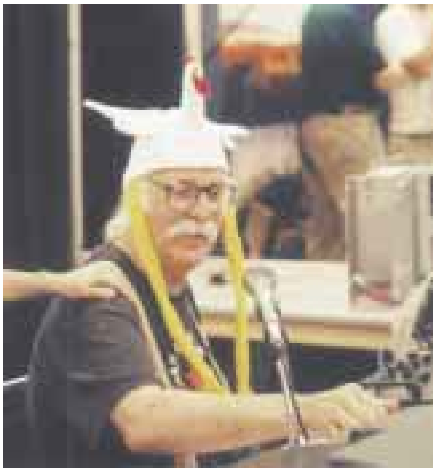
It was dubbed "the grand experiment" by Mick Sagrillo, noted wind guru and president of the Midwest Renewable Energy Association (MREA). In June, the MREA took the 2000 Midwest Renewable Energy Fair (the largest renewable energy fair in the known universe) on the road to Madison, Wisconsin.

This experiment was loaded with "research" questions. Could the MREA move our hometown energy fair from the sleepy burg of Amherst to the bustling metropolis of Madison? Would our exhibitors, vendors, and fairgoers follow us to a new location? Would our members support the move? If we built it, would they come? Would the staff revolt? Could we pay the bills? What would *Home Power* say? Were we crazy enough to pull it off?

The Hypothesis

Moving the fair to Madison for a year was a bold decision for our organization, and one that we did not take lightly. Countless hours over several years were spent at board and committee meetings discussing the pros and cons of moving the fair. Budgets were prepared (and re-prepared), plans were made (and re-made), scouting trips were taken (and re-taken). In the end, the board decided that we should give it a try, for one fair, in Madison.

We hypothesized that by taking the fair to an urban area, we would be able to reach a new audience. Madison, Wisconsin is the closest big city to our home



Rogers Keene hosts Rooster Radio—news, music, commentary, personal ads, and jokes.

in Amherst, and is a liberal and friendly city—an easy choice for our first road trip. We knew that we would draw new fairgoers from Madison, and hoped that we would tap into the large metro areas that are within easy driving distance of Madison (Milwaukee, Chicago, Rockford, etc.). With an airport in Madison, we also could try to stimulate interest from farther afield.

The Madison location also allowed us to host the American Solar Energy Society's Solar 2000 conference. By combining our fair with the Solar 2000 conference, we felt that we would be able to draw solar professionals and academics to the fair. We would also open up the ASES offerings to our typical audience of homeowners and do-it-yourselfers.

The Experimental Design

Volunteers, staff, and board members worked long hours at this year's fair. But the real work of putting on the event was the planning and design, which occurred in the months and years before the fair. We started with a new and improved name. The official title of this year's event was the Midwest Renewable Energy Association's Renewable Energy and Sustainable Living Fair. (OK, we knew it was a mouthful when we chose it.)

Our intention was to develop a title that our old friends would recognize (hence the first six words), while at the same time expanding the title to include a broader range of topics. We felt that the new title, while a bit wordy, more accurately described what actually happens at the fair—renewable energy and sustainable living. We also believed it would draw a broader audience to the event.

A site had to be chosen for the fair. After a great deal of shopping around and negotiating, we settled on the Dane County Expo Center. This site, while not ideal, had many great attributes. First, the setup of the Expo Center let us control access to the fair (something no available outdoor site in Madison could offer). Controlled access is a priority at the fair because the revenue we make from admissions needs to sustain the organization throughout the year.

The Expo Center also had great rooms for our workshops, complete with AV equipment and plenty of seating. Finally, it was one of the few places in Madison where we could offer on-site camping. In short, the Expo Center had everything except atmosphere. We realized that creating a festival atmosphere in a concrete building would be a challenge, but with no better site available, we set our minds to the task.

Gary Chemelewski of Exeltech takes time for the details.

Bil Becker, a professor at the University of Illinois, Chicago (UIC), became our major "atmosphere volunteer." He led a group of graduate students and UIC alumni in the design and construction of exhibition

Ian and Don spread the word at the *Home Power* booth.

Steve Wilke promotes Bergey's new bird.

structures that emulated the towers and tents that have come to represent the fair. The completed structures included five 20 foot towers with fair banners, information kiosks, and bookshelves. The central meeting place was a 30 by 40 foot geodesic dome tent—the village square.

We also set about to increase the "meat" of the fair (sorry vegans). New educational offerings were planned. For beginners, we developed a series of short introductory discussions to be held in the village square. These discussions covered a wide range of topics from electrical utility deregulation to building stone circles. To meet the needs of more advanced students and Solar 2000 attendees, extended half day and full day workshops were developed.

And finally, for folks wanting to learn about living with renewable energy, we planned "homeowner poster sessions." Homeowners were invited to show photos of their houses and systems, share stories about living with renewables, and answer questions in a small group setting.

The Test

The grand experiment became a grand reality on the weekend of June 16–18, 2000. Throughout the weekend, over 15,000 people visited the fair (a 23% increase from 1999).

Attendees came from every state in the U.S. except Mississippi. They traveled from nearly forty countries, including Nicaragua, Cuba, Scotland, Panama, Mexico,

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MREF 2000 RE Gear Report

Joe Schwartz

Many RE equipment manufacturers unveil new products at the Midwest Renewable Energy Fair. MREF 2000 presented happy fairgoers with a windfall of new RE hardware. Here's some gear that stood out.

Hydro

If I had to pick the renewable energy source with the most significant hardware advances in the past year, it would be small-scale hydro—without a doubt. Five new machines are making their way into the RE market. And three of them address the all too common dilemma of what to do with a low-head hydro site.

Ron McLeod's Nautilus uses a Francis runner to fill the low head-high flow niche.

Ron MacLeod's Nautilus hydro turbine turned more heads at the fair than any other piece of hardware. The turbine housing's scroll design is nothing short of beautiful. It has an enticingly organic look to it. Picture the spirals of a seashell in cleanly welded stainless steel. Ron has worked with utility-scale hydro turbines for over twenty years, and his new turbines reflect his expertise.

MacLeod's line of turbines are sized for large residential to village-scale hydroelectric generation. The Nautilus is an ultra low head, Francis-style turbine. It's designed for sites with 4 to 18 feet (1.2–5.5 m) of head. Two runner sizes are available, eight and ten inch (20 and 25 cm). At 1,330 gallons per minute (2.98 cf/s; 84 l/s), the 10 inch runner is capable of a 550 watt output with

Left: Efficient and natural building materials round out the energy focus.

Right: Traditional skills are the backbone of sustainable living.

Japan, China, Canada, Turkey, Australia, India, Kenya, and South Africa. A whopping 75 percent of the people at the fair were first time fairgoers. Two hundred and fifty Solar 2000 conference attendees (almost one third of their total attendance) visited the fair for at least a day.

There were also a record number of exhibitors at this year's fair. A total of 208 exhibit booths were sold to 149 different exhibitors. Twenty five new exhibitors joined us this year, including manufacturers like Kyocera, sales booths like The Chi Machine, and non-profits like Midwest Organic and Sustainable Education Services.

Over 100 workshops were offered throughout the weekend. Topics ranged from the technical to the philosophical. Sixteen introductory discussions were held under the dome in the village square (our central meeting place). The seven half-day and full-day workshops we offered were attended by 167 people.

This was also a year of great media events and fantastic keynote speakers. On Friday, Talk of the Nation's *Science Friday* broadcast live from the fair.

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a head or vertical drop of only four feet (1.2 m). Maximum output of the turbine is 3.5 KW. MacLeod is also manufacturing an open flume turbine called the Neptune. It has similar head, flow, and output characteristics. The Nautilus turbine displayed at the fair even had the flatlanders wishing they had 1,500 gallons per minute to spare!

Paul Cunningham and Bob Fife from Energy Systems & Design (ES&D) came down from New Brunswick, Canada to attend the fair. They displayed two new hydro turbine designs, along with their popular Stream Engine turbine. Like MacLeod, Cunningham has been hard at work drawing amps out of low-head hydro sites. His new low-head turbine produces 200 watts at roughly 700 gpm with only 3 feet (0.9 m) of head. At 9 feet (2.7 m) of head, the turbine's output can be over 1,000 watts. ES&D's low-head turbine uses the same field-proven permanent magnet alternator as their Stream Engine.

On the other end of the hydro spectrum, ES&D has also come up with a new high-head, low-flow turbine design. This turbine, called the Water Baby, will retail for about half the cost of ES&D's Stream Engine. ES&D is ramping up production for both of their new machines.

While Don Harris from Harris Hydroelectric wasn't displaying, we were all happy to see him at the fair. Don's been working on a new permanent magnet alternator for his turbine that promises great efficiency and durability coupled with a Pelton-style runner. Keep an eye out for this turbine as well.

Wind

Above water, two new wind gennys were displayed at MREF 2000. Tod Hanley and Steve Wilke from Bergey Windpower gave fair attendees the full tour of Bergey's new wind turbine (soon to be in production). The Bergey XL.1 is a low-cost, residential-scale machine backed by a full five year warranty. The turbine has an 8.2 foot (2.5 m) rotor diameter and a relatively low rated rotor speed of 490 rpm at 24.6 mph (11 m/s). The XL.1 includes their new "PowerCenter Multi-Function Controller." This controller incorporates an electronic boost circuit reported to increase turbine output at low wind speeds. It was a treat to have Tod Hanley, the turbine's design engineer, on hand. Tod provided detailed and thorough answers to fairgoers' technical questions related to the XL.1.

Host Ira Flato interviewed fair workshop presenters, entertained questions from the fair audience, and fielded calls from across the U.S. Mark Hertsgaard, NPR correspondent and author of *Earth Odyssey,* the story of his global journey to investigate environmental crises, was a guest on *Science Friday.*

Hertsgaard also presented a keynote speech at the fair on Saturday. More than 500 people attended the keynote to learn more about the environmental crisis facing the planet. The closing speaker for the fair was Green Party vice presidential candidate Winona LaDuke. LaDuke spoke to a full house (about 800 people) on our connection with the Earth, and how it should guide our actions.

During the fair, Rob Roy built a replica of Stonehenge out of straw bales and planks in the village square. Rogers Keene hosted Rooster Radio, an in-house broadcast that featured news, music, commentary, personal ads, and jokes. Doodle Doo, the fair's official mascot, was spotted around the Expo hall riding wind generators, sitting on solar panels, and making the world safe for renewables.

Footprint Follies, a group of performance artists and activists from Milwaukee, paraded through the fair on stilts, banging drums, fifing fifes, and explaining our "ecological footprint." And Puppet Farm, a children's entertainment group out of northern Wisconsin, brought Sunny the giant bicycle riding puppet, built a 25 foot tall rooster out of recycled plastic, and lead a march against the Corporate Rats.

The Results

So, what are the results of the grand experiment? Was the fair a success? You bet. We moved the fair to an urban area, drew in a new audience, hosted the Solar 2000 conference, and lived to tell about it. We also made a lasting impression on the city of Madison.

Bergey's new XL.1

African Windpower, out of Harare, Zimbabwe had a 1 KW turbine on display at the Dankoff Solar booth. Although AWP's turbines are not currently being commercially imported into the U.S., the machine is impressive, and would be a welcome addition to the U.S. wind market. The turbine is the result of the "heavy metal" approach to wind turbine design. It is large, heavy, low rpm, and quiet. The turbine has a 11.8 foot (3.6 m) rotor diameter and a very low rated rotor speed of approximately 400 rpm at 26 mph (12 m/s). This is a large rotor diameter for a 1 KW peak machine, making it an exceptional performer in the low to moderate windspeed regimes common in many locations.

Inverters

In 1993, Trace Engineering revolutionized the RE industry with their SW-series inverters. It looks like they're about to do it again. Trace debuted their new Sun Tie (ST) line of batteryless, utility interactive inverters at the fair. These inverters are targeting the rapidly growing market for grid-tied photovoltaic generation. Four models of ST inverters are available: 1, 1.5, 2, and 2.5 KVA.

The ST is designed to accept output from both traditional crystalline and new thin film modules (up to 125 VDC open circuit). The conversion efficiency of the ST inverters is over 90 percent, and peaks as high as 94 percent. Maximum power point tracking (MPPT) circuitry samples the array voltage and current once a minute, adding to the net efficiency.

All ST-series inverters include both DC and AC disconnects, and overcurrent protection via circuit breakers. This eliminates the need for any additional protective devices in most applications. The 1.5 and 2.5 KVA units feature onboard PV ground fault protection, a fused PV combiner board, and a surge arrestor. An optional futuristic-looking rain shield is available for all units, allowing outdoor mounting of the inverter in exposed locations.

Vanner Power Group also introduced their new RE24-4500 DGT inverter at the fair. The RE24-4500 DGT is a 4,500 KVA utility interactive, battery-based inverter. A unique feature of this inverter is its split-phase 120/240 VAC output. This allows you to run both 120 and 240 VAC appliances from the same inverter, which isn't possible using any other inverter on the market. The inverter has a true sine wave output, and peaks at 90 percent efficiency in utility interactive mode, and 92 percent when inverting.

During the week that the fair and Solar 2000 were in town, the Dane County Board of Supervisors declared Madison the Renewable Energy Capital of the World. June 14–21 was also proclaimed Renewable Energy Week by both the mayor of Madison, and the Dane County Executive.

Probably the most important legacy left behind by the fair is the 5 kilowatt photovoltaic array that was installed on top of the Arena at the Expo Center. This array will remain on the building, providing clean, quiet renewable energy for the citizens of Madison through Madison Gas & Electric's green power program.

Are we taking the fair to Madison next year? Nope. This was a one year move right from the start. While Madison was a great fair and a great learning experience for us, it was also significantly more work than putting on the fair in Amherst. And of course it did not have that hometown fair flavor. We are happy to be returning to Amherst for 2001.

Will we ever take the fair to an urban again in the future? Well, that remains to be seen. It is not out of the question, but for now our mantra is "There's no place like home!" Don't miss next year's Midwest Renewable Energy Association's Renewable Energy and Sustainable Living Fair, June 22–24, in Amherst, Wisconsin.

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Two additional modules are available to complement the RE24 inverter. A DC power center provides breakers for DC inputs, DC loads, inverter to battery wire runs, and metering. An AC module includes AC breakers and a generator/utility grid interface. Each module enclosure incorporates parallel raceways for a super clean installation. The electricians in the crowd all gave these spacious enclosures and raceways the big thumbs up.

There's More
Hal Newman represented UniRac, and their new line of PV mounts. Both roof/ground and top-of-pole mounts were displayed. UniRac has streamlined the parts count in their mounts. The result is a low cost PV mount that's modular in nature and relatively inexpensive to produce.

With all the promising new RE equipment on display this year at MREF, it was difficult to take it all in. I'm sure there's some new gear that I missed. What to do? Make the trip to the Midwest Renewable Energy Fair next year and check it out for yourself!

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Solar-Powered ARRL Field Day 2000

Roy Butler (KC2FSW),
with Debbi Koehler (KB2WEY)

Author Roy Butler, right, and Roy Koehler, KLARA president, left.

When I joined my local amateur radio association in February, I introduced myself as KC2FSW, and the owner of Four Winds Renewable Energy. Several of the members asked me, "Does that solar stuff really work?" Well, I hear this question almost every day in my business, and the best answer I've found so far is to show 'em. When I found out about the association's Field Day, and that extra contest points were awarded for the use of solar power, I saw the perfect opportunity to demonstrate what solar energy could really do!

During the last weekend of June, ham radio operators all over the U.S. gear up to set long distance contact records and practice emergency communications skills. During this annual event, amateur radio operators set up field radio communications stations, get on the air, and contact thousands of other operators in the U.S. and Canada.

Field Day

The ARRL Field Organization has been effective in establishing emergency communications nets during floods, hurricanes, fires, earthquakes, and other major disasters. Members of formal emergency organizations such as the Amateur Radio Emergency Service (ARES) and the Radio Amateur Communications Emergency Services (RACES) regularly participate. Field Day is a competition as well as a trial run for emergency communication skills used during disaster situations. The ARRL estimates that more than 35,000 hams participate in Field Day every year.

On June 24th and 25th, the Keuka Lake Amateur Radio Association (KLARA) set up operations on a 170 acre hilltop farm. The farm is owned by New Life Homes-Snell Farm, a group home for adolescent boys ages 12 to 18, and is located between Howard and Bath, New York. Debbi Koehler is an active member of KLARA and works at Snell Farm. She helped make arrangements for KLARA to use the site for the Field Day.

Roy Koehler, Debbi's husband and KLARA president, says, "It's a great way to fine-tune our emergency communication skills. We use generators and solar collectors for power, and set up antennas in fields and trees. Our goal is to put together self-sufficient, working stations quickly and begin making contacts. We also enjoyed introducing the boys at New Life Homes-Snell Farm to the wonderful world of ham radio."

Setting Up

The day before the event, the Four Winds crew and some of the KLARA club members set up a 256 watt Uni-Solar array (four US-64s) and a Whisper H500 wind generator on my 10 foot demo tilt-up tower. The EZ-Wire Center that comes with the Whisper was also used as the solar charge controller, system monitor, and DC load center. A Brand Power Meter monitored the output of the Portawattz 1000 inverter, which powered an old Tempo-1 tube rig. Four ancient 220 amp-hour golf cart batteries were used for our 12 volt battery bank.

I didn't really expect to get any serious power out of the wind generator with that wimpy 10 foot tower, and I wasn't disappointed. I didn't have the opportunity to evaluate the event site for wind potential beforehand. When I arrived on site and saw the trees, I knew right

ARRL Field Day Transmitter Details

Band (Meters)	*Mode*	*Power Source*
80	CW	5 KW Kohler generator
40	CW	12 V battery
20	CW	5 KW Kohler generator
15	CW	5 KW Kohler generator
80	Phone	Solar
40	Phone	Solar
20	Phone	Solar
10*	Phone	Solar
6	Phone	Solar
2	Phone	Solar

*Mike Hanna's personal solar-electric setup.

away there was little wind power potential at the 10 foot level.

I decided to set it up anyway, primarily to show off the wind generator and the demo tilt-up tower. I let everyone know that this was *not* the right way to install a wind generator, and not to expect too much. Our total wind power production for the event: zero! Next year I'll either increase the size of the solar array or try to get a wind genny above those trees.

The only serious problem we encountered during the event was power distribution. Logic dictates grouping the radio stations close together for ease of wiring and limiting line loss. But if we'd planned the distribution system for our wiring convenience, the stations would have been so close that RF interference would have been excessive.

The solution was to locate the CW radio stations at the far end of the field. We would then power them with the generator in the camper used by the club secretary (aka "the old man"). His RV has a Kohler generator to power his radio (and his air conditioner!).

Sun & Clouds

For the first day of the event, we had good solid sun. When the contest started at 1 PM, we were getting 16 amps of solar power to the batteries. We averaged 6 to 9 amps of DC load for most of the day, and the solar kept right up with that, with a total for the day of 96 amp-hours to the batteries.

After sundown, the power draw decreased, since most of the operators shut down for the night. We discharged the batteries 30 percent on the first day. The second day of the event was heavily overcast, with a maximum array output of 4 to 5 amps. By the time the contest officially closed at 1 PM, we had managed to get about 20 amp-hours into the batteries. The batteries had been discharged a total of 45 percent.

ARRL Field Day at New Life Homes-Snell Farm.

Our PV system was able to provide power for a total of five amateur radio stations for the 24 hour contest period. Mike Hanna brought his own separate solar-electric system to power his transmitter. An interesting side note: The only non solid-state radio at the event was a Tempo-1, a multi-band HF tube radio (which doubles as a space heater—just kidding, Glenn!). It consumed 186 watts in receive mode and over 300 in transmit mode! The Brand Power Meter showed a usage of 2,088 watt-hours for a duty cycle of eight hours in receive and two hours in transmit. Now here's a good demonstration for energy efficiency if I ever saw one. With the usage of all solid-state radios, we would have had little or no net discharge to the battery bank!

Talking Solar

There were ten operators at the event, and twenty-five guests. Seven transmitters were in action. We made three hundred contacts, and they included over twenty U.S. states, Canadian provinces, the USS Yorktown, and Zambia and Johannesburg, South Africa. Our group doesn't do Field Day primarily for "points," as many ARRL groups do. But if they gave out points for having fun, we'd be strong contenders.

I'm already looking forward to next year's event. We're going to pull out all the stops and solar power all the radios, *and* the coffee maker. I'm not so sure about the old man's air conditioner though! Anyway, it looks like we have a bunch of hams who now believe in the potential of solar energy!

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Things That Work

Tested by Home Power

When I first moved to Vashon Island, Washington this past May, my RV home was parked in the trees for three weeks, with no sun on the PVs. So I had to use as little energy as possible. I tried candles for light, but they weren't quite bright enough for me to see my laptop keyboard. No problem—I had a Solaris™ solar lantern kickin' around. Every cloud has a silver lining, and this one was fluorescent.

School of Hard Knocks

This is one burly unit—it has survived over six months of bouncing around in my roving RV. Once, I left it on top of the loft over the cab and I drove off. It rolled off the loft, bounced off the cat landing platform, hit the floor, and rolled to the back of the rig, colliding with everything in its path.

I heard the thumping in the back as I was driving down the curving mountain roads, but I had no idea what was bouncing around. I pulled over to check it out. When I saw the lantern on the floor in the back, I was worried. But nothing was broken, and the light came on (as it always does) when I flipped the switch.

Well Designed

The Solaris lantern is lightweight and very portable. The switch is easy to find in the dark—it's right on top of the unit under the handle. I like the handle because it's easy to grab, comfortable to carry, and can be hung up on a hook. The bright yellow case makes it easy to find when it's getting dark. With the clear saucer-shaped plastic disc above the bulb, the light is not blinding.

The U-shaped compact fluorescent (CF) bulb is well protected inside the unit. Because CFs are very efficient, the charge on the battery pack lasts a long time. It gets 4.5 to 6 hours of run time per full charge, and takes 2 to 3 hours in bright sunlight for each hour of run time. This lantern has an active low voltage disconnect (LVD), which prevents overdischarging the batteries. When the voltage gets low, the LVD activates and the light shuts off.

The bulb is a 6 watt compact fluorescent that puts out 350 lumens initially and 430 lumens max. This bulb should last for years, but when I need to replace it, it will be easy to change. I'll just unscrew the top of the lantern from "lock" to "open," and lift out the old bulb.

Cool Features

This lantern has some neat features, but by far the coolest thing is that it comes with its own charging source. The LM-3 Uni-Solar triple-junction amorphous PV panel is 8-1/4 by 11-1/4 inches (21 x 29 cm), and is rated for 2.68 watts. It's small, but it's enough to trickle charge the battery and keep it full (if you keep the PV plugged in to the unit). It can also run small electronic devices like a radio, cassette player, or MP3 player.

With all the abuse I've heaped on this lantern, the only thing that has come loose is the jack where the solar panel cord plugs in to the base. All I've had to do is tighten the hex nut on the outside of the jack a couple of times and it's been fine.

This lantern has also been cat tested. For starters, the rugged plastic case is too tough for cat teeth to gnaw through. And while the unit weighs only about 2 pounds (0.9 kg), the base is heavier than the top, so it's not easy to tip over when rubbed against. With much persistence and chin rubbing, the lantern will tip over, but it stays lit and keeps on shining.

Gardening at Night via Solar Light

One night, the solar lantern really saved my butt. I had planned to leave my place on Vashon early the next morning to head down to Oregon for magazine deadline. I was on a tight schedule, and had several hundred dollars worth of black bamboo to plant before I left. I called up my friend Maddy. She came over and we started planting bamboo.

As with most projects, this one took much longer than we expected. Soon the sun had set, but we still had a lot of work to do. The solution was close by. I ran up the hill and brought back my solar lantern. We kept going until midnight, and so did the lantern.

Joy has seen the light—and it's solar-powered.

The lantern took a beating and got covered in dirt. Later I opened it up to check out the innards. I unscrewed both the top (bulb compartment) and bottom (battery compartment). All was clean and dry inside. Congratulations to the manufacturer—I found nice tight seals that are also easy to open.

User-Friendly Energy Storage

When I opened up the bottom of the lantern, I checked out the battery pack. The lantern uses Quest batteries, made by Harding Energy, Inc. The manufacturer claims at least 500 charges before the battery pack needs to be replaced. The battery pack in this unit is nickel metal hydride, which is really great because I can use as much light as I want and then charge the unit when there is sun. I don't have to completely discharge the battery each time I use the lantern, as I do with my two solar flashlights that use NiCd batteries.

Waterproof Charging

They say that if you don't like the weather in western Washington, wait five minutes. I love it when the weather changes, but a non-waterproof lantern does not. While the lantern is rugged and has a coated circuit board for water resistance, it is not completely waterproof. I wanted to keep the panel out in the sun and the lantern out of the weather.

I tried some different setups, with the panel outside and the lantern inside. Since the cord is only 6 feet (1.8 meters) long, there weren't many choices. It was just long enough to snake through the loft window in my RV, with the panel on the roof. Unfortunately, when the wind blows, the panel doesn't stay in place. I suppose I could homebrew a longer cord, but the standard cord is sealed coming from the PV, and it already has the correct male plug end.

On one visit to Agate Flat for magazine deadline, I put the lantern inside the trailer I was staying in, with the panel outside on the step. The wind blew the trailer door closed, slicing the insulation and creating a small bare spot on the wire. As I wrapped the wire in electrical tape, I brainstormed.

I needed something to keep the rain off the lantern while the panel was charging the battery. So I bought a Sterilite 20 quart (19 liter) plastic tub. The lantern fits well in the tub, with room to spare. The solar panel sits right on the recessed lid of the tub, and the wind hasn't blown it off so far. And while the lid fits snugly on the tub, there is a small gap on the edge for the cord to come out without getting pinched.

The tub works great. The one drawback is that the tub is the perfect size for perching, and when The Bean sits on the panel, the cat gets charged but the lantern battery doesn't.

Appropriate Technology

This solar lantern is a good example of appropriate technology. Recharging the battery pack right in the unit using solar energy is a great idea. It eliminates wasteful throw-away batteries, and the need for a separate battery charger.

The Solaris solar lantern with PV costs US$169 and is available from Light Corporation. The whole unit is portable and ruggedly built, and is useful for emergencies and everyday use, in homes and RVs, in boats and treehouses. Come to think of it, this lantern would be useful just about anywhere on the planet.

Access

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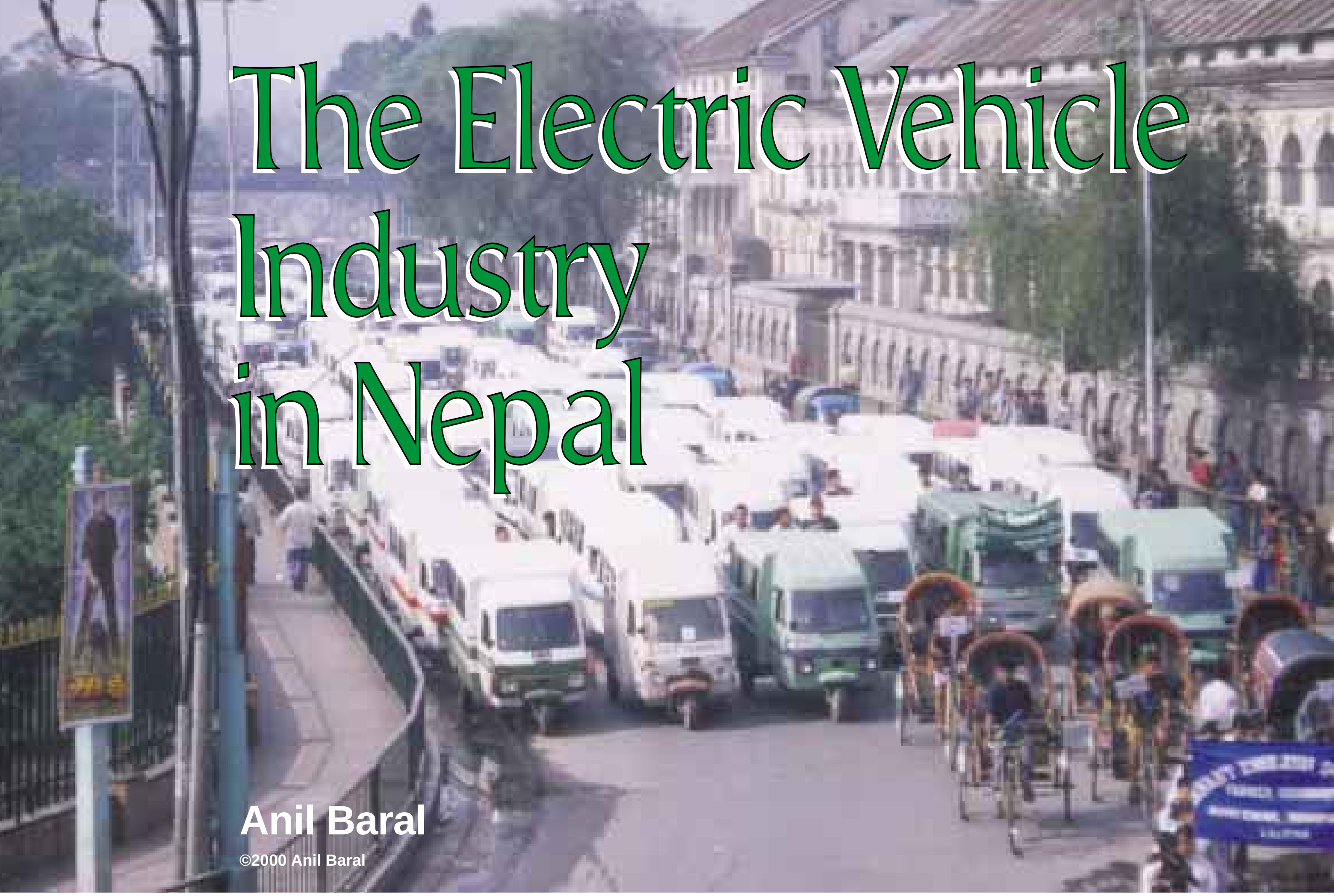
The Electric Vehicle Industry in Nepal



Anil Baral

Nepal was a forbidden land until the 1940s. As it opened to the outside world, tourists came pouring in to explore the untrodden land, virgin forests, rivers, lakes, and the majestic Himalayas. In the '80s, the symptoms of haphazard urban growth had begun to appear in Kathmandu, the capital of the country and entry gate to Nepal for tourists. Air pollution and traffic congestion from an increasing number of mostly old and worn out vehicles became everyday concerns of people in the Kathmandu valley.

Safa Tempo

Concerned authorities were grappling with these problems, and how to amend the tarnished image of Kathmandu in the international community. Then electric three wheelers—popularly known as safa tempos—came onto the scene. The term "safa tempo" is a Nepali name for a battery operated three wheeler. "Safa" in Nepali means "clean," since it is a zero emissions vehicle. "Tempo" is a generic name for three-wheeled vehicles.

Global Resources Institute (GRI), a U.S.-based non-profit NGO, built their three-wheeled model of a battery operated EV in the early 1990s. No one suspected that it could become a major force of public transportation and give a breath of fresh air to Kathmandu. In 1996, the GRI project ended and the private sector strode into the EV industry. Between then and now, the number of safa tempos on the roads has increased dramatically. This was due to government incentives and support for the EV industry, and the private sector's dogged determination to make it a financially viable venture—a feat seen nowhere else in the world. Currently, an impressive 550 safa tempos are providing public transportation.

A safa tempo is a small, three-wheeled vehicle used to provide public transportation service. Generally, low and middle income commuters use safa tempos as a means of daily transport. A few safa tempos are also being used in offices for ferrying staff, delivering mail, carrying solid wastes, and for hospital use.

The vehicle uses a 22 horsepower motor, and has a gross vehicle weight of about 1,050 kg (2,300 pounds), including one set of batteries. A safa tempo can carry

720 kg (1,600 pounds), which means twelve people including the driver. The maximum speed an empty safa tempo can attain is 40 km per hour (25 mph). The average speed with a full load of passengers is 25 km per hour (16 mph).

Cost Effective

These commercially operated electric vehicles are simple and low-cost technology in comparison to EVs operated elsewhere in the world. The cost of a safa tempo with two sets of batteries is either Rs. 505,000 (US$7,214) or Rs. 525,000 (US$7,500) depending upon the type of batteries installed. Safa tempos are assembled in Nepal, with the majority of parts coming from abroad. The chassis is from India, the motor is from England, and the batteries, DC-DC converter, speed controller, and metering come from the USA.

Two models of lead-acid batteries are being used in safa tempos in Nepal. They are Trojan T-105s and Trojan T-125s, both manufactured in California, USA. The T-105 gives a range of 55 to 60 km (34–37 miles) per charge, and the T-125 gives 65 to 70 km (40–43 miles) per charge.

Safa tempos run with twelve 6 volt batteries, for a total pack voltage of 72 volts. The cost of one set of Trojan T-105 batteries is about Rs. 60,000 (US$857), and one set of Trojan T-125 batteries is Rs. 70,000 (US$1,000). The capacity of the T-125s and T-105s for five hours of discharge is 197 and 187 ampere-hours respectively. Once the set of twelve batteries is discharged (which usually happens by noon), it is exchanged for a fully charged set of batteries at a charging station.

Private Sector Initiative

No safa tempos would be running today had the private sector not ventured courageously into this market and withstood the challenges. They played a key role in popularizing safa tempos by manufacturing the vehicles at a reasonable cost and providing associated services such as charging and maintenance in a cost-effective way. While EVs in other parts the world are far more expensive than gasoline vehicles, safa tempos are available at quite reasonable prices compared to their petrol and diesel versions.

The role of the private sector in infrastructure development for the EV industry is substantial. There are currently five EV manufacturing companies in Kathmandu, with a total production of about sixty per month. The investment capital for manufacturing came mainly from the entrepreneurs themselves, with only a small number of loans.

The operating cost of a safa tempo is Rs. 7 (approx. 10 cents) per kilometer, including depreciation cost of the batteries and vehicle, and a driver's salary. The average fare per km for a passenger is Rs. 1.25 (2 cents). A safa tempo carries a total of eleven passengers, and the average profit comes out be Rs. 6.75 (approx. 10 cents) per km. The average vehicle covers a distance of 110 to 130 km (68–81 miles) per day, so the profit per day comes to about Rs. 743–878 (approx. US$11–13) per day. The payback period is three to four years depending upon whether an entrepreneur has invested fully by himself or has borrowed from a bank.

The charging system infrastructure is also largely the result of private initiative. More than 75 percent of the chargers currently in use are manufactured in Nepal by four companies: Lotus Energy, Digitech, Everest Machinery and Electronic Complex, and Guraya. The technology of locally produced chargers ranges from manual to digital. The quality is quite comparable to those imported from abroad.

There are twenty-six charging stations located at different points along the routes. Charging stations are recording good profits. Martin Chautari (a non-profit advocacy organization) did a study, a project advocating alternative fuel vehicles (AFVs) in Nepal. It shows that twenty charging stations have been

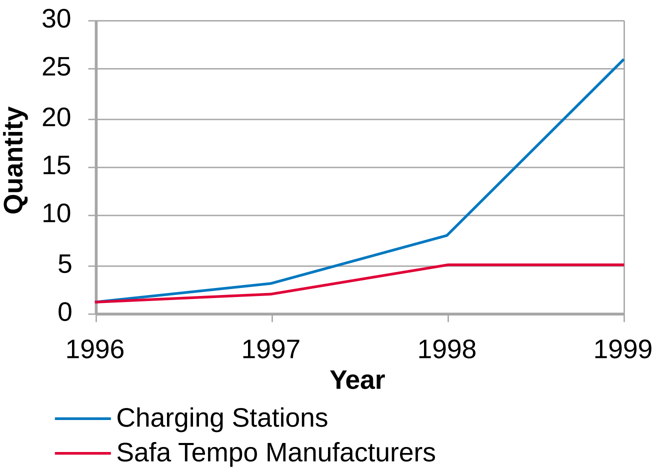
Safa tempo—Nepal's zero emissions, three-wheeled vehicle.

Partners—economic growth and environmental protection.

financed by the private sector entirely, while the remaining six charging stations have received loans from banks. The total investment in charging stations and safa tempo manufacturing alone has already exceeded Rs. 300 million (US$4.3 million).

The chassis for safa tempos have been imported from India. Now Hulas Motor Company and Kanchanjangha Auto Industry are developing a chassis to be built in Nepal. Other ancillary equipment for safa tempos is also manufactured in Nepal. These include pot boxes, forward/backward/reverse switches, and forklifts.

Growth of the EV Industry in Nepal



The EV industry is emerging as an important avenue of employment in the poverty ridden and resource-strained country of Nepal. According to a study conducted by Martin Chautari, there are 133 technical and nontechnical personnel employed in the 26 charging stations. Add to this the 550 jobs created for safa tempo drivers, and the jobs created by charger manufacturing, and the number looks quite impressive—well above 800 jobs.

Revenue generation from charging stations is also quite significant. Approximately Rs. 14 million (US$200,000) per year is collected by the Nepal Electricity Authority in revenues from 26 charging stations. As the EV industry expands, the possibility of employment generation in battery recycling plants within the country cannot be denied.

Institutional Structure & Support

The EV industry as a whole is forging ahead towards the process of institutionalization. To protect the interest of EV stakeholders, various institutions are emerging. There are associations of safa tempo owners, charging stations, drivers, and manufacturers. The most notable of them is Clean Locomotive Entrepreneurs' Association of Nepal (CLEAN), an association of safa tempo owners. It spearheaded the polluting vehicles drive-out campaign, and resisted the onslaughts of polluting vehicles (diesel Vikram tempos), which is quite remarkable.

CLEAN has made considerable inroads in improving quality service to customers, while at the same time creating a conducive environment for more safa tempos in the Kathmandu valley. The organization often acts as a mediator in resolving conflicts among manufacturers, owners, charging stations, and drivers, and unites all stakeholders for the betterment of the EV industry. The constitution of an umbrella organization of EV stakeholders is underway now. Many believe this will strengthen the position of the EV industry, and shield it from the threats of competition in the market from other means of transport.

The EV industry has also enjoyed considerable support from the outside. The government has provided incentives in the form of import duty concessions and VAT (value added tax) exemption for EV manufacturing. The charging stations have received concessions in

One of Kathmandu's 26 charging stations, which support 550 public EVs.

electricity tariffs from the government. The government has mandates under which banks are obliged to provide loans to the entrepreneurs who want to buy and operate safa tempos. Many entrepreneurs have benefited from this arrangement.

International institutions have also assisted in making the EV industry a commercially viable enterprise that helps combat worsening air pollution. USAID, through Global Resources Institute (GRI), played a key role in developing commercially feasible three-wheeler EV prototypes and demonstrating to the public the importance of EVs. Later, when commercial production and operation of EVs began, the Danish International Development Agency (DANIDA) got involved by making loans available for the purchase of safa tempos and setting up charging stations.

In a recent development, DANIDA has set aside an EV fund, through its Environment Sector Program Support (ESPS) project. It will initiate and support development of improved EV prototypes (three wheelers and four wheelers), studies to increase battery life, and local production of an EV chassis. The EV fund is also expected to provide training to mechanics, drivers, and owners, and environmental and technical upgrading of existing lead-acid battery recycling facilities within Nepal.

Diesel Vikram Tempo Ban

The decision to ban the operation of diesel-powered Vikram tempos because of their significant contribution to Kathmandu's worsening air pollution came as a boon for the EV industry in Nepal. (Vikram is a brand name for diesel and petrol-run three wheelers manufactured in India.) The demand for safa tempos soared after the ban, since more EVs were needed to fill the transportation gap. Within seven months after the ban, about 300 new safa tempos were brought to the market. At the end of April 2000, there were about 560 safa tempos on the streets of Kathmandu.

The decision to ban diesel tempos was hailed by environmentalists and the general public as a bold and progressive move. But there was criticism because the government chose microbuses (vans that seat 12–14 people) as a substitute for displaced tempos. As a concession, the government had decided to support displaced diesel tempo owners in importing microbuses (of Euro I standard) by providing concessions in import duty and VAT exemption.

Environmentalists felt that the government ought to have chosen the locally manufactured safa tempos as Vikram's substitutes rather than the microbuses. As it happened, the import of microbuses was delayed, and there was little competition to fill the gap. So more and more safa tempos came to the market.

Emerging Threats & Opportunities

The major technological constraint in operating safa tempos is the life of the batteries. Profit for safa tempo operators depends largely on this. In most cases, the batteries have survived for 450 cycles, which is quite low compared to what the manufacturer has claimed (754 cycles for the Trojan T-105). In a few cases, batteries could not run more than 300 cycles, which led to some operators going bankrupt. Also, the slow speed of the safa tempo has become an irritating factor to the traffic police in the Kathmandu valley.

The demand for safa tempos is gradually approaching the saturation point in Kathmandu. Unless new routes are opened up and opportunities for operating EVs in other cities of Nepal are explored, the demand for safa tempos is going to dwindle. There is also a need to explore and tap a market niche for four-wheeled EVs soon.

However, there is a light at the end of the tunnel. Manufacturers are gradually taking strides in promoting EVs outside the Kathmandu valley. Green Electric Vehicle (Pvt.) Limited has begun operation of safa tempos in the Lumbini area, the birthplace of the Lord Gautam Buddha, where diesel tempos are also banned. In Biratnagar, a city in eastern Nepal, one safa tempo has already been used to carry solid wastes for the municipality. Manufacturers are trying to introduce safa tempos for public transport there as well.

One emerging advantage of the EV industry is that it has become an opportunity for women to be employed as drivers. Already there are thirteen female safa tempo drivers, and many more are in the training process. Three institutes have been opened up to help women get driving training. Driving has traditionally been an occupation of men in Nepal. However, because EVs are a new technology, it has been easier for women to break social barriers and join the driving profession.

A working EV's daily ritual. Swapping in the second set of batteries at midday.

Industry Consolidation

The EV industry in Nepal is in the process of consolidation. It still requires support in the form of research and development, incentives, and infrastructure development and support. At a time when commercial operation of EVs is beyond imagination even in developed countries, it has become a relatively successful enterprise in Nepal. The case of safa tempos in Nepal shows that EVs need not necessarily be expensive. They can provide transportation at fares that even the poor can afford.

This has served as a good example of how economic growth and environmental protection can go hand in hand. The EV industry in Nepal has empowered women by generating employment in the driving sector while giving us great hope of combating air pollution. The industry has passed through a learning curve, and has begun to establish itself assertively in the market, providing employment as well as quality service to commuters.

Access

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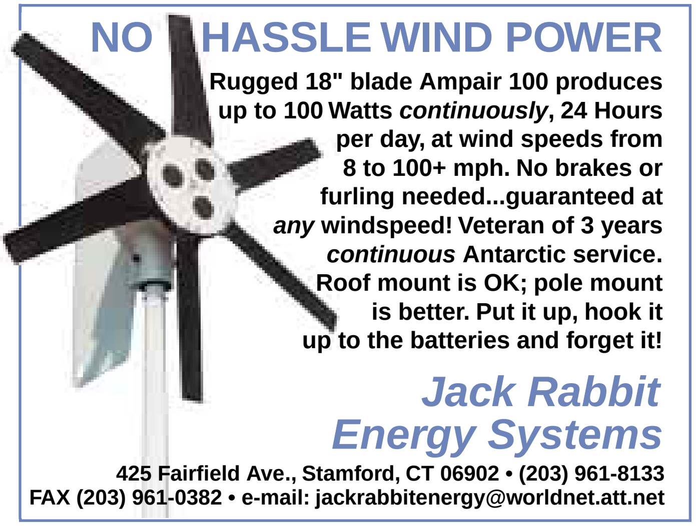
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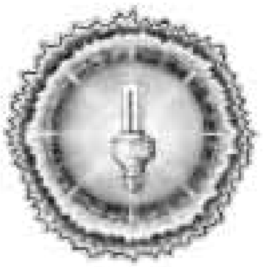

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TOP SECRET

GUERRILLA SOLAR:
The unauthorized placement of renewable energy on a utility grid.

PROFILE: 0011

DATE: August 9, 2000
LOCATION: Somewhere in the USA
INSTALLER NAME: Classified
OWNER NAME: Classified
INTERTIED UTILITY: Classified
SYSTEM SIZE: 3,840 watts of PV
PERCENT OF ANNUAL LOAD: 95%
TIME IN SERVICE: 9 months

Last year I asked my utility what it would take to convert to net metering. They responded, “The interconnection of residential renewable resource generation to our system is fairly new and uncommon, so we are in a learning process. I am working with the various departments that have a part in making this happen.”

Since I did not wish to be a test case, I went guerrilla.

The system I use has the capacity to supply most of our needs. All lamps are compact fluorescents, purchased from our local utility at a very low cost. I bought a Sears high efficiency fridge, and use propane for our stove and dryer. The house is heated by wood, with oil as backup.

I have also found a unique way of dealing with some of the phantom loads around the house. I use inexpensive converters (24 to 12 V) connected to the battery bank to power devices such as the answering machine, intercom, and clocks. This works for all devices that require a transformer to convert AC to DC. Our electrical energy consumption is about 10 KWH per day.

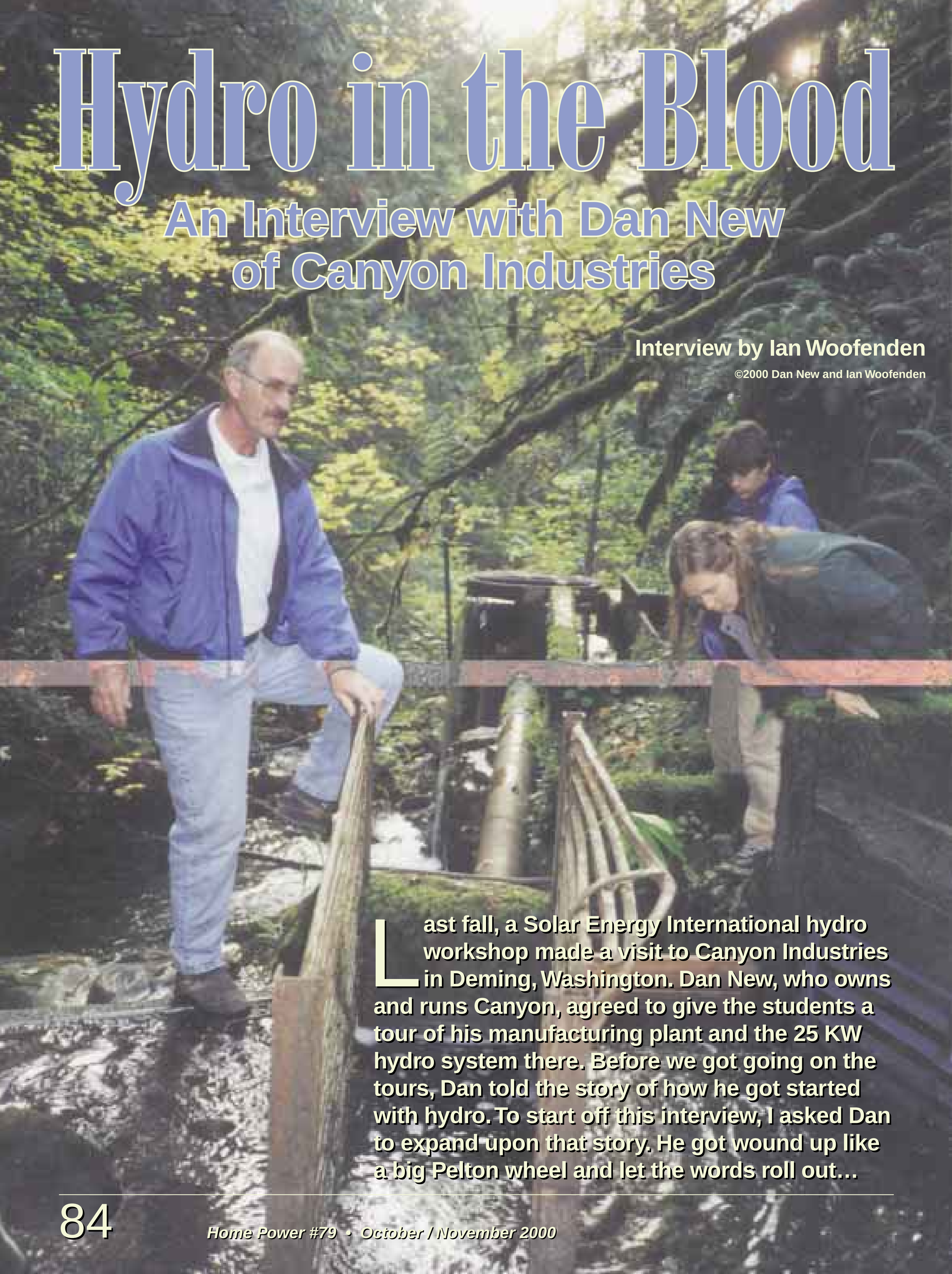
Our needs are met with thirty-two Kyocera KC-120s, which give us plenty of energy. I can often use the air conditioner at night, and still not use more kilowatt-hours than I put back into the grid. With this amount of solar energy, getting the energy from the arrays to the batteries was a challenge. I decided to use two pairs of 250 MCM cables and two fan-cooled Trace C-40 controllers running at a max of 55 amps each. I have one 24 volt 1,180 amp-hour Deka flooded battery, which supplies enough backup for three sunless days. The inverters are Trace SW4024s, one in use and one as a spare. I monitor my system with two C-40 displays and a TriMetric 2020.

With the Trace set for “sell,” my meter spins backwards at a rate of 2 KWH on a good day. Combining solar energy with energy efficient appliances and lighting has reduced our average bill from $180–250 per month to about $20 per month.

Even though there is a net metering law in my state, my local utility is using a data collection system that makes it impossible to net meter. They use wireless communications with their meters, and the system cannot recognize which way the meter is spinning. The more I use the grid for my energy, the faster my meter spins to the right and the faster my bill goes up. The more energy I put back into the grid, the faster the meter spins to the left and—guess what?—the faster my bill goes up.

The counting device doesn’t know which way the meter spins; all it knows is how many hash marks pass by. So I’m paying for any grid energy I use, AND for any solar energy I send back into the grid. Fortunately, I’ve reduced my consumption radically, and most of my usage is covered directly by my array.

For now I’m happy to have reduced my utility bills, and I enjoy the fact that I am utilizing natural pollution-free resources to generate my energy. When my utility company makes it easier to go through the process, I might go public with my RE system. In the meantime, I’m content to be a solar guerrilla.



Hydro in the Blood

An Interview with Dan New of Canyon Industries

Interview by Ian Woofenden

Last fall, a Solar Energy International hydro workshop made a visit to Canyon Industries in Deming, Washington. Dan New, who owns and runs Canyon, agreed to give the students a tour of his manufacturing plant and the 25 KW hydro system there. Before we got going on the tours, Dan told the story of how he got started with hydro. To start off this interview, I asked Dan to expand upon that story. He got wound up like a big Pelton wheel and let the words roll out…

In the mid sixties, my father was working to install his own hydroelectric system. Engineers at Puget Power told him it was not possible, that he had no idea what was involved, and that it was far too complex for the private citizen to understand. At the time, I was in my early twenties, and lots smarter than I am now. I told him I just couldn't understand why he was spending so much time and money on this hydro project. I told him he could just spend $500, get Puget Power lines into the place, and then get all the power he wanted for $15 a month for the rest of his life. Like many fathers, he was just too stubborn to listen.

My uncle took me aside, and explained that my dad had searched Oregon, Idaho, and Washington before buying the homestead in 1939, simply because it was best suited for a little hydro plant. During the second world war, my dad built airplanes at Boeing, and used his spare time to work on water turbine parts. As his family grew, my father had to put childish things like little hydro plants behind him, and support all of us instead.

So I quit bothering him. I gave him a hand off and on, but it was his project. I had no love for the work, or for the concept. I watched or helped while he hand built a little diversion in the stream, laid over 2,000 feet of 8 inch steel pipe, built a powerhouse, and worked in his shop on a Pelton wheel. I wasn't even around when he fired up the plant for the first time, on a day he described in his journal as a "red letter day," even going to the trouble of finding a red pencil to make the entry. I had no interest in the project when I visited him, or when I listened to him describe the virtues of having an abundance of "free electricity."

Dan with his Dad's original turbine—in the powerhouse where Dan had his hydro conversion experience.

During one of these visits, my dad said he needed to go down to the powerhouse to change nozzles. He explained that the stream flow was going down due to the recent dry spell, and that he needed to "nozzle down" to avoid taking too much water out of the stream. There were no restrictions to his licensed right to take 450 gpm from the creek, but he was always careful to keep a good flow going to "keep the fish cool."

It was dark as we walked the path down to the powerhouse, but the turbine was humming along, and the lights in the powerhouse were always on. My father slowly closed a big 8 inch gate valve, bringing the turbine to a stop, and putting us in the dim flashlight gloom. He quickly changed to a smaller nozzle, explaining things to me that I had no ear to hear. Once the new nozzle was in place, he said, "Start her up!"

A typical Canyon Pelton (75 KW) in a remote area of Papua New Guinea.

Dan and a Canyon employee with a Pelton wheel on the grinding and polishing stand.

Following his instruction, but with no enthusiasm, I slowly started to open the big gate valve. All the pressure on the penstock was against the closed valve, and I could feel this force as I began to open the valve. First there was the hiss of water, as the disc of the valve came off its seat. As the valve opened a little more, there was a louder sound, a "power" sound. Slowly the turbine shaft began to turn. I could hear the jet striking the buckets with a gentle flap flap sound.

I opened the valve a little more, and the speed increased. The jet was now a steady throb, and I added water until the throb became a buzz. The buzz quickly became a smooth hum, and the lights, like magic, returned to the powerhouse.

I've been hooked ever since. I loved hydro from that moment, and that affection has grown until I'm convinced that I have the best job possible.

What is it that keeps you excited about hydro?
Hydro is magic. I like the little teeny systems, and I'm excited by the kinda giant projects. I work with the neatest people, and hydro sites are always in the most beautiful parts of the world. The variables in sites, equipment design, and application are seemingly endless, and the good that hydro accomplishes is difficult to contest. What is it about the ocean, a lake, a river, or a creek that seems to draw the attention of all people? I don't know, but hydro holds the same fascination.

How did Canyon Industries get started?
After my father got his hydro going, people came asking him to build a very small turbine, just to charge batteries. He worked for years on a little turbine, setting up a test lab, and making design changes based on his tests.

The magazine *Popular Science* was doing an article on little water turbines, and interviewed my dad at his shop. My father died a month before the article came out, but the publicity generated by the story in *PS* in September of 1976 got Canyon Industries going. My son Richard and I now jointly run the business, which employs fifteen people.

A 15 KW Pelton turbine operating in Costa Rica.

What's your market?
We sell turbines throughout the world. Perhaps our biggest market is in Central and South America, but we have two larger turbines in the shop right now, one going to Ireland and one to Scotland. We have turbines in Papua New Guinea, Morocco, Zaire, Guatemala, and Colombia, just to name a few. North America accounts for the majority of the smaller micro turbine sales, but most of the larger turbines are shipped overseas.

Tell us about the turbines you make and sell.
We build two lines of turbines. Canyon has a number of turbines we call "standard" units. We use production practices to lower the costs of these standard units, and build several of each model at one time. These are the turbines in the size range of about 4 KW to 100 KW, and these are usually installed to provide electricity to remote homes, farms, ranches, retreats, or communities.

We also build larger units on a custom basis. These turbines, sized from about 100 KW to over 5,000 KW, are for remote communities, or for systems designed to tie into the national electric grid. Custom turbines are designed with highest efficiency in mind, and are built to be used at only one specific site.

A large (1,400 KW) Canyon Pelton turbine with two runners and four nozzles, operating near Idaho Falls, Idaho.

Do all of your turbines use Pelton wheels?
We build two types of turbines—the Pelton design, credited to the inventive engineer Lester Pelton, and the crossflow type, which is a design often referred to as the Banki or Mitchel turbine. The Pelton turbine is generally used at sites having something over 100 feet of head, but it may be used successfully at any head. Compared to other types of turbines, the Pelton uses quite small amounts of water, but can produce thousands of horsepower with very high heads. We currently have designs for Peltons up to 10,000 KW, but we build many Pelton turbines for projects generating under 10 KW.

The Canyon crossflow turbine is for projects that offer lower heads, say about 20 feet on up, but it can handle rather large amounts of water. By design, the crossflow is somewhat limited in power output. We build crossflow turbines for projects sized from 5 KW to 1,000 KW.

How are Canyon turbines manufactured? How much is done in-house?
We build every part of the turbine at Canyon, except for the foundry castings. All of the castings are made to our patterns and designs, but it takes a very good (and sometimes large) foundry to provide good castings. The Pelton turbine runners are all single piece castings, and we have patterns for over forty different designs.

The generators, controls, shafting, bearings, and other parts are all standard, but most other components of the turbines, such as housings, nozzles, seals, jet deflectors, and assembly bases, are fabricated in steel by artisans in our shop.

Our crossflow turbines are constructed entirely in our own shop, where we have lathes that will turn as large as 100 inches in diameter, computer numerically controlled (CNC) machine tools, shears, rolls, and a variety of welding machines.

What's the most challenging part of designing a quality turbine?
Boy, that's a tough question. The greatest challenge is to design a turbine that is the most efficient, most durable, and most affordable. With the standard turbines, we concentrate on building a rugged, compact unit, with reasonable efficiency. With the larger turbines, we have a bigger budget, which allows us to develop the highest possible efficiency. But even with the larger units, we must watch costs very closely, since we must compete on an international level.

As far as manufacturing, which part takes the most care and time?
With both Pelton and crossflow types, the most care goes into the design and manufacture of the wheel—what we call the runner. The runner is the heart of the turbine, and is the part of the machine that converts the energy of the water into the spinning of the turbine shaft. Of course, a good runner in a poorly constructed housing, perhaps with improperly built nozzles, will result in a mediocre turbine. They must all work together to get the most out of the water.

OK, so we have a pretty good view of why, who, and what you and Canyon Industries are. Let's talk more generally about small hydro power. What are the big hurdles for hydro power?
First off, we need to understand that not very many people can even consider a hydro project. Most people don't have a stream that's possible to develop with hydro. So the few people who are able to build a hydroelectric system are in a very small minority. Next in the line of hurdles is the need to maintain any stream so that it can continue to support flora and fauna.

After that comes the very difficult tasks of convincing the majority that the hydro system is a good idea, or at least permissible. The physical parts of a hydro project—diversion, pipe, turbine, and transmission line—are all easy to do, and offer a variety of choices.

For your average customer, are the politics more of a problem than the siting and equipment specification and installation?
Maybe "politics" is not the best word, but I know what you mean. You see, most streams are sort of public domain. So everyone has an interest in how that stream is used, maintained, and protected. That's a lot of interests, and there are few of us who are willing to see all sides. I'm a prime example. Show me a stream, and I automatically assess its hydro potential. Others see a stream, and feel it best that no one approach it for any reason.

Many others don't even know about the stream, but have strong opinions about how it may be used. So, with all these concerns, the "politics" of the project are often much more difficult to deal with than the actual work at the site.

What's to be done about that?
It may be that we need to teach people about electrical energy, and then let them decide where and how they want it generated. Despite the magic of hydro, there is truly no "free" electricity. A price must be paid for all forms of power generation: solar, hydro, wind, oil, coal, gas, or nuclear. What we seem to have, as we enter a new millennium, is a populace feeling that electricity is a basic human right, not to be denied anyone who regularly pays their power bill.

This same populace seems to be strongly opposed to any form of power production. I feel that education may assist all of us in making the best choices. Naturally, I feel that one of the best choices is hydro.

Let's talk about the small hydro industry a bit. How big an industry is it, and where does Canyon fit in?
Microhydro to small hydro is a very small industry. Remember, not many people have a stream in their back yards. Canyon probably provides 20 percent of all the micro to small turbines in the world, maybe 60 to 70 percent in the United States, and we're a very small company.

Is the market expanding, shrinking, or staying the same?
For Canyon, the U.S. market seems to be staying the same. The market in South and Central America is growing, as it is in parts of Europe, Australia, New Zealand, and Indonesia.

What does the future hold for small hydro?
The future is good for small hydro, worldwide. It makes sense, as it provides us with power at a comparatively low environmental cost.

What are your own personal hydro goals? Do you have designs, turbines, or systems that you hope to develop in the coming years?
For the last eight years, I've been studying the Francis turbine. Building a good, small Francis turbine is a personal goal, and I've infected just about everyone at Canyon with the idea. We expect to add this well-known design to our Pelton and crossflow types within the next two years, and I'm really excited about it.

What wise words do you have for people who want to use hydro and for people who want to work in the small hydro field?
Oh, Ian, you've saved the best question `til last. After getting me to ramble on and on, I can answer this one quickly and with enthusiasm—just do it!

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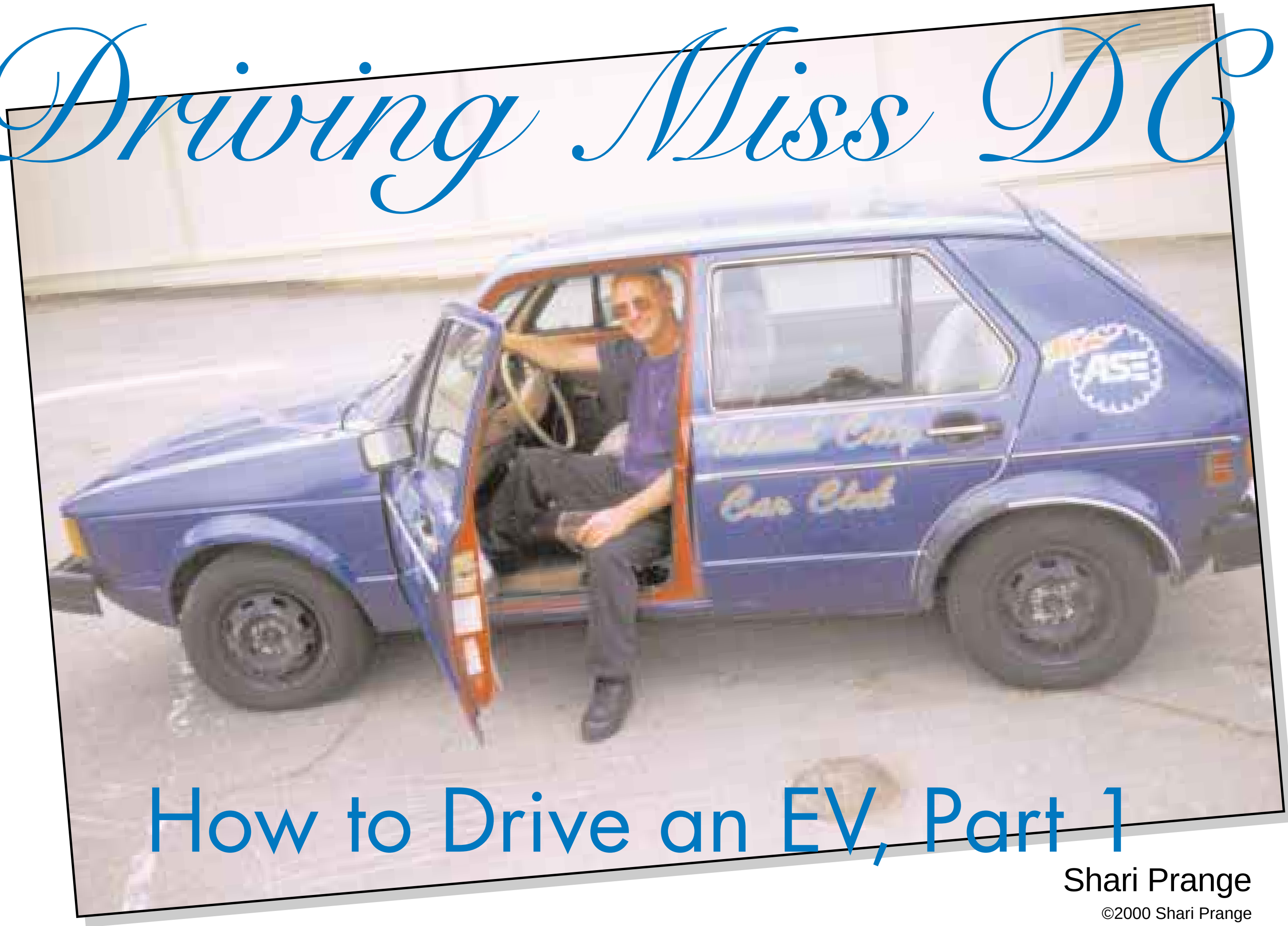
Driving Miss DC



How to Drive an EV, Part 1

Shari Prange

If you put two identical electric vehicles into service, one may get only a forty mile range, while the other gets eighty. Why?

Your EV's hardware controls its potential for performance. The combination of chassis, motor, controller, and batteries determines its maximum capabilities for speed, acceleration, and range. The last item—range—is actually the first priority for most EV drivers.

But what determines whether the EV actually reaches its potential in daily driving? The answer is the "wetware," which is you, the driver. There are simple techniques you can use to get the most out of your EV.

AC vs. DC

First, we need to make a distinction between manufactured EVs and conversions. Most manufactured EVs have several things in common that are different from most conversions. Manufactured EVs like the GM EV1 and the Honda EV Plus generally use AC drive systems set up so that the motor drives the wheels directly, drawing from a battery pack of about 300 volts. This means that there are no gears to shift.

These cars also have regenerative braking, which means that the motor creates drag to slow the car as soon as you take your foot off the throttle, just as a gas engine does. In the EV, the drag is used to generate a small amount of electricity, which is put back into the batteries.

The result is a car that drives very much like a gas car with an automatic transmission. Many of the tricks for optimizing performance are taken out of the driver's hands. This means that actual performance is more nearly uniform among manufactured EVs than among conversions.

Conversions, on the other hand, almost always use DC drive systems, manual transmissions, and battery systems in the 96 to 144 volt range. These systems are dramatically less expensive and more available to the hobbyist mechanic. Regenerative braking is also more difficult to achieve with a DC system than with an AC system, which is the reason it is not often found in conversions. This setup lends itself to some different driving techniques.

Since there are not many manufactured EVs on the roads yet, your experience is likely to be with a DC-powered conversion. So we'll concentrate on techniques for driving them.

Starting

When you turn the key on, nothing apparent happens—there is no sound. For this reason, many conversions have an “on” light on the dash. This is one of the car’s original warning lights, usually the alternator warning light, which has been rewired to turn on whenever the key is on.

Do not put the clutch in and rev the motor. For one thing, it just won’t make the same satisfying macho sound that a gas engine makes when you do this. For another thing, revving the electric motor with no load on it can overspeed and destroy it in the blink of an eye.

Unlike a gas car, you can start an EV from a stop without using the clutch. You can’t “kill” the electric motor the same way you would a gas engine. However, this makes for an abrupt, jerky, and unpleasant start. In some EVs, you can take off in second or third gear if you are lazy and don’t want to shift. This is not really a good idea though, because it draws a lot of current until you get up to the proper speed for that gear. This high current draw is hard on your components, and diminishes your range.

Your best bet is to start off just as you would in a gas car: engage the clutch, put the transmission into first gear, and release the clutch gently while depressing the throttle for a smooth, efficient takeoff.

Why Manual Transmissions & Clutches?

First, you need to understand that voltage equals speed. The higher the voltage to the motor, the faster it spins. AC motors can usually spin up to 12,000 rpm, or more, safely. It takes 300 volts to get them there, but it gives them a full range of road speeds from zero to freeway speeds without using a transmission.

The DC motors used in conversions top out at 5,000 or 6,000 rpm. They don’t need as much voltage to reach their rpm limit, but they do need multiple gears to provide a full range of road speeds for the vehicle.

Automatic transmissions have various problems that make them unpopular for conversions. One of these problems is that the shift points are poorly matched to electric motors. We’ll talk about this a little more later. If there is some reason you simply cannot operate a clutch, you can shift gears in a conversion without using it. However, it takes some practice to develop the right touch to do this smoothly, and it can be hard on the transmission. It’s a much better idea to use the clutch, the same way you would in a gas car.

Shift Points

But when should you shift? A practiced EV driver can recognize the shift points from the pitch of the soft whine from the motor, but this is much quieter and subtler than the sound of a gas engine. A beginner will be baffled by the lack of auditory cues.

Watch your gauges—as volts go up, amps go down.

Fortunately, the “redline” on the electric motor is very similar to the redline on the gas engine of most economy cars used for conversions. This means that the shift points are very similar. (The redline is the rpm limit above which you will damage the engine or motor. Don’t go there!)

For example, in a typical compact car conversion, first gear will be good up to about 25 mph (40 kph). Second gear extends to about 45 mph (72 kph), and covers the great majority of your driving needs. (If you cannot operate a clutch due to a physical problem, and you don’t ever need to drive on the freeway, you could simply leave the car in second gear all the time.) Third gear is good to about 65 mph (105 kph). Fourth gear will probably take the car as fast as it is capable of moving. Fifth gear is pretty unnecessary.

There is a formula you can use to determine the exact shift point for each gear in your car, and you can then mark them on your speedometer. This formula is:

$mph = (rpm \times r) \div (g_1 \times g_2 \times 168)$

mph = maximum speed for the specific gear

rpm = rated motor rpm at pack voltage

r = rolling radius of the drive wheel tires in inches

g_1 = gear ratio for the specific gear

g_2 = gear ratio of the vehicle’s differential (find it in your shop manual)

168 = constant value

This will give you the maximum speed you can safely drive in each gear. But that still doesn’t exactly answer the question of when to shift.

We already established that voltage equals speed. As you depress the throttle, the voltage to the motor increases, and it spins faster. At the bottom of the speed range for each gear (say, 25 mph for second gear), the motor is spinning more slowly. At the top of the speed range (45 mph for second gear), the motor is spinning as fast as it safely can—it's at or near its redline.

You need to know that electric motors work in the opposite way from gas engines, as far as efficiency is concerned. Gas engines are more efficient at low rpm. Electric motors are most efficient just under their redline. This is one reason why automatic transmissions are not good in EV conversions. They are designed to keep a gas engine running in the most efficient part of its rpm band, which means low rpm. But in an EV, the automatic will have the motor running at its least efficient rpm.

You can cruise at a steady 45 mph (72 kph) in either second or third gear. However, you will be much more efficient in second gear. The best technique for efficiency (which means the most range) is to drive as close as possible to the top of the speed band for each gear.

Efficiency Gauge

Is this confusing? Well, there's a handy "efficiency gauge" in EVs to help you understand it. It's the ammeter. This shows you the amperage you are using at any given moment. The higher the amperage, the less efficient you are running, so you want to keep the ammeter needle as low as possible. If you watch your voltmeter and ammeter side by side, you will quickly see that there is a relationship between the two. As volts go up, amps go down, and vice versa. Running at a high rpm is more efficient, and keeps the amperage low.

You can experiment by holding a steady speed and shifting up to a higher gear. You will see voltage fall off and amperage increase. You're traveling at the same speed, but burning more juice to do it.

Here's an extra credit item for advanced students. You can maintain a smoother speed and better efficiency if you keep the throttle partially depressed while shifting gears instead of lifting your foot off it entirely. Old racers call this speed shifting, and it helps keep the motor revs from falling off during the shift. However, it must be done carefully. Don't put the throttle down too far, and don't leave it there too long between gears, or you could overspeed the motor. If you don't feel confident about doing this trick, play it safe and lift your foot off the throttle completely for a moment while you shift.

The Sweet Spot

Electric motors can have a favorite speed they "want" to run at for a particular gear. This is not just anthropomorphizing. It has to do with how electric motors work. On flat ground, there is a spot that balances on the fine line between efficiency and safety. The motor revs are high enough to be efficient, but still low enough not to stress the motor by overspeeding it. If you are sensitive to the car, you will notice that it seems to run particularly smoothly and effortlessly at that speed.

If you have a load on the motor, like a slight uphill climb, the motor can actually limit its own speed. It works like this: when electricity flows through a motor, it creates a magnetic field, and the natural attraction and repulsion of the poles of this field make the motor armature and shaft spin. However, every motor is also generating electricity. The two processes are opposite sides of the same coin.

On the one hand, applying electricity to a motor creates a magnetic field, which causes the armature to spin. On the other hand, the motion of the conductive armature through the magnetic field induces an electric current. This is usually called the "back emf." The tricky part is that the induced current works in opposition to the applied current. The faster the motor spins, the greater the induced current, until it balances the applied current. At that point, the motor tends to self-regulate and maintain the same speed.

This is the zen of electric motors. What it means in real life is that sometimes, no matter how much more throttle you give it, the car just doesn't move any faster. You can mash the pedal to the floor, but it's just wasted effort.

This usually happens while climbing hills. The natural tendency is to step on the throttle harder, which is totally ineffective. Instead, try backing off the throttle to the point where the car starts to respond to it again. You may find, paradoxically, that you move faster with less throttle instead of more. You may also find that you make better progress if you shift to a lower gear.

Tune In Next Time

So far, we've covered the basics of getting an electric conversion started, in motion, and up to speed. We'll pause here to let you digest this information. Next time, we'll talk about strategies for dealing with different driving conditions, and braking to a stop. So if you've been following along in your EV while reading this article, I guess you'll just have to keep driving until the next installment comes out!

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