home power

The Hands-On Journal of Home-Made Power

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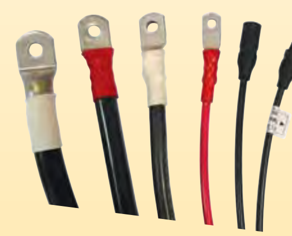

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On the Cover

Shawn Schreiner, with wife Claire and son Kai, installs itch-free cotton insulation made from recycled denim scraps and plastic fibers. For more on insulation options, see page 44.

Regulars

Changing the World

One Home at a Time

A few years ago, I approached a major solar equipment distributor for a donation of solar-electric modules for a demonstration project. My contact at the company responded that the industry is beyond the stage where demonstration projects are needed. I strongly disagreed. Until we have renewable energy (RE) systems in every neighborhood, we will not have outgrown the need for demonstration projects.

People are inspired by the positive examples set by other people. The most inspiring RE advocates don't just *talk* about how great RE is, they use it. Installing a renewable energy system on your home is the best first step toward a renewably powered community. If your home is visible to your neighbors, you'll likely have many opportunities to show off your system, educate the curious, and refer people to your favorite local system installer.

This renewable energy implementation plan doesn't depend on agencies, organizations, incentives, programs, politics, or even magazines. It depends on us as individuals. And it works. In my neighborhood, more and more people are installing RE systems. Ten years ago, it was tough to convince them. Now, I can point to more than a dozen modern systems within a few miles of my rural home. And I have to do less pointing than I did back then, because my neighbors are pointing at their own systems, and the word is spreading.

If we want to live in communities powered by renewable energy, we need to start by living in homes powered by renewable energy. Thanks to every one of you for setting this positive example, and sharing your passion and your results. Your commitment is contagious!

—Ian Woofenden for the *Home Power* crew

Think About It...

"It is not only what we do, but also what we do not do, for which we are accountable."

—Jean Baptiste Moliere

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Solar Innovation at the Capitol

Zeke Yewdall

Photos courtesy Chris Gunn & Stefano Paltera, Solar Decathlon

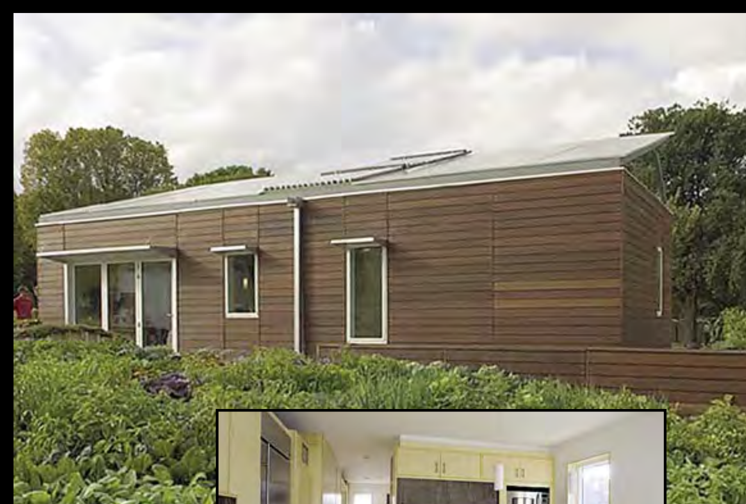
This past October, the U. S. Department of Energy sponsored the second Solar Decathlon competition. This university competition to build the best solar-powered house is held on the National Mall in Washington, D.C. Ten subcontests range from lighting to heating to operating a TV to running around town in an electric car charged from the house's solar-electric (photovoltaic; PV) array. This time, teams brought their houses from as far away as Madrid, Spain, and Pullman, Washington, and as close as College Park, Maryland.

After a few days of sunny weather for the teams to construct their houses and prepare, Mother Nature greeted the official opening of the solar village with 7 inches (18 cm) of rain, turning the entire mall into a swamp, with more water than land visible. This soggy opening day was followed by humidity, clouds, and rain for the following week. But anyone who lives in an off-grid solar house knows that life goes on, even when the sun goes away for a while. And so the competition went on.

The eighteen teams did their best to accomplish all their assigned tasks on battery power and what little sun they could catch. The solar houses were open for tours, and thousands of people came by to see the village. An hour after the official announcement of the winner at the end of the week, the sun came out again, for a glorious sunny weekend of public tours to end the event. Here's a taste of what each team brought to the competition.

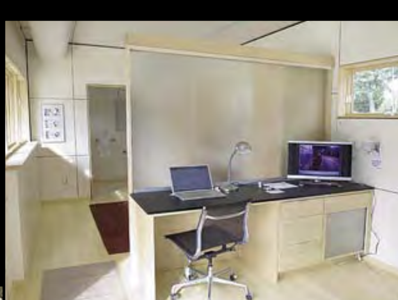
Colorado

The University of Colorado at Boulder and Denver upheld their winning title from 2002 with another first-place finish. As before, the house scored lower in architecture (6th), but excelled in the engineering, and in strategizing during the competition week. They also came in first in the documentation and communications contests. They chose a biobased materials emphasis (minimizing petroleum use), using SIPs (structural insulated panels) made partly from recycled cardboard and soybean oil-based foam, and using biodiesel in the semi-truck that pulled the house to Washington, D.C., from Colorado.



Cornell

Cornell University tied for second in architecture and dwelling, and came in second place overall. A unique feature of their house was the complete edible garden in the yard, from which they prepared all of the meals for the competition week. They came in first in the hot water and comfort zone contests. Part of their advantage over Colorado and Cal Poly was including dehumidifiers in the house—not something that people in the West even think about, but important when the humidity outside ranged from 75 to 96 percent.



Cal Poly

California Polytechnic State University, San Luis Obispo, tied for second in the architecture contests, and placed third overall. The engineering systems in their house performed well, and they were in second place for much of the competition, but the week of humid, cloudy weather was more than their batteries could handle on the last day. Despite this, they placed first in the appliances and lighting competition.

Virginia Tech

Virginia Polytechnic Institute and State University, another returning team from 2002, won the architecture and dwelling contests. The walls of their house used translucent aerogel insulation, lighted with multicolor LEDs to give a futuristic look. Unlike the winning three teams, they chose to conserve on energy a bit due to the cloudiness (as most users of stand-alone PV systems do). They didn't accomplish all of the contest's required household tasks, but they did make it to the end of the week without draining their batteries significantly. This gave them an extra 60 points in the energy balance competition, and put them in fourth place overall.

NYIT

New York Institute of Technology entered the competition with a compact two-story house, complete with a small roof garden, and a fuel cell to store energy. They tied for third place in the dwelling competition. A "green machine" pod houses the mechanical systems, the fuel cell and hydrogen storage, and the kitchen and bathroom. A roof garden provides space for growing food and collecting rainwater. The pod is attached to the living room, bedroom, and office via a sunspace. They also used many biobased building materials, including soy-based foam insulation and wheat straw building panels.

Fuel Cells

New York Institute of Technology used a hydrogen fuel cell instead of a large battery bank to store energy. A small battery bank was used to level loads, but a fuel cell/electrolyzer provided the majority of the storage. This system worked well, although throughput efficiency of the system is much less than with lead-acid batteries—the result was that the team's 12 KW array was equivalent to only about 6 KW.

The team wanted to demonstrate an application of hydrogen fuel-cell technology. It turns out that the fuel cell was not as efficient as they had hoped (estimates are between 25% and 40%, compared to about 80% for flooded lead-acid batteries). This proved to be a liability in the competition, showing that the hydrogen hype doesn't stand up when faced with reality. It is ironic that proven solar technology has stood up well and won in a direct face-off with hydrogen at the Decathlon, but hydrogen is often given more credit in the press nowadays, while solar energy is still treated as experimental.

Texas

Named the SNAP house (Super Nifty Action Package), the University of Texas at Austin house consisted of a set of prefabbed modules that snap together for easy transportation and quick construction. Native Texas grasses are planted into the north slope of the "green" roof and the floors are made from local Texas mesquite wood. A key part of their team's goal was community outreach, including educating local schoolchildren about solar energy and green building before the house even made its way to Washington, D.C.

Missouri Rolla

The University of Missouri at Rolla and Rolla Technical Institute returned with a new design that used amorphous Uni-Solar roofing applied to a copper standing seam metal roof. This same array also serves as the solar thermal collector, by collecting heat from the back of it. Their house is fairly traditional looking compared to many at the competition, but the dimensions throughout the design are based on both the golden and Fibonacci series mathematical ratios, which are found throughout nature in objects such as pinecones and flowers.

Maryland

The University of Maryland team returned with an innovative design based on shipbuilding. The house will be placed in a lot that is mostly marsh grasses, and the small central tower is the only spot that will touch the ground, to reduce its impact. It received first place in the "People's Choice" contest, a contest that doesn't count towards the official contest winner, but is important nonetheless. This house consistently had long lines waiting to get into it, even in the pouring rain, and you could tell that people liked the architecture.

Pittsburgh

This house was designed by a consortium of three universities—Carnegie Mellon, the University of Pittsburgh, and the Art Institute of Pittsburgh—as well as some students from the Technical University of Darmstadt in Germany, and many local Pittsburgh trade unions. The entire house tilts toward the south to "reach out to the sun," and has translucent northern walls to let in more daylight. Instead of conventional air conditioning, they used an absorption air conditioner that operates from the heat of the solar thermal system. The home also uses LED lighting throughout.

Madrid

Not only did the Universidad Politécnica de Madrid team do a lot of engineering and architectural design, but all the members of their team also entered an intensive English language course for the past two years to be able to compete. Their house had a moveable section that could join the rest of the house, or slide out to create a patio surrounded by the kitchen and living areas—a popular feature of houses in Spain.

Puerto Rico

On its return visit to the contest, Universidad de Puerto Rico didn't restrict its public outreach efforts just to solar energy, but also performed music and generally made the village a more festive place by bringing some island culture to it. They also focused on using conventional building materials and appliances where possible, rather than high priced experimental systems that the average person would not have access to. For many students, this project was a welcome chance to escape from their narrow disciplines in school, and experience being part of a multidisciplinary team—something that will be useful when they graduate.

Crowder (MO)

Once again, Crowder College, a two-year technical school in Nashao, Missouri, participated with a well-built, well-performing house. The combination PV/solar thermal collectors were improved over last time. They also finished the week with more energy than they started with. This house didn't look flashy or architecturally as exciting as some others, perhaps, but it would have fit right into many suburban developments, and many visitors were interested to see this.

Florida International

Florida International University's house has a lot more glass than most solar houses in warm climates. This gives it a much more open feel—doors can be opened to connect the house with the interior courtyard and make it feel much bigger than its 800 square feet (74 m^2). However, it must also be shielded from the sun, hence an array of external louvers to keep unwanted solar gain out. The Florida team was composed of more than just the usual architects and engineers. It also included students from journalism and mass communications, and creative writing, ranging from freshmen to doctoral candidates.

New PV Modules

Several teams used integrated PV and solar thermal collectors. All of these were fabricated by the teams. This idea has been pursued by many people over the years, but a commercial product is still not available.

Two teams used the new SunPower PV modules, which achieve their very high efficiency (approaching 16.9%) partially by not having any contacts on the front of the cells. These modules also experience less efficiency degradation from high temperatures than normal crystalline modules.

Many innovative PV technologies that are commercially available in Europe are just beginning to be available here in the United States. Some of these include colored solar cells (made by adjusting the thickness of the antireflective coating, which normally appears blue), translucent amorphous modules, and crystalline laminates with transparent glass between the cells instead of a white background. Expect to see more of these available in the United States in the future.

Canada

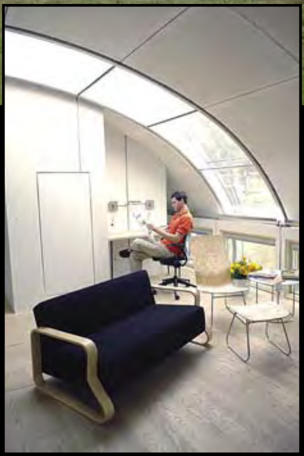
The Concordia University and Université de Montréal team built a very high-tech house, but hid the technology in a home designed to feel inviting and nonthreatening. They actually wrote control software to operate the house behind the scenes, including automated blinds in the south-facing windows. The house also includes phase-change materials to store more thermal energy—cooling is not much of an issue in Montreal, but heating certainly is. One additional hurdle faced by this team and the Spanish team was importing a house through U.S. Customs, which required extensive documentation of all the materials and systems.

Washington State

Washington State University's house included several innovative engineering systems, such as linking the refrigeration and heating systems to use all of the waste heat from the refrigeration and air conditioning. Washington State is also home to a new type of PV incentive—the feed-in tariff, one of the authors of which was on site helping to give tours of the house. Used to astounding success in Germany, the feed-in tariff rewards PV systems with ongoing payments per KWH of energy produced, rather than a single up-front payment per KW of rated capacity. The Washington law uses a graduated payment based on how much of the PV system is manufactured in-state, thus trying to promote local jobs in a new energy economy, in addition to promoting solar energy.

RISD

Rhode Island School of Design entered the competition with a house that used innovative phase-change materials to store thermal energy—both heating and cooling. These plastic bricks, filled with specialized wax that melts or freezes at a specific temperature, are available in Europe, but are almost unheard of in the United States. The team is working with the manufacturer to try to introduce them here. Architecturally, one of the major features of their house was a beautiful roof garden and patio—a popular idea with several teams, designed to give more useable space in a house constrained by competition rules to only 800 square feet (74 m^2).



Michigan

The University of Michigan, known for its successes in solar car races, entered the Solar Decathlon this year. Some of the automotive engineering expertise is visible in their entry. The curved south wall and roof of their house is a double wall, with vents than can direct the hot air collected in the gap between the walls either into the space to heat it, or outside to keep it cool.

Why Such Large PV Arrays?

All of the competition houses had very large PV arrays, especially for one-bedroom houses. The sizes ranged from about 4 KW to almost 12 KW rated. So a lot of people touring the houses assumed that a three-bedroom house must need a 30 KW array.

This is one of the places where the rules of the competition override reality. In a real off-grid house, you design a renewable energy system for average conditions. During an unusually long snowstorm or cloudy period, you will either turn a generator on or put off energy intensive tasks like doing laundry for a day or two until the sun comes out again. During the competition, teams are severely penalized for using engine generators to charge batteries.

To get the most points, the teams had to emulate the typical American lifestyle of turning on loads on a schedule not affected by the climate or weather. If you want to win the competition, you don't design for average conditions. You design for worst-case conditions, and then add some to that. And that's what we saw this time. The entire *week* had the equivalent of 5.5 full sun-hours. Yet, because of their oversized systems, many of the houses still collected enough energy to do most, if not all, of their tasks. The three winning teams even drove their electric cars regularly—318 miles (512 km) for the Colorado team—but depleted their batteries severely doing this.

UMass Dartmouth

The University of Massachusetts Dartmouth entry was designed from the very beginning to be used as a home after the contest. The students had previously built several other such houses, including an "energy smart" one with Oak Ridge National Laboratory in Tennessee. Because of this goal, the house is designed to be as "normal" as possible, and use off-the-shelf materials and appliances. A large portion of the building materials are from the ReStore Home Improvement Center, a company in Springfield, Massachusetts, that sells reclaimed materials from demolished or renovated houses.

Solar Technology Now

The Solar Decathlon was a competition, and to compete effectively, many of the teams made design choices that you or I would not make. Despite their design differences, even the most competitive teams would agree on the Decathlon's common goals of changing the way people think about houses, convincing the building industry to integrate solar technology into houses, and educating people that solar energy is within the average person's reach right now.

Most of the houses will be used after the competition, and often their future owners were involved in the design. The Colorado house is going to be the leasing office for an affordable housing development in Colorado. Others are going to become housing for visiting professors on campuses. These may not be "real" houses because of the constraints of the competition, but the students are obviously well connected with reality.

Students tried a lot of innovative designs and schemes in these houses, and some entries attempted to define a new paradigm for housing or push architectural envelopes. But even more evident was a push to make solar houses that look "normal." Solar houses are not the homes of the future, but the homes of today. We don't have to wait for some technological breakthrough. The overwhelming sentiment from visitors was that they wanted a solar house, and wanted to know where to buy one now.

Access

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Solar Decathlon • www.eere.energy.gov/solar_decathlon • Includes contact info & detailed scoring for all of the teams


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SUSTAINABLE SKIING

Snowmass Ski Area Gets Hydro

Auden Schendler

Courtesy Hal Williams

The histories of Aspen, Colorado, and hydroelectricity converge underground. Silver lodes drew the miners who first established Aspen. And Lester Pelton, the inventor of the modern waterwheel, was a gold miner in California. Both were pursuing a holy grail—vast wealth from the earth's natural resources.

The silver miners found it in Aspen, once in the form of a 2,200-pound silver nugget. Pelton discovered no gold, but he extracted something more valuable—an efficient way to make clean energy from falling water. One hundred and forty years later, his invention, the Pelton wheel, is being put to use at a ski resort near Aspen, in a revolutionary way.

Sustainable Vision

The silver lodes are long since tapped out, but there is a new grail, of sorts, for the residents of this resort town. It is the idea of a sustainable community, one that can thrive with minimal impact on the environment. In the big picture, the main barrier to that vision is energy use.

As Vijay Vaitheeswaran points out in *Power to the People*, his superb book on global energy issues, "The needlessly filthy and inefficient way we use energy is the single most destructive thing we do to the environment." The average American household is responsible for the annual emission of 23,380 pounds (10,605 kg) of carbon dioxide, the primary greenhouse gas, much of that from electricity use. Now, consider the emissions from plugging in a ski resort. And yet, "With enough clean energy," Vaitheeswaran notes, "most environmental problems—not just air pollution or global warming, but also chemical waste and recycling and water scarcity—can be tackled."

The microhydroelectric plant on Fanny Hill now has an educational display that will be viewed by an estimated 750,000 skiers annually.

The Pelton Wheel

In 1864, when Lester Pelton worked in the mines, mechanical power came from waterwheels spun by jets of water. As the technology evolved, millwrights replaced wooden slats with metal cups, which turned the wheel faster. One day, Pelton observed a broken waterwheel. The jet was hitting the edge of the cup instead of the center. Pelton observed something else—the wheel turned faster than other wheels nearby. Based on his observations, Pelton developed a more efficient design and patented it.

That design became the key component of many modern hydroelectric turbines. A Pelton wheel looks like an industrial flower, or a blacksmith's rendition of the universe. It is a beautiful and timeless tool, a reminder of human ingenuity that evokes the creativity of a silversmith more than the equations of an engineer. Pelton wheels have brought great affluence to the world through the sale and use of electricity, and great environmental damage through the construction of large dams. But the first wheel that Lester Pelton put to practical use ran his landlady's sewing machine. Now, that legacy is helping to stitch together the fabric of a sustainable community.

Water from the turbine exits the tailrace.

Why Hydro?

Aspen Skiing Company, which operates four ski mountains—Aspen, Snowmass, Highlands, and Buttermilk—and several hotels, is responsible for 28,000 tons (25,401 metric tons) of greenhouse gas pollution every year. Roughly 23,000 tons (20, 865) of that is from electricity use. One of the only ways to address this impact is to buy renewable electricity, which anyone, even homeowners, can purchase from the local utility, Holy Cross Energy.

Tech Specs

Location: Fanny Hill, Snowmass Ski Area, Snowmass, Colorado

Owner: Aspen Skiing Company

Project cost: US$155,000

Head: 746 feet (227 m)

Pipeline length: 4,103 feet (1,251 m)

Static pressure at turbine: 323 psi

Average flow: 1,100 gpm (2.45 cfs)

Turbine: Single-nozzle Pelton turbine from Canyon Hydro, 18.5-inch pitch diameter

Generator: 175 hp, 480 V, 3 phase, 60 Hz, 115 KW

Annual generation: 250,000 KWH, estimated

The city of Aspen buys 67 percent of its electricity as renewables. Aspen Skiing Company buys wind power—about 5 percent of total usage—and increases its purchases annually. But the business can't afford to buy renewables in the volume necessary to offset impacts, and the practice sometimes confuses guests. The most common question is, "Where's the windmill?"

Installing a wind turbine on site would be a significant investment. The best sites are far from transmission lines, on the local ridgetops. Areas closer to the transmission infrastructure are more sheltered, so there's not enough wind. Photovoltaic panels are an option, but they're expensive, especially for the quantity of energy required. However, one source of renewable energy on ski hills is plentiful, economical, and readily at hand—water.

Early Aspen

Early Aspen was all hydro-powered. In fact, according to *The Electric Review* from January 1907, "Aspen led the way in the use of electricity for domestic lighting and mining. For years, it was the best-lighted town in the United States. It was the first mining camp to install an electric hoist, and the first to install generators run by water power."

Today, three substantial microhydro systems are still running in the area (and likely many smaller ones). One is on Maroon Creek, and puts out 450 to 500 kilowatts (KW). A 20 KW system is in the basement of the Mountain Chalet in Snowmass. And local microhydro enthusiast Tom Golec has a 40 KW turbine on Ruedi Creek. Unlike dams, microhydro plants take some of the water out of a creek, but don't have to block the flow. Such systems can generate electricity from relatively small water flows, even seasonal streams—you don't need to rebuild the Hoover Dam. The water runs through a pipe to a turbine, and then back into the creek downstream.

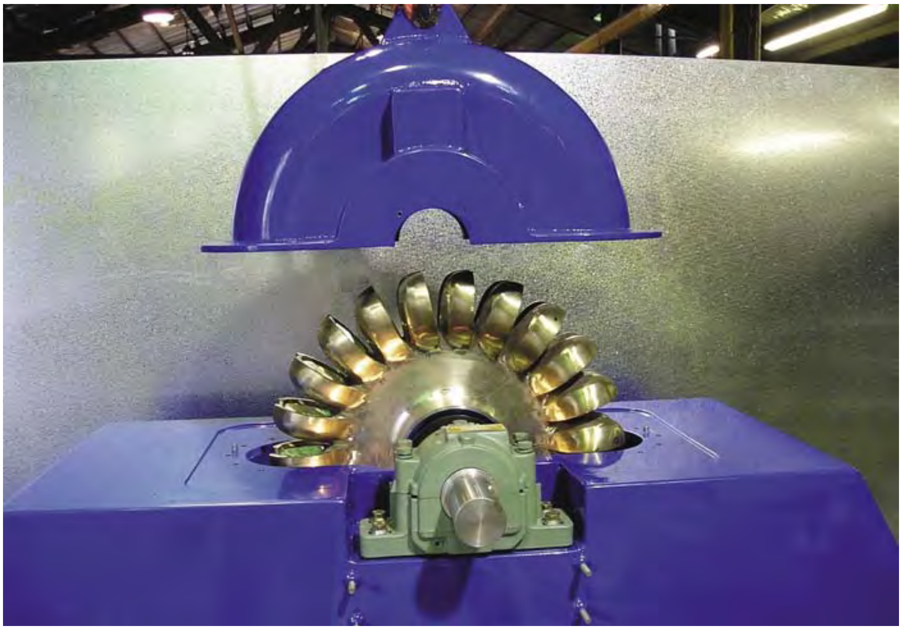
A Not-So-Costly Installation

The biggest expense of most microhydro systems is the "penstock," or pipe, that runs from high elevation to low, creating pressurized water that can spin the Pelton wheel. The economics of installing a penstock can often kill a project. At Snowmass Ski Area, installing a basic hydroelectric system would require building a retention pond (at a cost of about US$1 million), and burying 4,000 feet (1,220 m) of 10-inch (25 cm) steel pipe. The cost of such a project is mind-boggling. Once you add up pipe cost and excavation equipment time, you're pushing a system's payback into the next millennium. Unless, of course, you have the pipe and pond already in place. At the Snowmass Ski Area in Aspen, we do. We call it a snowmaking system.

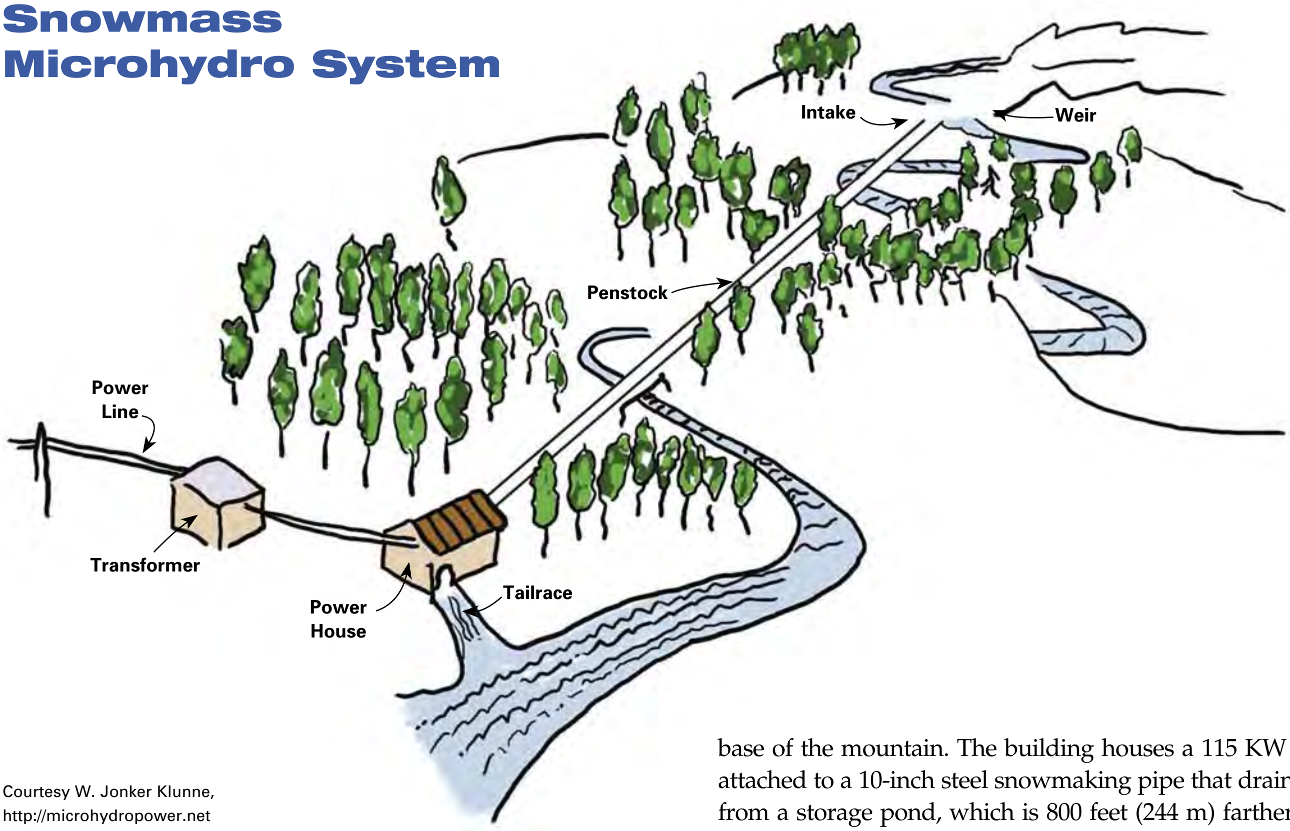
Snowmaking pipes run everywhere at some ski resorts. So snowmaking supervisor Jimmy Holton asked, "If we already have half a hydroelectric system, why not just add a turbine and start making electricity?" We determined that a hydro plant could generate renewable energy at a fraction of the cost of using solar-electric panels. And the return on investment could be as low as seven years.

Convinced that a microhydro system was the best way to generate onsite renewable energy, Snowmass Ski Area built a small powerhouse on Fanny Hill, the beginner slope at the

The Pelton wheel used in the Snowmass Ski Area hydro plant was custom-made for the project by Canyon Hydro.



Snowmass Microhydro System



Courtesy W. Jonker Klunne, http://microhydropower.net

Snowmass Microhydro Costs

Equipment	Cost (US$)
Turbine & switch gear	$65,610
Structure & foundation	48,957
Excavation, pipe connection & associated fees	7,500
Consulting fees	7,240
Flow meter	6,000
Electrician	5,200
Utility interface	5,000
Shipping	3,000
Installation & crane	2,000
Permits	1,500
Total Costs	$152,007
Grants	
CORE/REMP/Ruth Brown Fdn.	-$20,000
OEMC	-15,000
StEPP	-10,080
Holy Cross	-5,000
Town of Snowmass Village	-5,000
Total Grants	-$55,080
Grand Total	$96,927

base of the mountain. The building houses a 115 KW turbine attached to a 10-inch steel snowmaking pipe that drains water from a storage pond, which is 800 feet (244 m) farther up the mountain and is fed by West Brush Creek. In 2005, our first complete year of operation, we made some 200,000 kilowatt-hours (enough to power 40 homes), while preventing the emission of 400,000 pounds (181,437 kg) of carbon dioxide.

A Turbine On Every Slope

Think about the possibilities. Hundreds of ski resorts in America have snowmaking systems. On our four mountains alone, we have half a dozen more good opportunities for hydro. If we had five or ten turbines running, we'd be generating an enormous amount of renewable energy—enough for say, 200 homes—contributing to clean air, stable climate, and the long-term sustainability of the ski industry and the town. Any ski resort with a snowmaking system should look into installing a turbine.

Inside each of those turbines, you'd find a Pelton wheel, a tool so elegant that it meets Einstein's design criteria that everything should be made as simple as possible, but not simpler. It's a device that has its origins tied to the origins of this town, and now, tied to its future as well.

Access

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Project Partners

The Snowmass hydroelectric project is so exciting and forward-looking, and has such broad applicability, that a wide range of partners were interested in providing financial support to help make it happen.

Donors included Holy Cross Energy, the utility that buys the electricity and has also covered all grid interface fees (www.holycross.com); the Colorado Office of Energy Management and Conservation, which supports innovative energy projects all over Colorado (www.state.co.us/oemc); the Community Office for Resource Efficiency (CORE), which is a national leader in renewable energy and energy efficiency and helped bring a green pricing program to Colorado (www.aspencore.org); the Renewable Energy Mitigation Program (REMP) from the town of Aspen, which collects fees from new homes that use large amounts of energy (www.aspencore.org/NEW_FORMAT/REMP_new_format.htm); turbine manufacturer Canyon Hydro, which discounted its equipment (www.canyonhydro.com); the StEPP Foundation (Strategic Environmental Project Pipeline), whose contribution made Aspen Ski Company (ASC) the only corporation in state history to receive money from environmental mitigation funds (www.steppfoundation.org); the Ruth Brown Foundation; the town of Snowmass Village (www.tosv.com); and Snowmass Water and Sanitation, which contributed time, space, and technical support.

Dan Batdorf, Bat Electric, 20200 Charianne Dr., Redding, CA 96002 • 530-221-1336 • Fax: 530-221-3496 • batelecinc@aol.com • Controls & switchgear

Pat Costello, Costello & Co., 405 Park Ave., Ste. E-6, Basalt, CO 81621 • 970-927-1421 • Fax: 970-927-2008 • Contractor for powerhouse

Robert Gardner, Holy Cross Energy, PO Drawer 2150, Glenwood Springs, CO 81602 • 970-945-5491 • Fax: 970-945-4081 • bgardner@holycross.com • www.holycross.com • Radio-link remote terminal unit (provides generator output & bill info)

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Mike Hoffman, TPE–Twin Peaks Electric, 145 Cheyenne Ave., Carbondale, CO 81623 • 970-963-1021 • Fax: 970-963-0958 • twinpeakselec@aol.com • Electrician

Mark Gressett, Gressett Excavation, 510 Sopris Creek Rd., Basalt, CO 81621 • 970-948-4686 • Excavation

Charles Brugger, Advanced Mechanical Services, PO Box 33237, Denver, CO 80233 • 303-818-5434 • advmech1@aol.com • Laser alignment & turbine installation

Tom Golec, Ruedi Creek Water & Power LLC, 15401 Fryingpan Rd., Basalt, CO 81621 • 970-927-4212 • golec@msn.com • Project consultant

Randy Udall, Community Office for Resource Efficiency (CORE), PO Box 9707, Aspen, CO 81612 • 970-544-9808 • rudall@aol.com • www.aspencore.org • Project consultant

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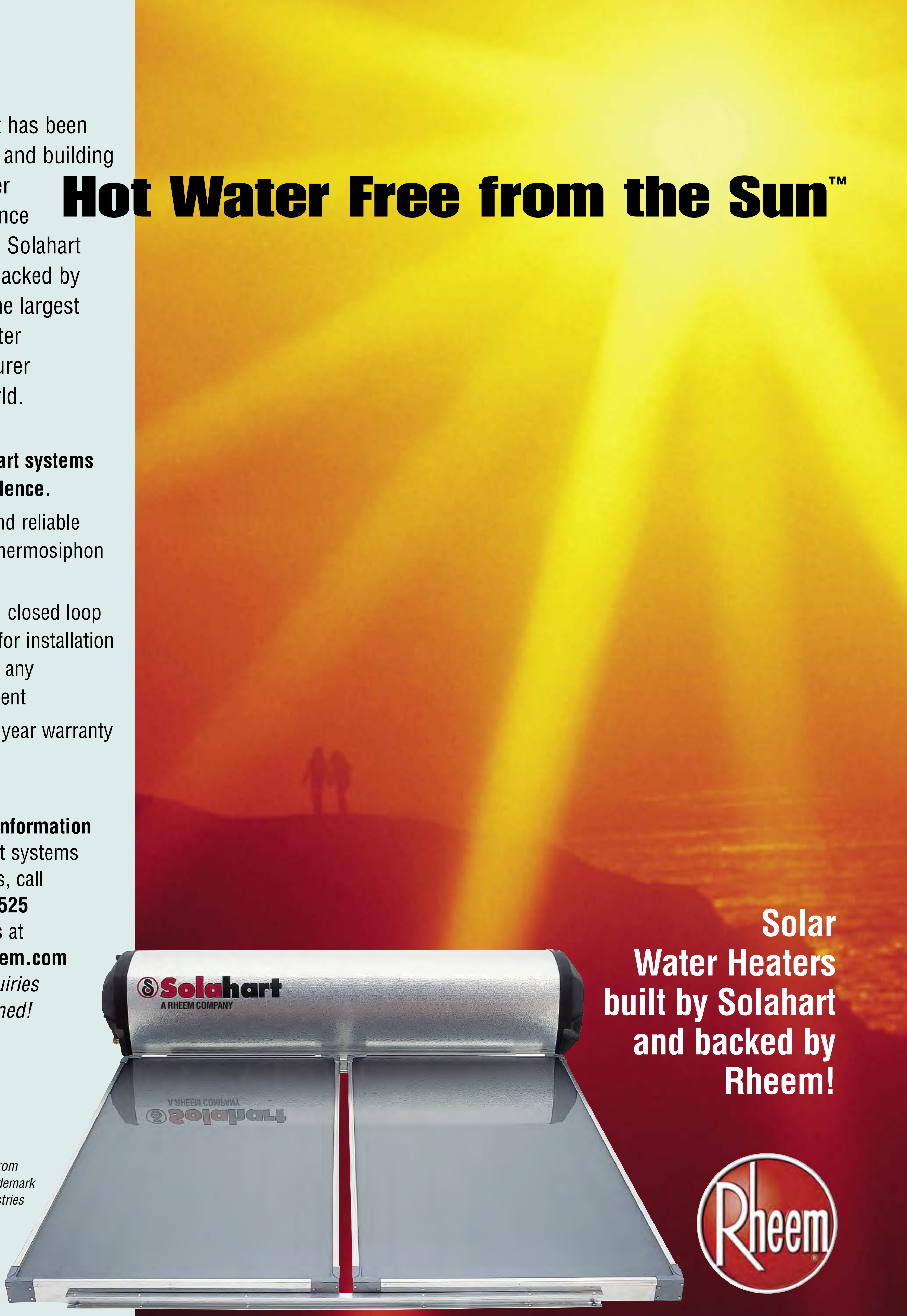

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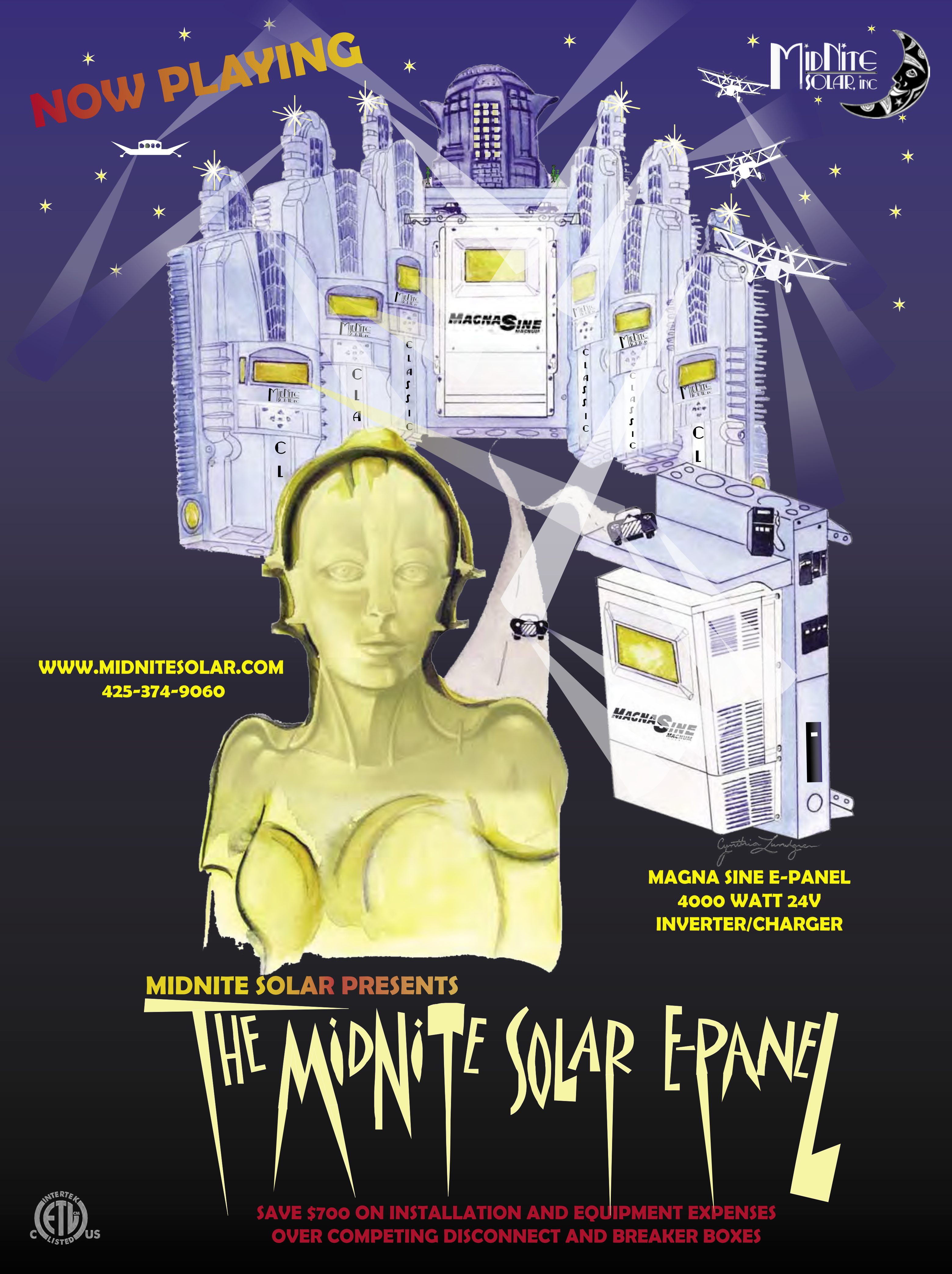
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Outsmart the 7 Worst Gas Guzzlers

WISE DRIVING

George Harvey with Shari Prange

In these times of climbing fuel costs, chances are that getting better gas mileage has moved up on your list of priorities. One option is to buy the most fuel-efficient vehicle you can find, or even an alternative fuel vehicle that you make your own homemade fuel for. But if you're not in the market for new wheels, is there anything you can do to limit your trips to the pump?

The resounding answer is "Yes!" No matter what you drive, *how* you drive and maintain your vehicle can make a big difference. In addition to sparing your pocketbook, by using these techniques, you'll also reduce your dependence on nonrenewable, imported fuel sources and, at the same time, reduce pollution. Driving wisely means less wear and tear on your vehicle. And as a bonus, your fuel-efficient driving habits will also make you safer on the road.

Mileage Myths

When I bought my hybrid electric car, a 2001 Toyota Prius, the mileage estimate on the highway was 45 mpg (19 km/l) and the city estimate was 52 mpg (22 km/l). I expected an average mileage about halfway between, perhaps 48.5 mpg (20.6 km/l). This year, at the beginning of spring, I reset the mileage meter, and in the 5,880 miles (9,463 km) I have put on since, I have averaged 58.5 mpg (24.9 km/l).

My car is not special. When I loan it to other people, they get the estimated mileage or worse. My message: These cars can deliver their EPA-rated mileage and sometimes more, but drivers must do their part. And this is true for all vehicles, not just hybrids.

The good news is that by improving your worst mileage situations, you can get a dramatic improvement in overall mileage. Your best bet is to identify and outfox the worst mileage thieves. Here's how.

1 Lose the Lead Foot

If there is a single rule that says almost everything, it is this: Aggressive, impatient driving (quick starts and stops) produces the worst mileage. At highway speeds, this road rage packs a wallop, shaving off more than one-third from your car's fuel economy. Racing around town knocks off another 5 percent. If you want to spare your pocketbook and go green, the first thing to do is relax, be safe, and drive defensively. Believe it or not, it usually makes the trip more enjoyable, and nearly always makes it less stressful.

✔ In stop-and-go traffic, try to find the speed that you can hold more or less constant. When the car ahead of you speeds up, more of a space will open between you and it. When its driver hits the brakes, you will close up the space. If you time it right, that car will start moving again just about the time you catch up to it.

- ✓ Never tailgate. Doing this puts your fuel mileage into the hands of the driver in front of you. It should take you three to four full seconds to get to where they were.
- ✓ Accelerate moderately. Avoid jack-rabbit starts and unnecessary acceleration, such as over a short distance before a turn or stop.
- ✓ When at cruising speed, keep a steady foot on the gas pedal—accelerating and decelerating can significantly decrease your mileage.
- ✓ Delay acceleration for short distances if doing so allows you to take advantage of a downward slope to give you a gravity assist.

- ✓ Slow down. At speeds above 60 mph (97 km/h), the fuel economy of most vehicles takes a big hit—from 7 to 23 percent.

  My Prius seems to get its best mileage at speeds below 50 mph (80 km/l), possibly even below 40 mph (64 km/l). On the other hand, the Honda Accord hybrid shuts down three of its six cylinders when it's cruising, and its best mileage is probably at highway cruising speed—possibly at 65 mph (105 km/h). For most vehicles, though, mileage takes hit at speeds above 60 mph.

2 Cruisin' & Coastin'

The flip side of acceleration is braking. Unless you have an electric or hybrid car with regenerative braking (which charges the battery), every time you touch the brakes, you throw away energy. In *all* vehicles, it pays to plan ahead for braking.

- ✓ Instead of keeping your foot on the throttle up to the instant you switch to the brake, learn to use the third state of driving—coasting. If you see the light turning red ahead of you or traffic bogging down, lift off the throttle and coast.

  Coasting is most effective in an all-electric car with no regenerative (regen) braking. You can coast for a full block to a gentle stop. In an internal combustion engine car, you can use this technique on long downhill stretches. Instead of pushing the car down the hill in second gear, let it roll down the hill in third, with your foot off the throttle, gently tapping the brakes from time to time if needed.

  In hybrid vehicles or some all-electric vehicles, gentle braking is regenerative. With the pedal barely engaged, the motor captures part of the braking energy and transfers it into the battery. Pushing harder on the pedal makes the brake pads contact the rotor, turning this energy into heat, which is dissipated. In any car, longer and lighter braking has the advantage of reducing the time the car is using energy.

- ✓ When possible, slow down gradually. Try to avoid heavy braking unless it's absolutely necessary.

3 It's a Drag

Above a certain speed, another thief—wind resistance—steals most of a car's power. This varies from car to car, and depends on a lot more than the vehicle's drag coefficient. But there are things you can do easily to improve your car's aerodynamic characteristics. For pickup trucks, a tonneau cover over the truck bed can make a real difference. For vehicles in general, if you want to get really serious about it, a bellypan—a sheet metal, plastic, or any durable covering underneath a car—can reduce air drag. Just be sure you are not interfering with airflow needed for component cooling.

An open convertible has more wind resistance than one with the top up. Even a hardtop car has more resistance at high speeds with the windows open than closed. Of course, in hot climates, the choice may be between open windows, air conditioning, or heat stroke. Operating an air conditioner is a mileage thief too, and can steal up to 20 percent from your mileage. But above a speed of about 50 mph (80 km/h), the energy lost to turbulence from open windows is more than the energy lost to running an air conditioner.

- ✔ At low speeds, use "natural air conditioning" (open windows); at high speeds, turn on the mechanical air conditioning.
- ✔ Remove the detachable roof rack or cargo box—a loaded roof rack can lower fuel economy by 5 percent. Flags, banners, stuffed toys, and other exterior decorations will also increase drag. If you can, avoid ornamenting the outside of your car. Save your decorating for the inside—fuzzy dice, anyone?
- ✔ Keep the body in good shape. Dents are not aerodynamic (unless they are strategically applied, as on a golf ball). While you're at it, give your car a good wash and wax. Mud is not aerodynamic, either.
- ✔ When it rains, slow down for good mileage, regardless of the type of car you have. Pushing air around is one thing—but pushing water around is even more difficult, especially when you're traveling at high speeds.

4 The Cold, Hard Truth

One of the jobs of a cold engine is to warm up, and it uses fuel to do this. And any car, regardless of type, gets worse mileage when its engine is cold. According to the Web site FuelEconomy.gov, combining errands into one trip always saves time and money, especially if each of the short trips would involve a cold start. Considering the temperature is especially important in hybrids because the engine shuts off when the car does not demand power, and it won't shut down unless the car is warmed up.

- ✔ Try to eliminate short trips, especially those followed by long intervals, when the engine can cool. In general, if the distance is less than a mile (1.6 km), you could walk. Good health is a side benefit.
- ✔ Limit or eliminate unnecessary trips in cold weather—or any weather, for that matter. Plan ahead to do multiple errands on a single trip instead of making multiple trips, and keep backup supplies of essentials (like toilet paper or toothbrushes) to reduce "emergency" runs. A side benefit will be less stress on you, and time saved.
- ✔ In a hybrid vehicle that shuts its engine off at a stop, be prepared to shut off the engine manually for a stop of a minute or longer during the first five minutes of driving. (However, don't do this in very cold weather; you'll put too much strain on the engine.)

5 Go on a Diet

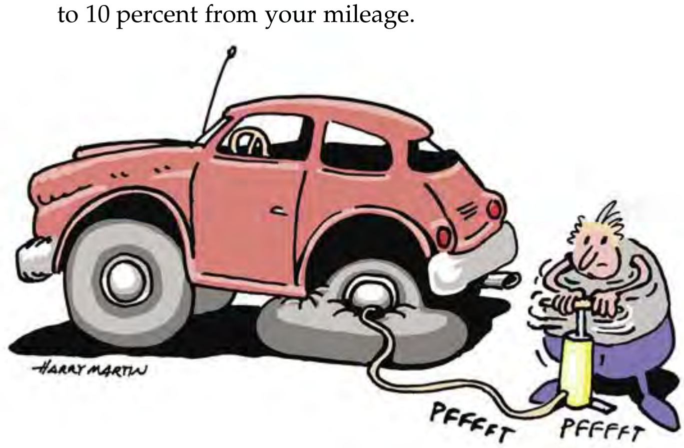
Not you, but your car. Every extra 100 pounds (45 kg) you carry around cuts 1 percent to 2 percent from your fuel economy.

- ✔ Clean out all the extraneous clutter in the car, including in the trunk and under the seats, and only keep the necessary items that you *really* need. Then make it a habit to unpack the car completely every time you come home, instead of carrying everything around until you either need to use it or run out of room.
- ✔ Lighten your load. Replace a full-size spare tire with a mini-spare. This will also encourage you to fix or replace a flat tire promptly. If you have back seats you rarely use, take them out and store them at home. Note that replacing fenders or hoods with fiberglass is often *not* a good idea—to provide the necessary rigidity, these pieces may weigh as much or more than the original steel ones.

6 Keep It in Shape

Several simple things can make a big difference in fuel economy, for any kind of car.

- ✔ Get your car serviced promptly when it is due. Tuning up a car can improve mileage an average of 4 percent. And while you're under the hood, don't forget to replace the air filter. A clogged, dirty filter can suck up to 10 percent from your mileage.



✔ Keeping your tires properly inflated can improve your car's fuel economy up to 3 percent. On electric cars, this usually means inflating tires to their maximum pressure rating.

Another maintenance job I've done to increase mileage was to have wheel alignment done with extra precision, the side benefit being better tire wear. Make sure that the wheels are properly aligned, and that you don't have any dragging wheel bearings or brakes.

Low rolling-resistance tires can also help, but these can be hard to find. The original factory tires on a car are usually pretty good for fuel economy, because they are the ones the car earns its EPA ratings with. So when it's time for new tires, spend a little more for factory replacements. If they aren't available, go to a major tire supplier and ask for "fuel efficient" tires for your car model. Stay away from trendy tires and wheels—short, wide ones or big knobbies. "Cool" will cost you mileage.

✔ Stick with the fuel your manufacturer recommends, and change the oil early and often. This can improve your mileage by 1 to 2 percent. Use a low-friction synthetic oil in your transmission. My winter mileage is about 85 percent of my summer mileage. The main reason for this is that the oil, grease, and other fluids are more viscous in cold weather and produce more friction.

7 Find the Sweet Spot

Different cars perform better in different circumstances. For example, some cars have arrow indicators, which light up on the dash to urge you to upshift to a higher gear for better efficiency. A higher gear means lower rpm, and less fuel use.

✔ Try to understand how your car performs best for speed and use that information as you drive. Get this information before you buy, of course, so you can mate the car to your needs.

In an electric car, you will get best efficiency by keeping the motor's rpm high. Your car will be more efficient at 40 mph in second gear than in third. You can see this easily by watching the ammeter as you drive.

Going the Extra Mile

Keep your car well maintained, and learn what techniques are most effective for it. Practice efficient driving habits until they become second nature to you. With these straightforward strategies, you can improve your car's mileage without a lot of hassle or expense, no matter what kind of vehicle you drive.

Access

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Shari Prange, Electro Automotive, PO Box 1113-HP, Felton, CA 95018 • 831-429-1989 • Fax: 831-429-1907 • electro@cruzio.com

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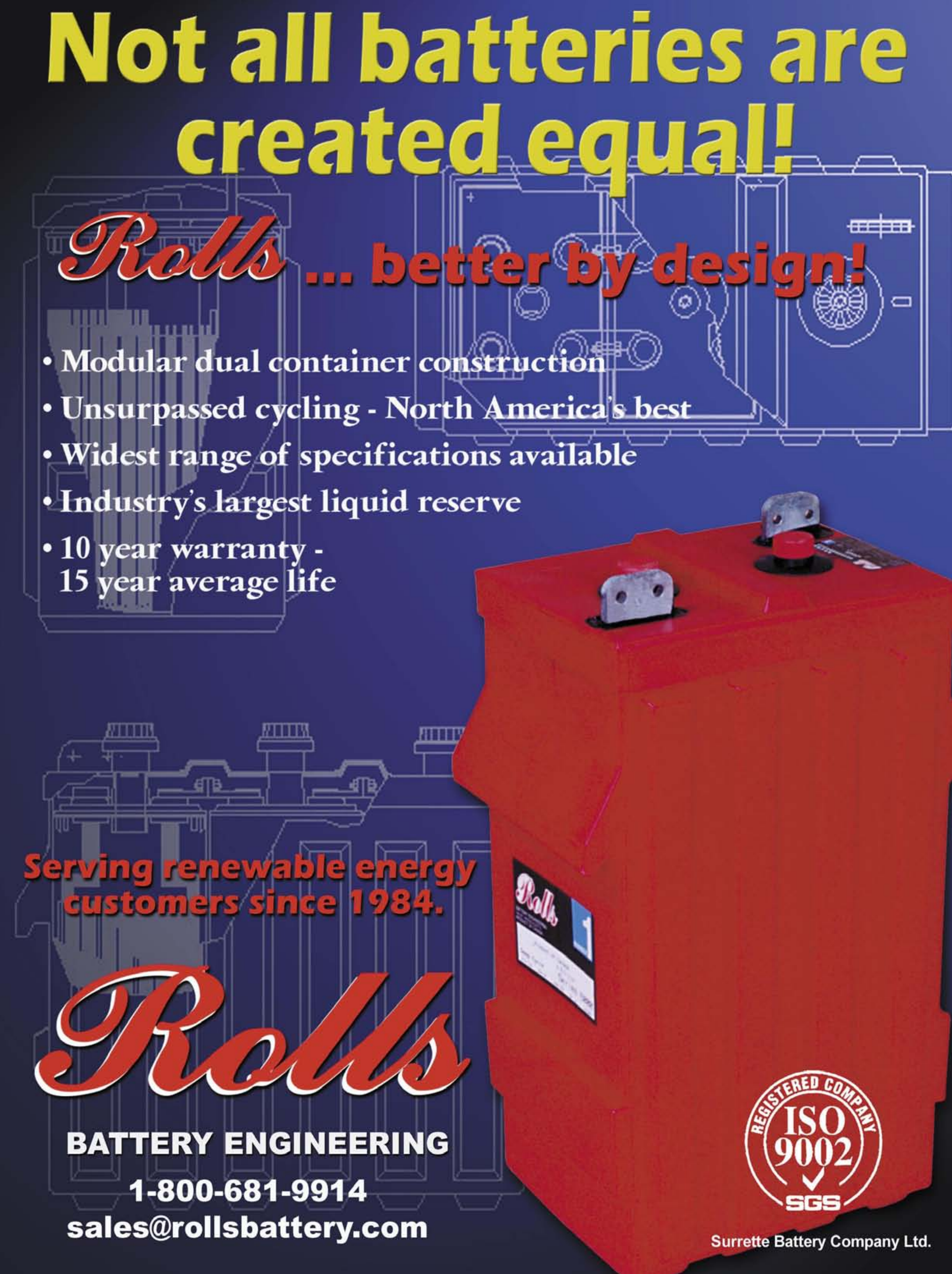
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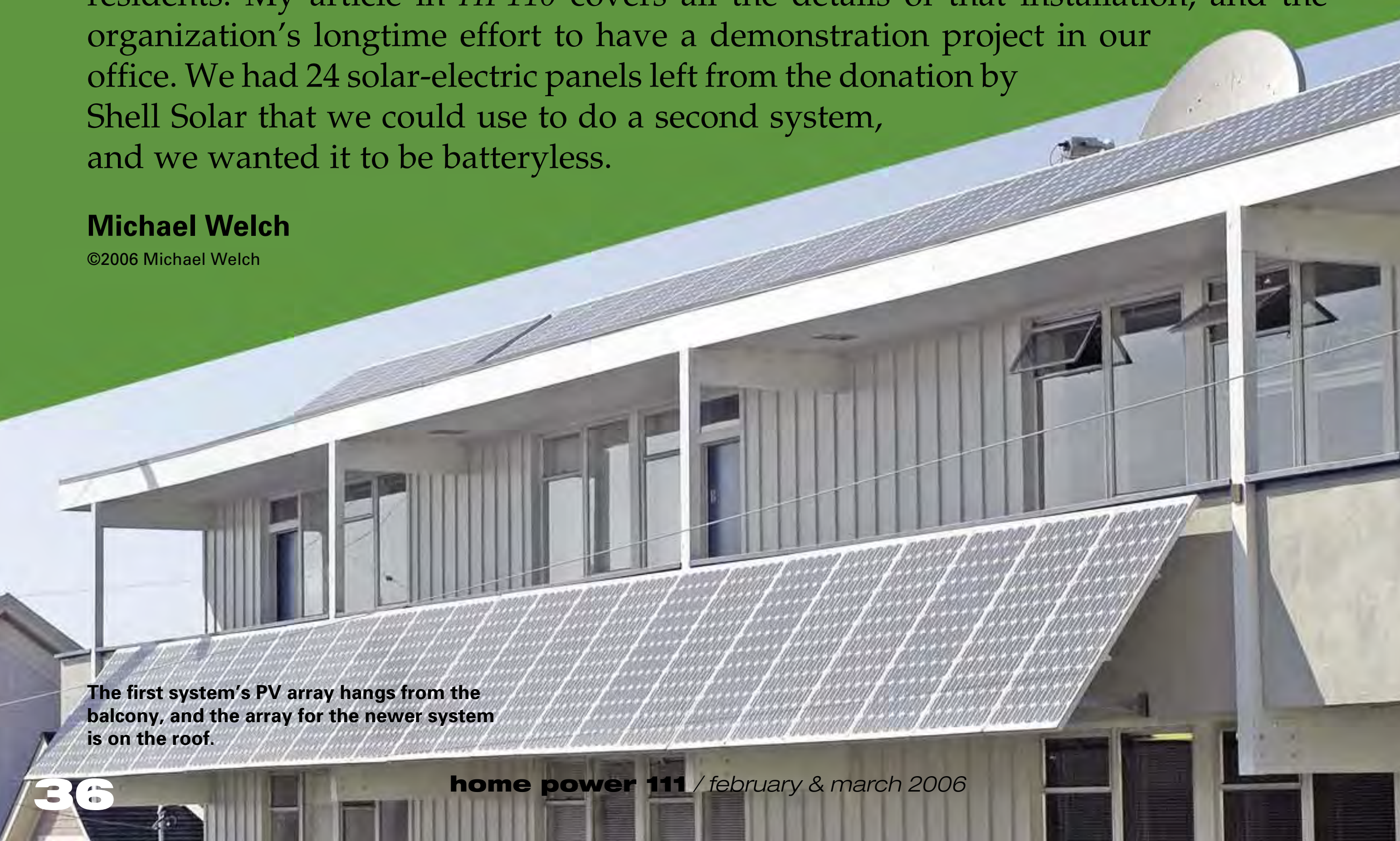
Walking the Talk

Emilly Larson, Claire Anderson and her son Kai, and Debbra Haven drop by to visit author Michael Welch and check out the Redwood Alliance solar-electric systems.

The Next Step

Redwood Alliance's (RA) first solar-electric installation is battery-based and grid-intertied, intended to demonstrate a modern photovoltaic (PV) system to a community that has both plenty of utility outages, and lots of off-grid residents. My article in *HP110* covers all the details of that installation, and the organization's longtime effort to have a demonstration project in our office. We had 24 solar-electric panels left from the donation by Shell Solar that we could use to do a second system, and we wanted it to be batteryless.

Michael Welch



The first system's PV array hangs from the balcony, and the array for the newer system is on the roof.

Volunteers move the 24 Shell Solar panels to the roof for the second installation on the Redwood Alliance building in Arcata, California.

Even in our rural community, many more people are interested in batteryless installations. So it was appropriate that our second system demonstrate that technology.

Maximize Efficiency & Savings

Batteryless setups are less expensive and more efficient than battery-based grid-tie systems. With an identical number of Shell modules, our batteryless system consistently produces about 10 percent more energy than the battery-based installation. It makes a big difference not having to use energy to keep batteries charged up!

In addition, the balance of system (BOS) equipment costs for a batteryless system are significantly less than for a battery-based system. If you have a small PV array but need a big battery backup, your costs including installation could be up to double that of a batteryless setup. The bottom line is that unless you live off grid, have frequent or extended utility outages, or have a nagging fear that worldwide energy woes are going to bring the grid to its knees, you should install a batteryless system.

Peter Brant demonstrates how to remove the inverter from its wiring box, a great feature of the Xantrex GT3 series inverters.

Inverter Choice

When we started looking into which inverter brand to choose, we immediately decided that we did not want to use multiple inverters. That meant we needed an inverter that would handle at least 3 kilowatts (KW) of PV. We investigated most of the inverters included in the grid-tie inverter survey article in *HP106*, and found all the choices to be quite excellent. But we had a special need—the inverter had to be silent, since it would be sitting just three feet from my desk.

After inquiring among a group of RE professionals, the Xantrex GT3 series was recommended to us as being efficient and silent. Through the generosity of Xantrex, we got a chance to find out for ourselves. With the arrival of the inverter, the last piece of our design puzzle was in place. Our contractor Roger, his crew, and our volunteers started the installation.

The inverter was simple to mount. The inverter's mounting plate was lag-screwed to a wall, and the inverter and its wiring box were hung from that plate. All the DC and AC wiring is done inside the wiring box. If the inverter ever needs to be removed or replaced, the wiring box can

The Xantrex GT3 series inverter assembly complete (above), and with the inverter removed, leaving the handy wiring box (shown open, at right).

stay on the wall to provide a safe place to terminate both the AC and DC wiring.

The GT inverter's wiring box has conduit knockouts on both sides, the bottom, and the back, for maximum flexibility. We used two on one side, one for the DC wiring from the array and the other for the AC wiring to the breaker. Our array is divided into two subarrays, and

there was space inside the wiring box to easily attach both of them. Both the DC and AC terminals are easy to get to, making wiring handy.

Aesthetics were a paramount concern. Unlike our neat OutBack installation, this time we weren't able to hide all the conduit behind a wall. But we ended up with only two short pieces of conduit between the inverter and our building's wire chase. It still looks great.

Up on the Roof

The installation of the PV modules went pretty smoothly, though as installers know, you always run into some things that do not go perfectly. Getting onto the roof of this two-story building was a hassle and required some bravery on the extension ladder. The landlord was concerned about roof penetrations leaking, and rightfully insisted that a professional roofer be brought on board to guarantee the installation be leak-proof.

The biggest problem we ran into was that the roof surface was inconsistent. The Direct Power & Water racks we used on our first installation's balcony mounts came with infinitely adjustable telescoping legs—necessary for making up for inconsistencies in the balcony construction. There were similar inconsistencies on the "flat" roof our second system was going on, but the legs were not infinitely adjustable, so we had to drill bolt holes in the legs in the

Tech Specs

System Overview

Type: Batteryless, grid-tie PV

Location: Arcata, California

Solar resource: 4.4 average daily peak sun-hours

Production: 360 AC KWH per month (to date)

Utility electricity offset: 80 percent

Photovoltaics

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

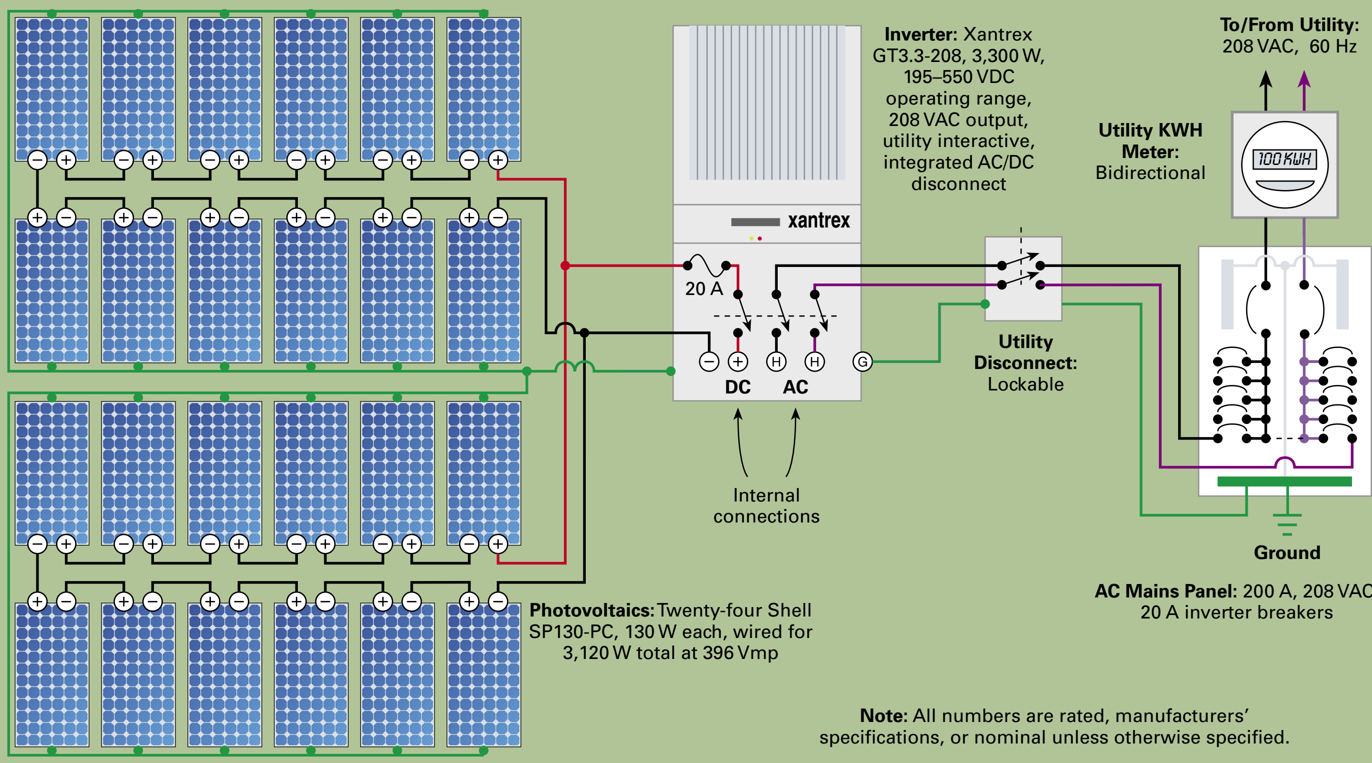
Array: Two, 12-module series strings, 3,120 W STC total, 396 Vmp

Array installation: Direct Power & Water LPRGM mounts with custom feet installed on flat roof, SSW-facing, 40-degree tilt

Balance of System

Inverter: Xantrex GT3.3-208, 3,300 W, 195–550 VDC operating range, 208 VAC output

System performance metering: Xantrex GT series internal display, Xantrex GT-View software



proper places to get the tops of the modules even and parallel with the roof eave. Beware—"telescoping" legs are not the same as infinitely adjustable legs.

Once the final DC wiring from the arrays was done, we were ready for inspections. As with the first system, the electrical inspector liked what he saw and immediately approved it. He only checked what equipment we were using, and gave a cursory look before granting us the approval so the utility could install the new two-way digital meter.

Usage Vs. Production

Redwood Alliance shares the building with four other businesses, and each floor has a separate utility service and meter. The newest array on the roof of the building feeds into the electric meter and utility service that supplies the bottom floor of the building, which has two businesses in it.

It looks like our first system will meet the annual demands of the building's second-floor tenants. But it appears that there needs to be more energy education for the first-floor tenants, since their meter is showing more energy used than the new, second system can possibly produce. I often see lights left on there, and the heater sometimes runs all night. The heater's big blower is part of their electric bill, even though the heater burns gas.

We will be spending some of our California state rebate money on energy efficiency for the building, and when it comes to some electrical users, money talks. We hope to get both first-floor tenants on the energy efficiency bandwagon.

The meter for the Xantrex GT showing net -0.48 KW.

Next Steps

All in all, we are quite pleased with both installations, their output, the equipment choices we made, and the level of support from the manufacturers and the community. Our next step includes a datalogging system that will monitor array outputs, inverter outputs, and total usage for each of the five businesses in the building. We are working with engineering students at Humboldt State University (HSU) with the goal of turning the new information system into someone's master's thesis. Other HSU students are using our building as a test site for their energy auditing class.

We are also working on getting the word out in the community about the demonstration systems. We've been receiving visitors who see the PV arrays from the street and are curious. We've participated in two of the nationwide solar home tours sponsored by the American Solar Energy Society (ASES). In 2004, we had just the first system to show, and last year we were able to show off both.

Redwood Alliance System #2 Costs

Item	List or Street Price (US$)
24 Shell Solar SP130-PC modules	$14,229
Xantrex GT3.3-208 inverter	2,300
4 DP&W LPRGM6-SQ roof mounts	1,568
Miscellaneous wire, conduit, electrical	1,133
Labor, PV system installation	1,000
24 DP&W custom mounting feet	437
Labor, roofer	362
Labor, AC electrical site preparation	342
Permits & documentation	306
Miscellaneous hardware	73
Square D DU221RB utility disconnect	48
Total	$21,798

We welcome the opportunity to demonstrate our two systems. We would also love to show you how we are improving the energy efficiency of our appliances and other loads to maximize the effectiveness of our solar-electric installations. You too can "walk your talk." To find out how, give us a call, and please come by for your own visit.

Access

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

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

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

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

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

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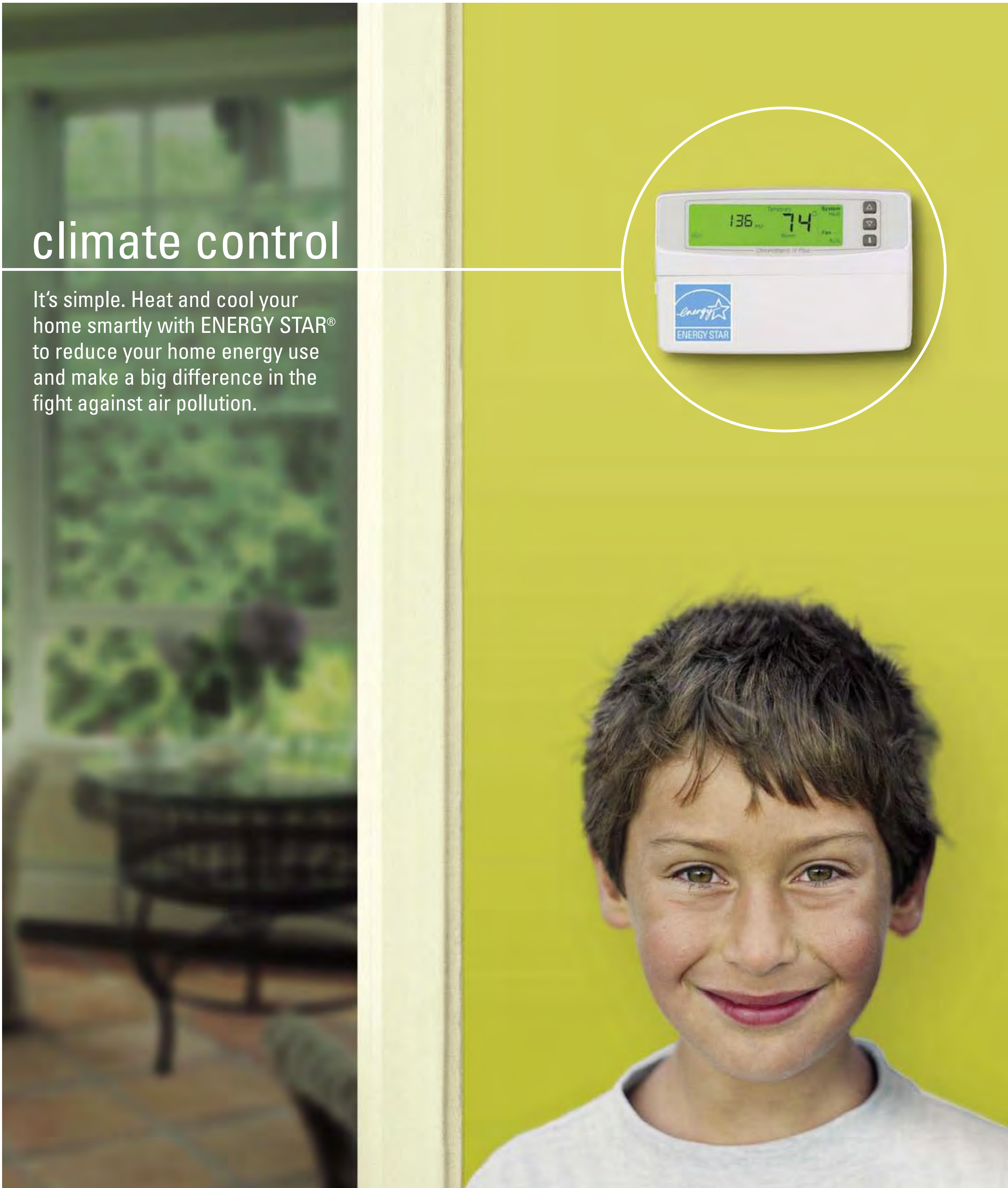

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Get Energy Smart

Insulation Options

Claire Anderson

Johns Manville's line of formaldehyde-free fiberglass insulation is available in pre-cut batts to fit standard wall cavities.

Courtesy Johns Manville

Do you know where your energy dollars are going? Chances are, if your energy bills are going through the roof, your home's heat might be going there, too—as well as through your walls, ceilings, and floors.

If you want to cut your costs, reduce your overall energy use, and make your home more comfortable, insulation is one of the best energy investments you can make. If you're living in an old home, it's almost assured that you can make improvements in insulation, and save energy and money. And even new homes built within the past few years may benefit from additional insulation.

The good news is that according to the U.S. Department of Energy (DOE), investing just a few hundred dollars in good insulation and home weatherization strategies can reduce your heating and cooling needs by up to 30 percent. Paired with good passive solar design, having a well-insulated home could even eliminate the need for mechanical heating and cooling in some climates.

Why It Works

Heat naturally migrates from warmer objects to cooler ones. Insulation helps slow this heat transfer considerably. Most insulation works by trapping tiny air pockets within the material. These pockets effectively reduce the material's conductivity, and help it resist heat transfer. This thermal resistance (or "R-value") is usually measured per inch of material. The more material you add, the greater its effectiveness (see R-value table on page 46). Insulation's performance also hinges on how and where the insulation is installed. (See the sidebar "Adding It Up.")

Taking Shape

Insulation takes many forms: loose-fill, blankets (batts or rolls), rigid board, and liquid foam (which expands to fill a cavity as it dries). Insulation is also being integrated into building materials like structural insulated panels (SIPs) and insulated concrete forms (ICFs). If you're building a new home or an addition, you may want to investigate these "all-in-one" options. Some types of insulation require professional installation, while others are fairly easy to install yourself.

Loose-fill and liquid foam insulation are usually best suited to places where they can be blown in, such as attics and wall cavities. Special pneumatic equipment is usually necessary. Batts and rolls are sold in standard widths to fit between wall studs or ceiling or floor joists, and can be hand-cut to fit nonstandard spaces. Faced batts, covered on one side with a kraft paper or a reflective-foil vapor barrier, can be used where required by code. Rigid foam board can be used to insulate exterior walls, basements, concrete slabs, and foundation and stem walls.

Besides choosing an insulation material based on how well it works within a particular building system, also consider its long-term performance, its embodied energy (the energy used to make and transport the material), and any potential health impacts it might have, while it's being installed or after it's in place.

Measuring Up

The DOE provides minimum R-value recommendations for homes based on climate, heating source, and the space needing insulation, such as attics, basements, or walls (see the R-value map on page 48). Consider exceeding these levels (also known as "superinsulating" a home) for maximum energy efficiency. You'll need to compare the life-cycle savings to your initial budget for insulation to figure out the best return for your investment.

Start at the Top

If you have a limited budget for insulation, experts recommend insulating your attic or ceiling first. Compared to floors and walls, attics are a major contributor to a home's heat gain and loss, and bundling up an attic can shave up to 30 percent from your energy bills. Besides having a large surface area for heat transfer, attics can also have other conduits for air infiltration, such as recessed lights, plumbing and electrical chases, chimneys, exhaust fans, and ductwork. Together, these can account for more heat transfer than the *entire* flat surface of your attic.

Shawn Schreiner

Cotton batt insulation, made from post-industrial denim and other fibers, offers itch-free, easy installation and similar R-values to cellulose insulation.

Next, insulate walls and floors. In new homes, adequately insulating walls is a no-brainer. In older homes, however, it may be an expensive and difficult task. Get an estimate first, and then do the math to see how long it will take you to recoup your investment at a 16 to 20 percent savings on your heating and cooling costs. Insulating crawl spaces and underneath floors can save 5 to 15 percent on heating costs, and is usually an easier job.

These days, a wide variety of insulation materials are available. Here are some of the more common types you might choose, and brief descriptions of their properties.

Fiberglass. You might be most familiar with the "fluffy pink stuff"—fiberglass insulation. This insulation uses molten silica sand spun into fibers, along with different additives, such as boron, or a phenol formaldehyde or acrylic binder. Fiberglass is widely available in loose-fill and blanket products, and is relatively inexpensive.

Most fiberglass insulation manufacturers use recycled bottle glass—either pre-consumer glass scraps (known as cullet) or post-consumer glass from bottle-recycling

Adding It Up

An insulation's R-value indicates how well it resists heat flow. Generally, the higher the R-value, the better the insulation is at doing its job. But how and where insulation is installed also affects its performance. Insulation that is compressed too tightly into a space will not give its fully rated R-value. And a ceiling or wall's total R-value will usually be lower than the R-value of the insulation, mainly due to thermal bridging (increased conduction) that occurs through studs or joists because of their lower thermal resistance.

programs, incorporating 20 to 30 percent post-industrial and/or post-consumer material into their products. The production of the glass fibers can be energy intensive, but the low-density product means that the embodied energy is comparable to other insulation types.

Airborne fibers may be inhaled and absorbed into the lungs, particularly during installation. But phenol formaldehyde products used as binders have overshadowed this risk. This chemical off-gasses, and can contribute to poor indoor air quality. Acute effects of formaldehyde exposure include watery eyes, throat irritation, and nausea. Long-term effects have been harder to study, but the International Agency for Research on Cancer (IARC) classifies formaldehyde as a "probable human carcinogen." In response to this concern, some insulation manufacturers, like Johns Manville, have replaced formaldehyde binders with an acrylic binder. This formaldehyde-free insulation is off-white—the natural color of the fiberglass.

Cellulose. Old newspapers enjoy a new life in cellulose insulation, which is applied as loose fill or damp-sprayed into cavities. Cellulose insulation manufacturers purchase newsprint, cardboard, and paperboard that have been collected at recycling centers and shred it into fine pieces. After shredding, fire-retardants and mold inhibitors, such as boric acid, sodium borate (borax), and ammonium sulfate, are added. The finished product is about 80 percent recycled material by weight.

In terms of energy performance, cellulose insulation rivals high-density fiberglass batts, at roughly R-3.7 per inch. But because it generally packs more tightly than fiberglass batts, especially in damp-spray applications, cellulose is more effective at controlling air leakage. Settling can be a problem in loose-fill applications and can affect thermal performance.

Cellulose insulation is considered one of the greenest conventional insulation materials—from its raw materials to its manufacture. Because its production relies on a low-tech process, manufacturing plants can be small and localized, so transportation energy is usually low.

Questions have been raised about possible health risks of the chemicals and heavy metal residues (from newspaper ink) in cellulose insulation. But most researchers conclude that cellulose insulation does not pose a health risk to a home's occupants. As with other insulation materials, installers should minimize their risk of inhaling dust and fibers by using proper respiratory protection.

Cotton. Cotton insulation offers similar insulation value to cellulose. It's made primarily of blue-jean manufacturing trim waste (85 percent), with the remaining 15 percent consisting of microscopic plastic fibers to give it loft, and borates to resist pests and combustion. This product offers the installer itch-

Insulation Comparison

	R-Value Per Inch*	R-Value Per Thickness*
Loose Fill		
Fiberglass	2.2–2.9	–
Rock wool	2.2–2.9	–
Cellulose	3.1–3.7	–
Batts		
Fiberglass	2.9–3.8	–
Wool	3.5	–
Cotton	3–3.7	–
Rigid Board		
EPS	3.9–4.2	–
XPS	5.0	–
Polyisocyanurate	5.6–7	–
Liquid Foam		
Air Krete	3.9	–
Polyurethane	5.6–6.2	–
Other		
Straw bale	1.5	–
Straw-clay	1.6	–
Rastra (8 in. thick block)	–	11.0
SIPs (3.5–9.38 in. thick)	–	14.0–37.0
ICFs	–	18.0–35.0

*All values are estimates; total R-value will vary depending on material and installation techniques.

Courtesy Thermafiber

Slag wool, made from by-products of the steel mill industry, can also be sprayed into wall cavities.

free, fairly easy installation. Its installation and use poses few, if any, health risks to installers or a home's occupants.

Mineral (or Rock) Wool. Although "mineral wool" can be used to refer to fiberglass insulation or natural stone (usually basalt), most often it refers to a brittle material made from steel-mill slag—calcium, magnesium, and aluminum silicate minerals that are by-products of the steel manufacturing process. The slag is melted and then spun into fibers, an energy-intensive process, but one that doesn't require mining raw materials.

Moisture-resistant mineral wool retains its insulation abilities even when wet. It has excellent acoustic dampening qualities, and is more fire resistant than either fiberglass or cellulose. The company Thermafiber manufactures a spray-on mineral wool product with an R-value similar to sprayed cellulose insulation or high-density fiberglass batts.

The IARC puts mineral wool (rock and slag wool) in its Group 2B class: "possibly carcinogenic to humans." Although in some study groups, an elevated risk of death from respiratory system cancer and nonmalignant respiratory disease was observed, no consistent evidence of an association between those elevated risks and respirable mineral wool fibers was found. Mineral wool poses no off-gassing risks, and few health risks to a home's occupants.

Rigid Foam. Also called foam board, rigid foam insulation is most commonly used to insulate foundations and slabs, as well as exterior roofs and walls. With up to twice the R-value per inch of fiberglass or cellulose, it packs an insulation punch. Three types of rigid foam insulation are available.

Rigid foam polyisocyanurate insulation can be used to completely cover a building's exterior walls, reducing heating and cooling losses significantly.

Don't Forget Ducts

After ceilings, floors, and walls, ductwork can account for up to 15 percent of a home's winter heat loss, according to the DOE. This network of tubes in a home's walls, floors, and ceilings carries conditioned air to the rooms in your home. Most systems, unless they're relatively new, are uninsulated or not insulated properly. And uninsulated and leaky ducts translate into energy dollars down the drain.

Insulating and sealing ducts is especially important if they are located in unconditioned, unheated spaces. In the wintertime, ducts can leak heat, and in the summertime, they can actually draw in hot air, decreasing your central air conditioner's efficiency.

Minor duct repairs are easy to do yourself, but you may want to consult a pro to insulate and seal ducts in unconditioned spaces. First look for sections that should be joined, but have separated, and then look for obvious holes. Seal your ducts with Underwriters Laboratories (UL) certified tape to ensure a long-lasting bond. Insulating ducts in a basement will make the basement colder, so if both the ducts and the basement walls are uninsulated, consider insulating both. To help prevent condensation on cooling ducts, make sure that a well-sealed vapor barrier exists on the outside of the insulation. In most areas, use duct wrap insulation of R-4 or R-6.

Going Green

Because insulation reduces energy consumption—and the pollution associated with this energy use—any type of insulation can be considered "green," says Alex Wilson of BuildingGreen.com. Over a home's lifetime, the environmental benefits of that alone can outweigh any negative consequences that result from an insulation's manufacture.

From an embodied energy standpoint, some materials measure up quite differently—from what kind of materials they were made of and their manufacturing process—and this may be a consideration when you're making insulation decisions. You may also want to consider the health implications of using certain materials, whether you're doing it yourself or hiring an installer. Some insulation may off-gas (slowly release) volatile chemicals, such as formaldehyde, or shed small fibers, which can be inhaled, during installation.

Expanded polystyrene (EPS), extruded polystyrene (XPS), and polyisocyanurate (polyiso) are made from polymers—petrochemical-based foam plastics—that are expanded with a blowing agent.

XPS has a higher R-value and compressive strength than EPS, and is more moisture-resistant. Inch for inch, polyiso boasts the best insulation value of the three rigid foam boards. Aluminum-foil and plastic-faced polyiso offer even greater resistance to heat flow. Most of the rigid foam insulations undergo a gradual deterioration in their insulation value over time. This "thermal drift" eventually stabilizes, but can represent a significant shift from the product's original, rated R-value.

Blowing agents that are used to manufacture foam boards have been the target of environmental concerns because of their damaging effects on atmospheric ozone, a molecule that screens out harmful high energy ultraviolet rays. EPS, or beadboard, is made from polystyrene beads that are expanded with liquid pentane. As the agent disperses from the foam board, tiny, trapped bubbles in the material fill with air, giving the foam its insulative value. EPS has the least environmental impact because it is not manufactured using ozone-depleting chemicals. The pentane used as an expansion agent in EPS does, however, contribute to the formation of ground-level smog.

Most XPS or blueboard is made from polystyrene and HCFC-142b—a hydrochlorofluorocarbon expansion agent. While HCFCs are only 5 percent to 11 percent as damaging to atmospheric ozone than their CFC precursors, a single molecule can still damage *thousands* of ozone molecules. In the United States, HCFC-142b must be phased out by 2010.

Until 2003, most polyisocyanurate foam board was manufactured using HCFC-141b as the blowing agent. Today, most polyiso companies have switched to using a hydrocarbon mix, which causes no damage to atmospheric ozone.

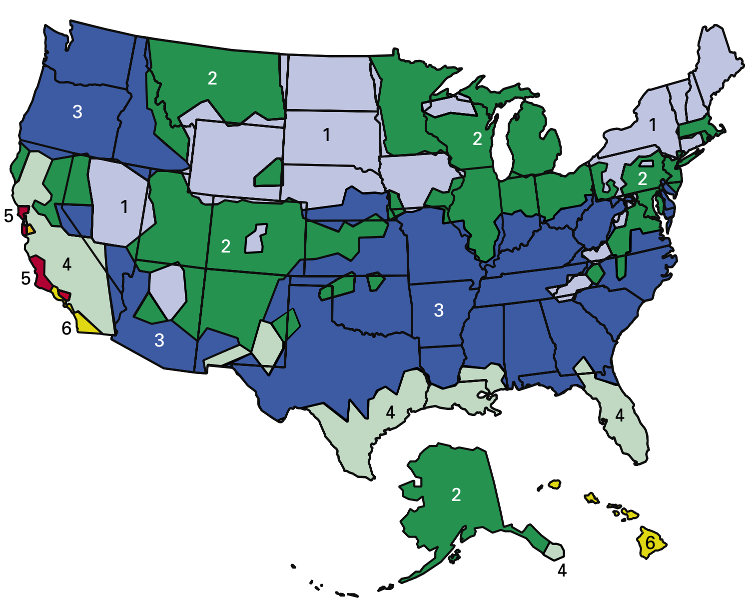
Besides relying on petrochemicals, foam board is energy intensive to manufacture, making it one of the insulation materials with the highest embodied energy. The use of

Recommended R-Values

Zone	Attic	Wall	Floor
1	R-49	R-18/R-28*	R-25
2	R-49	R-18/R-22	R-25
3	R-49	R-18	R-25
4	R-38/R-49	R-13/R-18	R-13/R-25
5	R-38/R-49	R-13/R-18	R-11/R-25
6	R-22/R-49	R-11/R-18	R-11/R-25

*First value is for homes heated with natural gas; second is for electric furnaces

Source: U.S. DOE, www.eere.energy.gov/consumer/tips/insulation.html




Courtesy Agriboard

All-in-one insulation and wall systems, such as Agriboard's SIP, made with strawboard and compressed straw, can reduce thermal bridging and air infiltration.

rigid foam board insulation poses few health risks, although there have been some concerns about the potential off-gassing from flame retardants and the plastic polymers.

Liquid Foam. Foamed-in-place insulation has the advantage of filling wall and ceiling cavities completely, providing high R-values (3.6 to 6.5 per inch) and blocking air leakage very effectively. Installation requires special equipment, however, and must be done by licensed contractors. Generally, liquid foam is sprayed into open wall cavities, where it rapidly expands—sometimes up to 100 times its original volume—to fill the space. Once it has dried, excess insulation is easy to trim off. Some foams can be used in closed wall cavities. These products expand more slowly, to reduce the risk of structural damage.

Most liquid or spray-foam insulation products are high-density, closed-cell polyurethanes, made from petroleum—and some of these still use the ozone-depleting HCFC-141b blowing agent. Open-cell, low-density polyurethane foams have been produced with water or carbon dioxide as the blowing agent for some time.

Compared with closed-cell polyurethane, open-cell products also use significantly less material, making them attractive from a resource standpoint. These spray-foams provide an airtight, water vapor resistant seal, and eliminate the need for vapor barriers in stick-framed homes. And most resist shrinking, settling, and sagging.

Polyurethane foams rank close to rigid foam insulations in terms of their embodied energy. To improve this energy-to-efficiency balance, some manufacturers are reducing their reliance on petroleum, replacing up to three-quarters of the petrochemical-based foam with a soy-based product.

Air Krete is one of the few nonpetroleum-based foams. Made with magnesium chloride, ceramic talc, and a proprietary foaming agent, it is sprayed into wall cavities with pressurized air. One drawback is that since it does not adhere to surfaces, material shrinkage or movement in a building may eventually cause gaps in the insulation, compromising the whole wall R-value. Air Krete offers superior fire-resistance.

Installers need to take safety precautions when working with these materials; others should not be present while polyurethane insulations are being installed. However, most indoor air quality professionals consider this product to be inert once it has cured.

Other Options: Wool & Straw. Sheep's wool has been commonly used in Australia and New Zealand for decades, but is now just starting to make its way into U.S. homes. With an insulation value higher than standard fiberglass, it also retains its value when wet and is naturally flame-resistant, although some wool insulation manufacturers add boric acid as an additional flame retardant.

Straw bales have been used as a cheap and effective building and insulation material since the nineteenth century. Oak Ridge National Laboratory determined the R-value to be R-27.5 (or R-1.45 per inch), or R-33 for three-string (23-inch-wide) bale wall systems. The California Energy Commission reports that a plastered straw bale wall has an average R-value of 30. Straw-clay, a mixture of short, chopped strands of straw and clay slip, can be packed into wall forms or ceilings to create thick, fire-resistant, and fairly mold- and mildew-resistant walls, with an estimated R-value of about R-1.6 per inch, according to research results reported by the Canadian Mortgage and Housing Corporation.

Because these materials undergo little or no processing, and can be sourced locally, their embodied energy and resulting environmental impacts are generally low. They pose no or very little health risk to installers or a home's occupants.

Integrated Insulation. Some homebuilders today opt for all-in-one construction, combining insulation within their wall and ceiling structures. Several different products are available to meet this need. Structural insulated panels (SIPs) sandwich a polystyrene, isocyanurate, or even a compressed straw core between plywood, oriented strand board, or strawboard panels. Using these large panels reduces thermal bridging and air gaps more common in conventionally insulated stick-frame homes.

Insulating concrete forms (ICFs) integrate poured concrete into interlocking foam board or hollow-core polystyrene blocks to make a complete wall or foundation system. Because of its flammability, though, ICFs exposed to occupied spaces must be covered with a fire-resistant material.

Rastra "blocks" incorporate recycled polystyrene, Portland cement, and additives into a framework, which is glued or clamped together until the concrete is poured. This lightweight, strong material can be easily worked with all woodworking tools, and carved to achieve curves. By volume, Rastra contains 85 percent recycled content. No energy is used to cure the elements, and only about 1 KWH is required to produce one Rastra element—a 10-inch-thick, 15 by 10-foot panel. This product provides high insulation values with no off-gassing, and is pest- and fire-resistant.

Access

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Thanks to Mark Piepkorn, Associate Editor at *Environmental Building News* (www.buildinggreen.com), and Andre Desjarlais, Program Manager of the Building Envelopes Program at Oak Ridge National Laboratory's Buildings Technology Center, for their expert review of this article.

Select Insulation Manufacturers/Distributors:

Agriboard Industries, 8301 E. 21st N., Ste. 320, Wichita, KS 67206 • 866-495-3595 or 316-630-9223 • Fax: 316-636-9255 • info@agriboard.com • www.agriboard.com • SIPs made with a compressed wheat-straw core

Bonded Logic Inc., 411 E. Ray Rd., Chandler, AZ 85225 • 480-812-9114 • Fax: 480-812-9633 • www.bondedlogic.com • Cotton insulation

Good Shepherd Wool Insulation, RR 3, Rocky Mountain House, AB, Canada T4T 2A3 • 403-845-6705 • Fax: 403-845-6705 • www.goodshepherdwool.com • Sheep's wool insulation

InnoTherm, PO Box 226, Newton, NC 28658 • 877-466-0612 or 828-466-1147 • Fax: 828-466-1498 • rcfrazier@hickorysprings.com • www.innotherm.com • Cotton insulation

Insulating Concrete Forms • www.icfweb.com • General ICF information

Johns Manville, PO Box 5108, Denver, CO 80217 • 800-654-3103 or 303-978-2000 • www.jm.com • Formaldehyde-free fiberglass insulation

Nu-Wool Inc., 2472 Port Sheldon Rd., Jenison, MI 49428 • 800-748-0128 • Fax: 616-669-2370 • info@nuwool.com • www.nuwool.com • Cellulose insulation

Rastra Corp., North American Corp. Office, 7621 E. Gray Rd., Ste. A1, Scottsdale, AZ 85260 • 877-935-3545 or 480-443-9211 • Fax: 480-443-9228 • info@rastra.com • www.rastra.com • Rastra insulated blocks

Structural Insulated Panel Association, PO Box 1699, Gig Harbor, WA 98335 • 253-858-7472 • Fax: 253-858-0272 • staff@sips.org • www.sips.org • General SIP information

Thermafiber, 3711 W. Mill St., Wabash, IN 46992 • 800-294-7076 or 260-563-2111 • Fax: 260-563-8979 • info@thermafiber.com • www.thermafiber.com • Rock wool insulation

Urethane Soy Systems Co. Inc., PO Box 500, Volga, SD 57071 • 888-514-9096 or 605-627-6393• Fax: 605-627-5869 • tom.kosakowski@soyol.com • www.soyol.com • SoyTherm 50, soy-based polyurethane insulation

U.S. GreenFiber LLC, 809 W. Hill St., Ste. A, Charlotte, NC 28208 • 800-228-0024 • Fax: 704-379-0685 • greenfiber.info@us-gf.com • www.us-gf.com • Cellulose insulation

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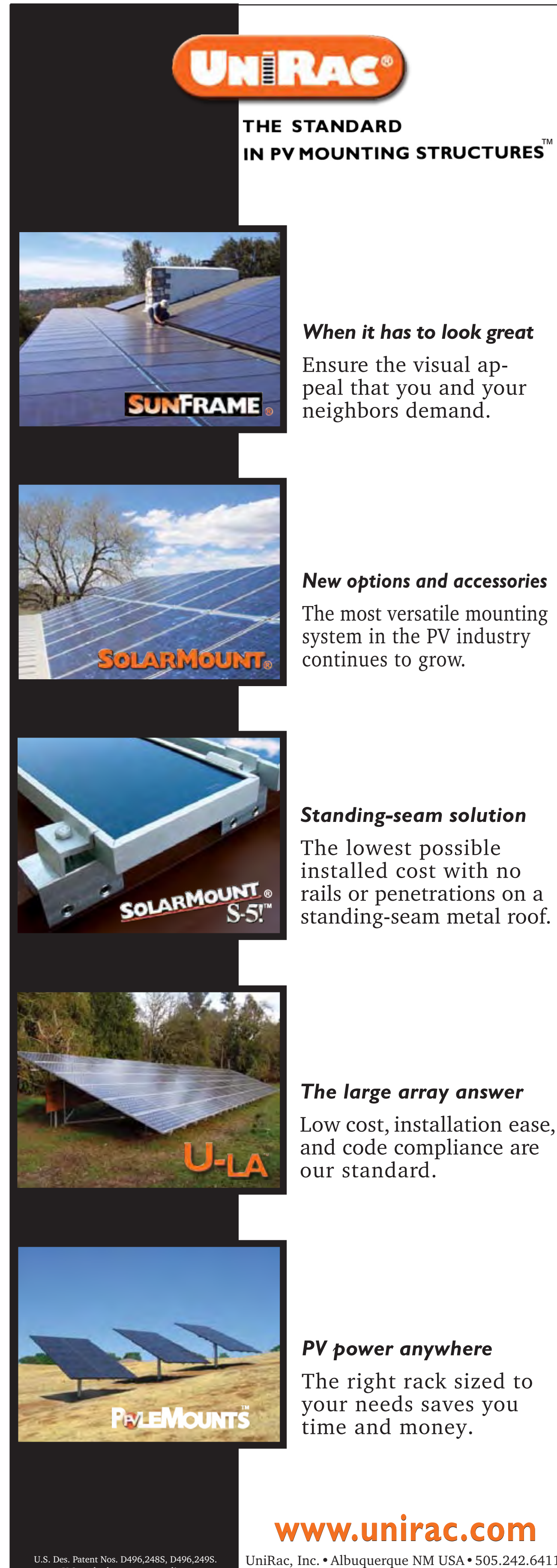
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A 34 KW system, the largest in Minnesota and the surrounding five states, was installed at the Green Institute, a Minneapolis nonprofit.

Randy and Kris Olson show off their 1 KW solar-electric shingle system in Elk River, Minnesota.

Courtesy Kris Olson

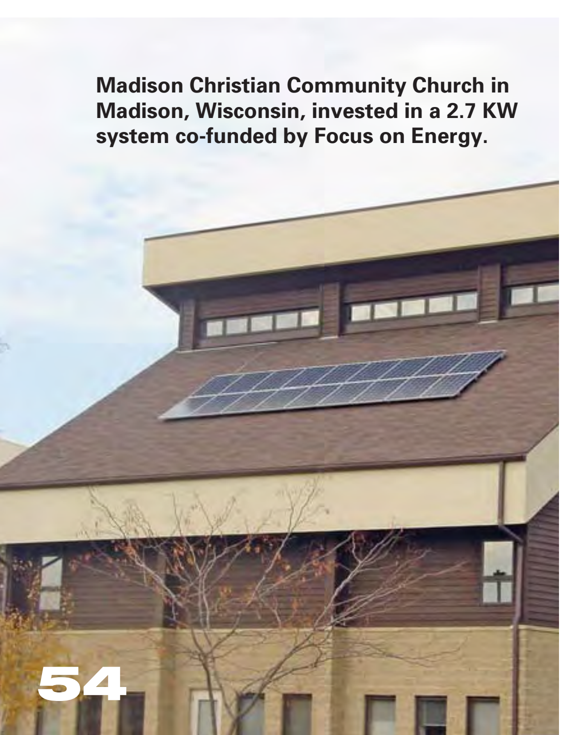
A Tale of Two States

Small Solar Rebates—Steady Success

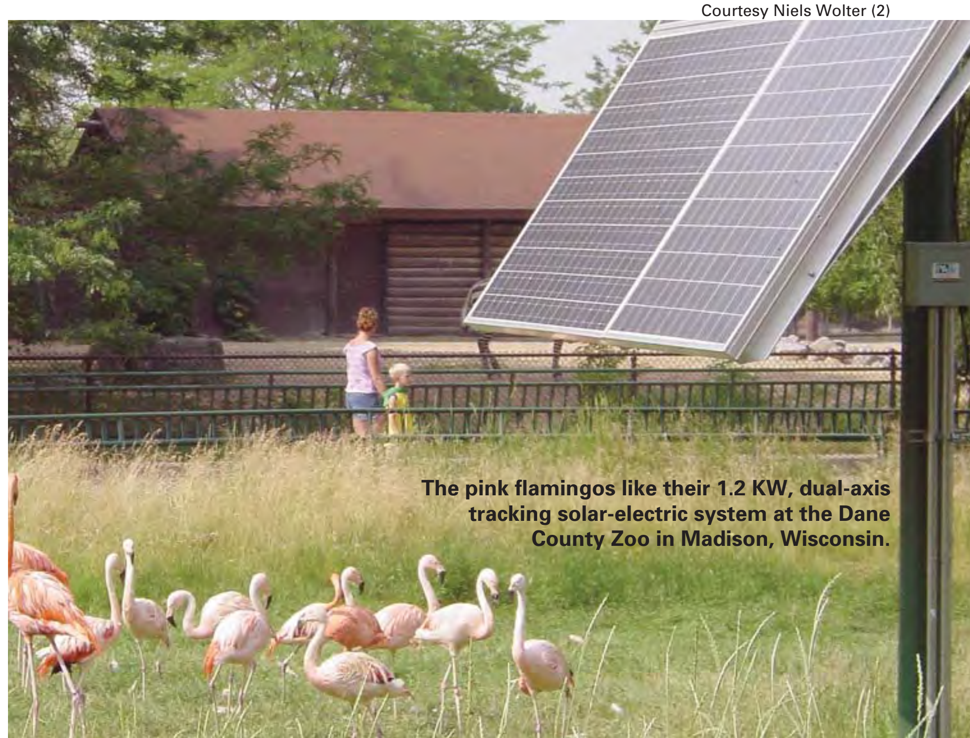
With as good or even better solar resources than parts of Florida or Texas, Minnesota and Wisconsin have become movers and shakers in the Midwest's solar-electricity markets. In this region known for its pragmatic attitudes and reliance on tradition, there is a decidedly progressive movement toward residential renewable energy.

Mike Taylor, Minnesota Department of Commerce & Niels Wolter, MSB Energy Associates Inc.

Courtesy Niels Wolter (2)



Madison Christian Community Church in Madison, Wisconsin, invested in a 2.7 KW system co-funded by Focus on Energy.



The pink flamingos like their 1.2 KW, dual-axis tracking solar-electric system at the Dane County Zoo in Madison, Wisconsin.

In fact, both states have more solar-electric capacity per capita than either Florida or Texas. In the past three years, the amount of grid-connected solar electricity in Minnesota has more than doubled—from 186 kilowatts (KW) to 421 KW—largely because of Minnesota's PV (photovoltaic; solar-electric) rebate program. Similarly, Wisconsin's PV rebate program has co-funded about 200 KW of PV installations, increasing the state's PV-produced electricity capacity to about 460 KW. And this is despite small budgets and smaller-than-average incentives—typically a 20 percent to 25 percent rebate.

Program Particulars

The Minnesota Solar Electric Rebate program pays US$2,000 per installed KW (the sum total of the DC ratings of the solar-electric panels in the system) for systems ranging in size from 0.5 to 10 KW of grid-connected solar electricity. Larger systems are eligible for the rebate on a case-by-case basis. Only new equipment qualifies, and a site assessment, performed by the applicant or their solar-electric dealer, is required.

To qualify for Minnesota's rebate, a site needs to meet an estimated annual production of 960 kilowatt-hours (AC energy) per KW installed. (For comparison's sake, an unshaded, nontracking, 1 KW system in Minneapolis produces an estimated 1,100 KWH per year.) Typically, the solar-electric installer submits a Solar Pathfinder diagram, photographs, and a copy of the rebate program spreadsheet used to calculate the system's estimated performance. Applicants not using solar dealers can opt to provide just photographs with their applications. However, if site shading is evident in the photos, the rebate program requires a Solar Pathfinder diagram and spreadsheet assessment.

Gordon Carlson of Duluth, Minnesota, received the standard state rebate of US$5,340 for his 2.67 KW PV system, and an additional US$4,000 from his electric utility, Minnesota Power.

Courtesy Helen Carlson

The Wisconsin program uses the U.S. Department of Energy's PVWatts calculator, along with information (panel capacity, orientation, shading, and percent snow cover) supplied by the prospective system owner to estimate the system's anticipated production. The PVWatts production estimate is reduced by 20 percent to account for system losses (inverter and wire losses, and panel temperature correction).

The 3.06 KW solar-electric system on their Minneapolis, Minnesota, home makes this modern *American Gothic* couple much happier than the ones in Grant Wood's painting.

Both programs allow homeowners to install their own systems, provided they meet applicable local building codes and pass the electric utility's anti-islanding test (which determines that the system can be successfully shut down in the even of a grid failure). However, Wisconsin incentive amounts are tiered to reflect various parameters, awarding:

- US$1 per KWH for self-installed systems
- US$1.50 per KWH for professionally installed systems
- US$2 per KWH for North American Board of Certified Energy Practitioners (NABCEP) installed systems
- US$3 per KWH for NABCEP-installed systems on new Wisconsin Energy Star Homes or new commercial buildings

The incentive is a one-time payment based on the yearly electricity production estimate made at the time of application.

Owners of this home in Waukesha, Wisconsin, installed a 4.32 KW solar-electric system.

Courtesy Jon & Janell Wilcox

PV Rebate Program Comparison

Demographics	Minnesota	Wisconsin
Population (2003 census)	5,059,000	5,472,000
Households (2003 census)	1,895,000	2,085,000
Grid-Connected PV		
Pre- or non-rebate (KW)	186	260
Rebate program (KW)	235	200
Total KW	421	460
Program Specifics		
Participating households (to date)	79	100
Rebate amount per KW (US$)	$2,000	$1,200–$3,600*
Eligible system types	On-Grid	On- / Off-Grid
Spent to date (US$)	$497,000	$870,000
Total budget (US$)	$1,150,000	Annually Renewed
Program end date	Dec. 31, '07	Annually Renewed

*Approx. per KW; actual rebate is US$1–$3 per KWH, dependent upon installation variables

Funding

Minnesota's PV program funding comes from Xcel Energy's Renewable Development Fund (RDF), a mandated funding source that was part of a legislative compromise to allow additional nuclear waste storage at the Prairie Island nuclear power plant in Red Wing, Minnesota. (Most of Minnesota's utility-scale wind energy development was also the result of the compromise.) Xcel Energy issued a competitive request for proposals to spend the RDF, and the solar-electric rebate program was one of many chosen for funding. The Minnesota Department of Commerce State Energy Office administers the program, and Xcel Energy funds it through periodic payments to the state.

Focus on Energy administers Wisconsin's rebates. The state's electricity and natural gas utility ratepayers fund the program through a "systems benefit charge," a small fee that appears on their bills. The state collects this fee from the utilities and disperses it through Focus on Energy's energy efficiency and renewable energy projects. As a result of this funding centralization, they are able to provide enhanced coordination of their solar programs, which include training, workshops, and other industry and consumer educational efforts. Since the program's inception, the number of PV installers in Wisconsin has more than doubled. Several installers are NABCEP-certified, and several more are in the process of being certified. The program also supports renewable energy education in primary and secondary schools with its K–12 Energy Education Program (KEEP) and at Wisconsin's technical colleges. However, the program's centralization has also made it subject to significant funding cuts during recent Wisconsin state budget downturns.

Minnesota's simple dollar-per-KW approach provides for an easily marketed message and low administrative costs, but does not provide funding for training, workshops, or other industry or consumer educational programs. Although Minnesota isn't able to offer a more comprehensive program, its funding is somewhat insulated from potential cuts because of the legal contract that exists between Xcel Energy and the State, making it a more difficult target for budget cuts.

Although Minnesota's rebate program lacks the breadth of Wisconsin's, it has sparked many unanticipated changes in the state. Minnesota Power, a northeastern Minnesota utility, now offers a companion rebate program for their customers, and another cooperative utility, Great River Energy, is developing one for its members. Community solar-electric projects are emerging on schools, nonprofits, and businesses, where local citizens actually help plan and fundraise for PV systems in their neighborhoods. Three solar home tours take place in various parts of the state. Solar Saver Homes, a building developer, constructed and sold eight energy efficient town homes that have integrated solar-electric shingles. A Million Solar Roofs Initiative was started in Minnesota, and

The Dodge Nature Center in West St. Paul, Minnesota, features a 1.0 KW system on a single-axis tracker.

Courtesy Anderson family

Tom Anderson from Cloquet, Minnesota, stands in front of his 2.53 KW solar-electric system on a sunny winter day.

various organizations are slowly awakening to solar energy opportunities in the state.

Incentive Levels

Both Wisconsin and Minnesota's programs are limited to relatively small budgets. This translates into either a small number of systems that receive larger incentives or more systems with less funding for each. By starting small, both states independently concluded that the market would grow in a more moderate fashion and attract the passionate installer and system owner. Interestingly, if Minnesota had offered a US$4,000 per KW rebate, the funding would have been used by the end of 2005. As a result, fewer individual photovoltaic projects would have ultimately been installed, and no additional funding to continue the program would be available now.

Getting Tied In

Connecting PV systems to the grid in Minnesota is a mixed bag that is improving. Net metering, which allows system owners to offset their electrical usage with their electrical production, has been available since 1984, but the rules have not been revised in many years. While strong in spirit, the interface with recently adopted distributed generation interconnection standards is not clear and in some cases conflicting.

However, Minnesota Power, which was the first to offer a companion rebate program, has stepped up its leadership on training solar dealers, code officials, and its internal engineers to streamline interconnection in their service territory. Other utilities may follow this model of cooperation. In addition, system owners continue to press interconnection issues with their local utilities. And those who have made it through the interconnection grind are making it easier for those who follow.

In Wisconsin, utility-tied systems are no longer an issue. A collaboration of interested parties (electric utilities, renewable energy groups, regulators, and the public) developed uniform, statewide technical standards, forms, and processes for interconnection, and presented them to the Public Service Commission of Wisconsin and the Legislature in 2002. Today, these standards are law.

Wisconsin's Renewable Energy Program helped the state develop a simple, uniform interconnection application and requirements. And We Energies, the largest regional utility in Wisconsin, recently agreed to buy solar-electric generated energy at a rate much higher than the retail rate, for use in their green pricing program.

Program Results

The response to both programs has been very similar over roughly the same time period—about 200 KW of new capacity has been installed in each state. Together, this represents more than US$3 million in solar investments.

Initially, both states were challenged with few PV installers and needed to grow their installer base. Today, both states maintain lists of solar energy installers for consumers to reference. There is no licensure requirement to be listed in either state, but there is a designation if an installer is NABCEP certified.

In Minnesota, 89 percent of the funds have gone directly to rebates. The average system size is 2.5 KW, and 78 percent of these systems are installed at residential locations, with an average cost of US$8,177 per KW for a dealer-installed system. A 34 KW system, the largest in Minnesota and the surrounding five states, was installed at the Green Institute, a Minneapolis nonprofit.

The biggest underestimation of the Minnesota program was that the progress of solar installations was slower than proposed in the funding application. Originally slated as a four-year program, after three years, the solar rebate program is only about halfway toward the goal of 500 KW of installed PV.

Program Statistics

	MN	WI
Avg. system size (KW)	2.5	1.9
Avg. on-grid system cost (US$/KW)	$8,177	$9,230
% Residential	78%	75%
% Dealer installed	80%	68%
Largest system funded (KW STC)	34	12

In Wisconsin, the influx of applications for solar-electric incentives is highly variable. A seasonal cycle exists, with applications peaking in the June–July time frame. Applications also increase whenever funding is threatened, or when incentive levels are poised to decline. Other factors thought to influence application rates include local and world issues and events, and the state's economy.

Lessons Learned

More than 400 KW of new photovoltaic systems have been added in three years using only about a 25 percent rebate between the two states. This bears witness to the progressive nature of Midwesterners who have committed to PV, despite the common misperceptions of the lack of solar resources in this region.

Although each program's measure of success is to get more PV installed, the programs are also helping to build grassroots and organizational support for solar energy and the solar industry. These rebate programs are moving the Midwest solar-electric market forward, providing consumers with an incentive to say "yes." The respective programs also provide the PV industry with a predictable, long-term market. And, as more people become aware of the rebate programs, the goals of a self-sustaining industry will become attainable.

Minnesota's program is set to expire at the end of 2007; Wisconsin's is dependent on annual funding availability. The key will be the transition away from the incentives—will the market dry up or will the low incentive levels help the industry in the long run? Time will tell.

Access

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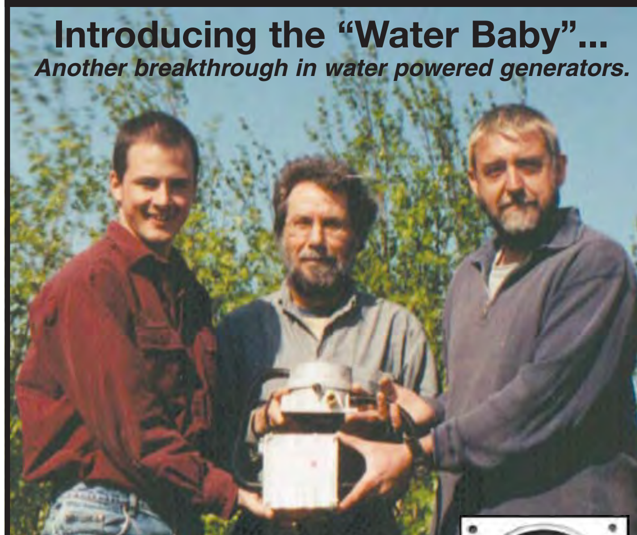
Wisconsin Focus on Energy Program, 211 S. Paterson St., 3rd Fl., Madison, WI 53703 • 800-762-7077 • renewinfo@focusonenergy.com • www.focusonenergy.com

PVWatts Calculator • http://rredc.nrel.gov/solar/calculators/PVWATTS/ • Performance calculator for grid-connected PV systems

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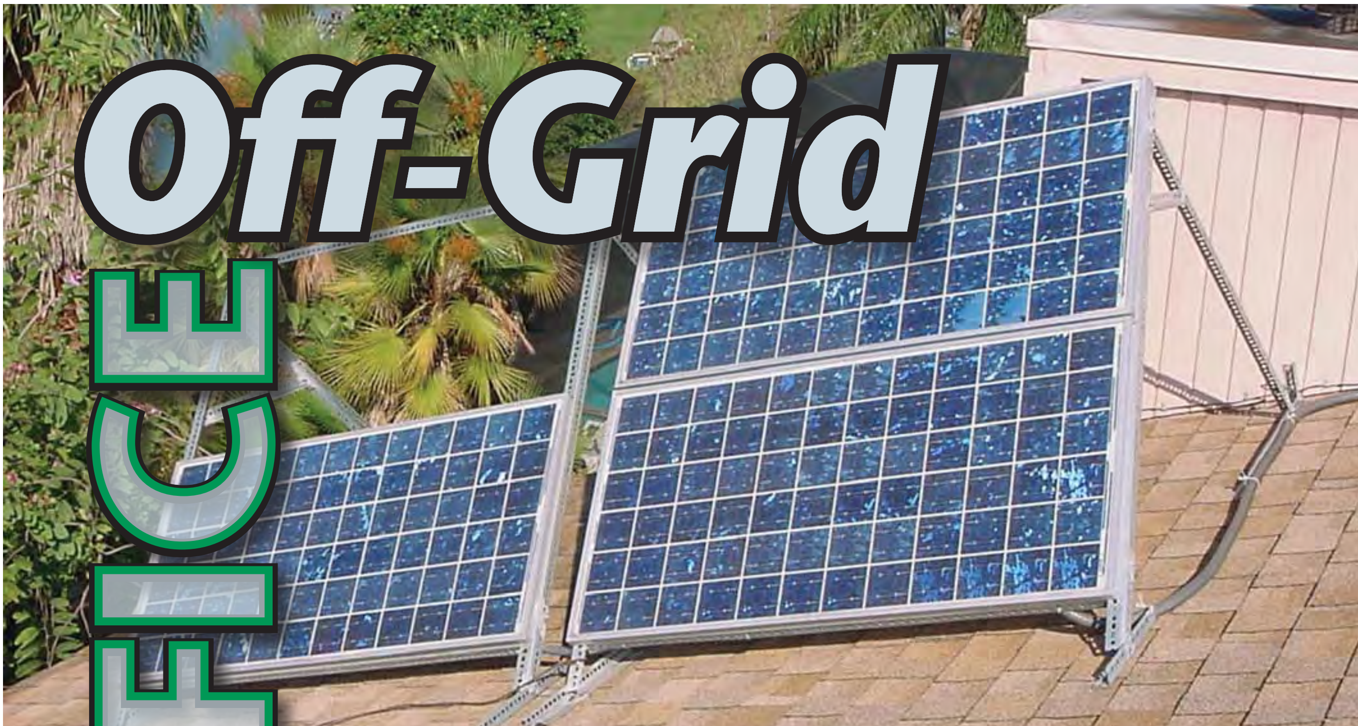


Most people in suburbia are grid connected and content. They would like to do something with solar electricity, but really don't know where to begin. I found myself in a similar position. I loved the idea of going solar, but wasn't ready to make a large investment. Instead, I decided to start small and take my wife's home office off the grid. I also decided that I wanted to do the work myself.

Bob Owens

With these ideas as a starting point, I designed a small, stand-alone solar-electric system. I wanted:

- To remove a single electrical circuit from the grid, and power it with solar electricity.
- To have an emergency power supply (EPS) during extended utility outages.
- The EPS function to allow a generator to be connected to all the house circuits.
- All circuits to be switch-selectable between utility and generator, with no possibility of the system energizing a downed grid.
- To take advantage of the fact that a PV system produces more electricity in the summer than in the winter. A battery-powered lawn mower would use the excess energy during the summer.
- To install the system by myself, with no special tools.
- All parts to be readily available and costs reasonable, with future upgrades to system capacity already planned.
- To install the system in phases, with each phase able to function independently.

Getting Started

Well, that is quite a list, but I did it! Where did I start? As with any solar energy project, you start with a load analysis. In this case, I wanted to remove one house circuit from the grid, but which one? My wife Barbara uses one of the bedrooms as her office. It contains a computer, scanner, printer, fax machine, and overhead fan with a light on its circuit. It is in use two to four hours each day. Most of the time, only the computer and its monitor are on. We decided that her office would be a good candidate for solar electricity.

The computer draws 200 watts and the monitor another 100, for a total of 300 watts. Assuming that the computer and monitor are used three hours per day, we needed 900 watt-hours per day. The other loads (printer, scanner, fax machine, and lights) were small and only used intermittently—they could be ignored. The fax machine is only turned on when needed. The printer and scanner are plugged into one plug strip switch, eliminating any phantom loads. This had the added benefit of turning both machines on or off with one switch—you couldn't leave anything on by accident.

System Design

How many PV panels would we need to run the office? Stand-alone, battery-based PV systems have an overall system efficiency of roughly 65 percent, and our site receives about five peak sun-hours per day on average. A 300-watt PV array would generate about 975 AC watt-hours per day (300 x 5 x 0.65), enough to cover the office load on a sunny day. Once the number of panels you need has been determined, all other system components can be sized appropriately.

We wanted enough battery storage to run the office for three days without sun. If cloudy periods extended longer than that, the office could be switched back over to the utility grid until the PV system fully recharged the batteries. I calculated the required size of the battery bank as follows. Four, 220-amp-hour (AH), 6-volt (V) deep-cycle batteries wired in series–parallel would provide 440 AH of battery storage at 12 volts nominal, or about 5,500 watt-hours (WH) total (440 AH x 12.5 V) during normal operation. But completely discharging your batteries will quickly destroy them, and discharging them less deeply will make them last longer. Limiting the battery discharge to 50 percent gives me an effective storage capacity of about 2,750 WH (5,500 x 0.5), which met my design goal of three days of autonomy.

A 20-amp PWM (pulse-width modulated) charge controller regulates the solar charging. To keep costs down, I went with an inexpensive modified square wave, 600-watt inverter. While a sine wave inverter would have provided higher quality electricity for the office electronics, everything has been running fine so far. Finally, I needed an EPS subpanel to wire into our main house panel. This panel is designed to transfer electrical loads between a backup generator and the grid in case of a grid failure. They are stocked by most hardware and home improvement stores.

The author with his batteries and inverter.

Legal Protections in Florida

Florida Statute 163.04 forbids ordinances, deed restrictions, covenants, or similar binding agreements from prohibiting solar equipment use. Under this law, a homeowner may not be denied by any entity permission to install a solar collector, clothesline, or other energy device using renewable resources. Homeowner associations in deed-restricted communities cannot forbid solar equipment installations.

System Installation

First, I installed the EPS subpanel, following the manufacturer's directions exactly. Hire an electrician if you don't feel confident about installing this panel yourself.

The next item was the battery box. You can buy a plastic tub, or fabricate a wooden or steel box, and make it as simple or elaborate as needed. I wanted a battery box that would contain all the electronics in a separate compartment from the batteries, and have a cover. I built the box using pressure-treated 3/4-inch (19 mm) plywood, and added a hasp and handle on the lid.

I decided to build my own panel mounts from galvanized steel strut material, bolted together. I assembled as much on the ground as I could. The less time spent on the roof, the better. Once the array was assembled, I tried lifting it. If you have any doubts about your abilities, get some help. An incident on the ground could become an accident on the roof. After pre-positioning the tools and parts I would need up on the roof, I hoisted the array, positioned it, and fastened it directly to the trusses with lag bolts. Silicone sealer was used to keep the roof penetrations watertight.

Wiring

All that was left to do was the wiring. First I connected a bare copper ground wire to each of the PV module frames and to a ground rod. This equipment-grounding approach keeps static electricity from building up on the array, and reduces the chance of lightning damage to the equipment. All of the PV system's electrical equipment is bonded to this same equipment ground. PV wiring between the array and the batteries was run in conduit for safety.

I made up custom battery cables. The lugs were crimped and then sealed with heat-shrink tubing. Next I wired the batteries in series–parallel. An AC battery charger and an inverter were installed with breakers to protect against fire, according to the manufacturers' instructions. Finally, I made the connection from the inverter to the transfer panel.

The battery box stores the batteries, PWM charge controller, and inverter. A divider separates the batteries from the electronics.

Tech Specs

Overview

Type: Battery-based PV system

Location: Brandon, Florida

Solar resource: 5 average daily peak sun-hours

Production: 30 AC KWH per month

Photovoltaics

Modules: 3 Photowatt PW 1000, 100 W STC, 17.1 Vmp, 12 VDC nominal

Array: 3 modules in parallel, 300 W STC total, 17.1 Vmp

Array installation: Self-made mounts installed on south-facing roof, 30-degree tilt

Energy Storage

Batteries: 4 golf cart batteries, 6 VDC nominal, 220 AH at 20-hour rate, flooded lead-acid

Battery bank: 12 VDC nominal, 440 AH total

Balance of System

Charge controller: BZ Products, 20 A, PWM

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

Performance metering: BZ Products LPM 10u battery monitor, digital ammeter

Applications

The solar-electric panels are now powering my wife's office circuit most of the time. If a few cloudy days occur in a row, it is a simple matter to flip the circuit breaker back to using the utility until the batteries get recharged. A breaker in the battery box allows the array to be disconnected easily for any maintenance that may be required.

In the event of an extended utility outage, any circuit in the EPS panel box can be switched over to the solar-electric system as needed. With judicious use, the system can provide electricity to select appliances in case of an emergency. This is much more desirable than trying to use flashlights, candles, or generators to get through a crisis.

Owens System Costs

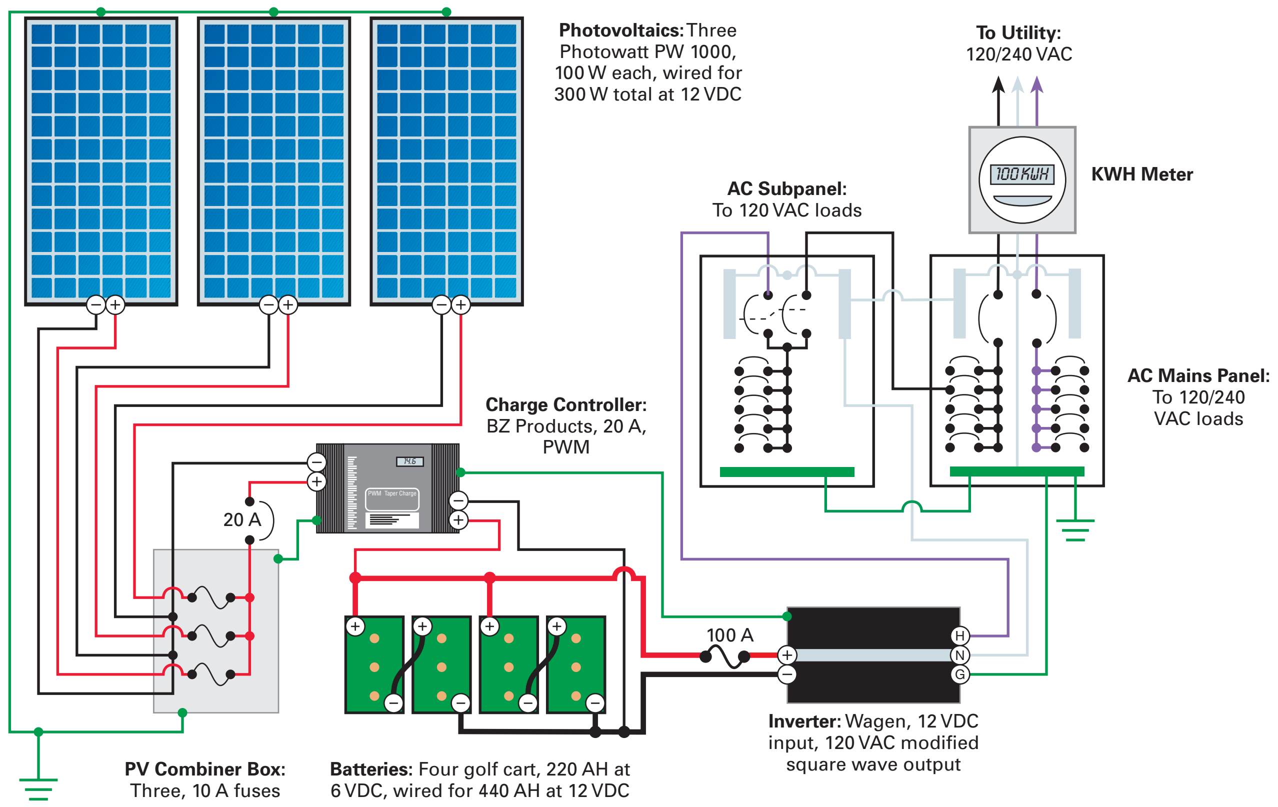
Item	Cost (US$)
3 Solar-electric panels, 100 W	$1,300
2 Mounting frames	200
4 Golf cart batteries, 6 V	200
Subpanel, EPS	200
Cable & lugs, #4 100 ft.	100
Battery charger, 20 A	100
Inverter, 600 W	100
Charge controller, 20 A	100
Weather-proof cables & connectors	80
LED battery meter	50
Lightning protector	50
Ground rod system	50
Miscellaneous	50
Rain-tight disconnect box	20
Total	$2,600

The last item, the addition of a battery-powered lawn mower to the charging circuit, was the easiest part to accomplish. I went online and bought Sears' best battery-powered electric lawn mower. I ran an extension cord from the inverter to the transformer cube that powers the mower's battery charger. Once charging was complete, it was time to try the mower out on the grass. The unit mowed my entire lawn without a problem, and it was easier to maneuver around the lawn than my old gas mower. It was much quieter and didn't require pull-starting, gas, or oil.

Positive Steps

Well, all the goals I initially set have been accomplished and the system has been up and running for about three years. How does it work? It covers the load it was designed for reliably, and worked well within its limits. When Barb's computer use went from two hours a day to more than eight hours, her computer and monitor had to be upgraded to keep up with her needs. The system was not designed for that. More PVs will need to be added to cover the added load.

Off-Grid Office System



During the hurricanes in 2004, we had no utility electricity for five days. The PV system was an excellent emergency power system during those times. It's amazing how much better you feel if a couple of house lights are working normally.

It is comforting to go to bed every night knowing that our EPS system is functional and can be turned on with the flip of a switch. There are also the less tangible benefits of contributing less to air pollution and, best of all, the satisfaction that comes from knowing that I have taken a positive, powerful step towards a better future.

The power transfer box (right) connected to the mains panel (left). Circuit breakers keep everything safe.

Access

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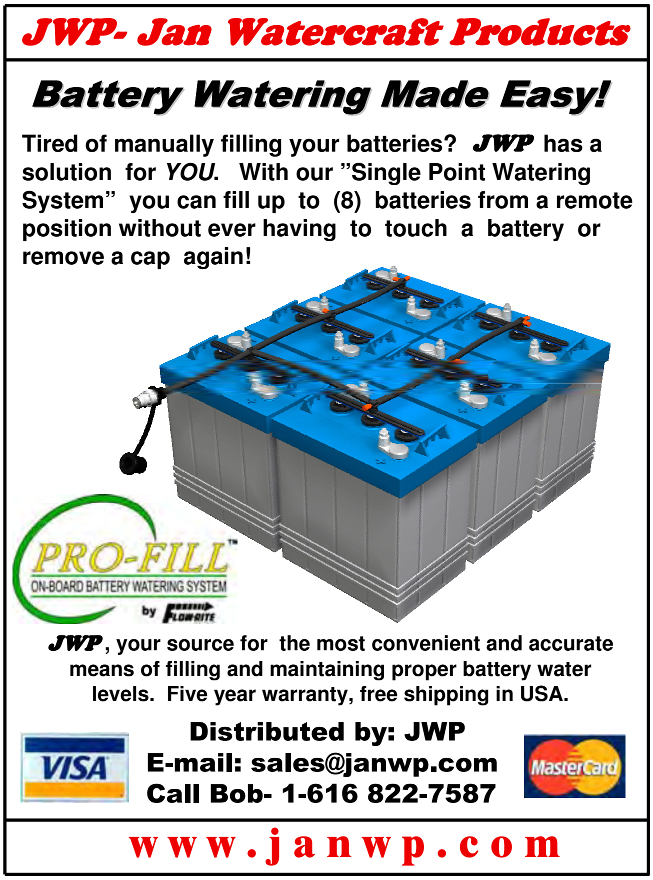
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Solar Transformation
One Village at a Time

Jeff Lahl

In the dry savannah villages of northern Nigeria, just south of the Sahara Desert, most people still scratch out a subsistence living, growing their crops in extremely harsh conditions. Although wood is a rapidly disappearing resource, it is still the primary fuel used for cooking. For lighting, most villagers still rely on kerosene lamps, which produce toxic fumes and pose a fire risk. Many villages obtain their water by a rope and bucket from open wells, which are often contaminated. Health resources are minimal, and village primary schools are often no more than dilapidated buildings lacking chairs, desks, and books.

And yet Nigeria is not without resources. As a member of OPEC (Organization of the Petroleum Exporting Countries), Nigeria exports nearly US$15 billion worth of oil each year and is the sixth largest supplier of oil to the United States. Ironically, very little oil revenue filters down to help the rural population. Of the funds that do make their way to northern Nigeria, most are used for larger-scale development projects, such as roads. Seldom do the funds or projects benefit the poorest people, the rural villagers.

Electrical energy has tremendous power to catalyze development in all sectors of community life, ranging from health and education to economic development. Although electricity is sporadically available in larger towns and cities, it is almost never found in small villages. Since oil revenues and the national grid offer little hope in the foreseeable future, another source of energy is needed to help these villages.

An Ambitious Project

In 2001, Robert Freling, executive director of the nonprofit Solar Electric Light Fund (SELF), and his excellency Ibrahim Saminu Turaki, Governor of Jigawa State in northern Nigeria, initiated a proposal to use solar electricity (photovoltaics; PV) to provide energy for essential services in three villages. The projects were funded by the U.S. Department of Energy, through an interagency agreement with the U.S. Agency for International Development, and the Jigawa State government.

After extensive surveys and consultation with community members, an ambitious goal developed—to demonstrate the comprehensive use of solar electricity for a range of applications, including education, health care, water pumping, agriculture, and economic development.

To implement the project, SELF partnered with the Jigawa Alternative Energy Fund (JAEF), a nongovernmental organization that promotes renewable energy use in northern Nigeria. As SELF's project manager, I visited the three villages with my JAEF associates, meeting with community members to assess each village's development needs. After getting their input, we drafted proposals to discuss with them. Once the proposals were approved, the equipment list was put out for international bid, which was won by Kyocera Solar.

All from the Sun

Our first completed system was a streetlight. We had announced to the village of Wawan-Rafi that the first light would be installed by that evening, and a crowd of 40 to 50 people had gathered to watch the light click on. When it finally flickered on, people cheered and looked up at the

As a beautiful sunset blossoms, technicians race to complete the wiring on the first solar-electric streetlight—and the first source of electricity—in this village. Besides providing a measure of safety for the community, these solar-powered lights now illuminate evening gathering spaces for village members.

light with delight and wonder, and children danced around the light pole. Electricity had come to this village for the first time.

We completed the other systems over the next few months. Below are brief descriptions of the types of projects we accomplished.

Streetlights. In a hot climate where people enjoy the cool of the evening, streetlights provide safe and pleasant gathering places for socializing and commerce. Each stand-alone system consists of a 50-watt PV module, a 100 amp-hour battery, a charge/light controller, and a 13-watt CF floodlight.

Village schools. A 320-watt PV array and 400 amp-hour battery provide energy to illuminate two primary school classrooms with nine, 11-watt compact fluorescent (CF) lightbulbs in each classroom. The school principal now has the village's first computer and the AC electricity to run it.

Village health clinics. A 160-watt PV array, charging a 400 amp-hour battery, provides energy for three, 11-watt CF lightbulbs, a small vaccine refrigerator, and a DC table fan.

Community water pumping. A 1-horsepower submersible pump, powered by 24, 80-watt PV modules, provides between 3,000 and 5,000 gallons (11,356–18,927 l) per day of clean, fresh water from an uncontaminated aquifer.

Mobile solar irrigation pumps. In one village that has a year-round source of surface water, solar-powered pumps help the poorest farmers grow crops during the dry season, providing a critical inflow of food and cash into the village. Four durable Uni-Solar 64-watt PV modules (in a folding array) are connected through a linear current booster to a

Village PV Applications

Application	No. of Systems
Three-light home system	40
Streetlights	34
Five-light home system	20
Health clinics	3
Microenterprise centers	3
Mosques	3
Schools	3
Village water pumps	3
Mobile irrigation pumps	2

A stand-alone solar-electric system provides energy for this remote clinic's vaccine refrigerator, a small table fan, and compact fluorescent lighting.

This mobile solar irrigation pump makes watering tomatoes and other crops a much easier task.

Conergy Solar Force piston pump. The systems are mounted on traditional two-wheel carts that can be pulled from field to field by two cattle.

Microenterprise centers. A 1,600-watt PV array and a 1,440 amp-hour battery provide both DC and AC electricity for six small businesses at each center.

Peanut oil expeller. Making and selling peanut oil is one of the few sources of income for village women. An experimental solar-powered expeller saves time and labor, which helps the women earn more income. The 1-horsepower expeller is integrated into one the microenterprise centers and runs off of a Xantrex DR2424 inverter.

Home lighting systems. Both three-light and five-light home systems demonstrate the benefits of CF lighting, a vast improvement over kerosene lamps. Besides offering improved brightness, using CF bulbs also eliminates toxic fumes and the risk of fire. The three-light systems pair 50-watt PV modules with 100 amp-hour batteries; the five-light systems have 80-watt PV modules with 160 amp-hour batteries. The CF bulbs are rated at 9 watts each.

Mosque systems. Lighting makes nighttime activities possible, and an AC-powered public address system facilitates the call to prayer. An 80-watt PV module with a 100 amp-hour battery powers the system.

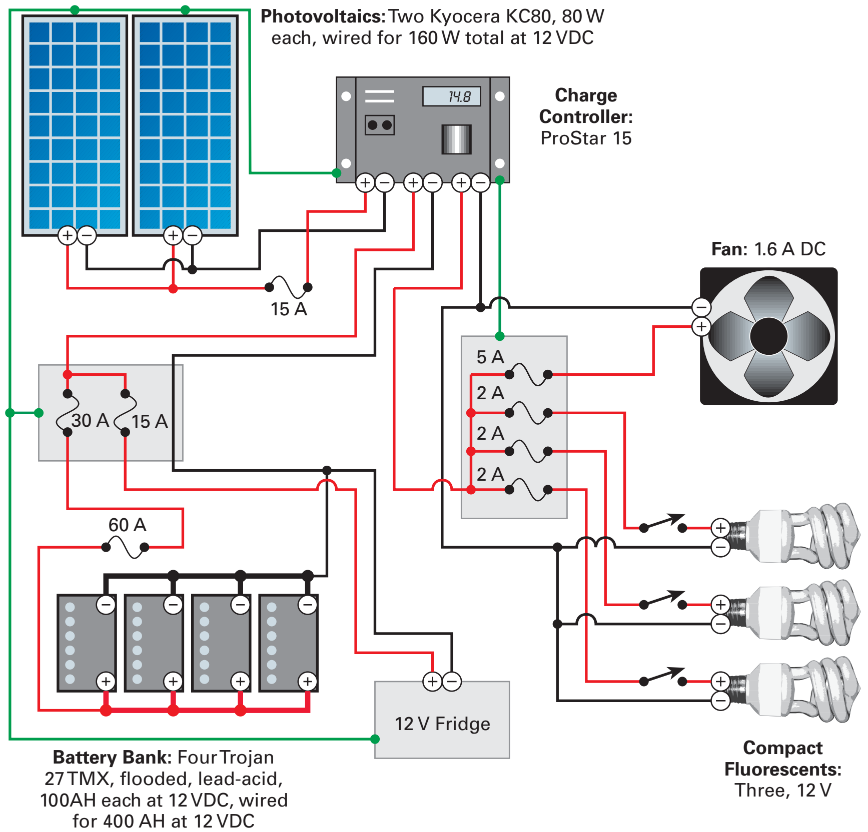
Future Sustainability

The true measure of project success is not if you can complete the installation, but rather if the installation is still working in five or ten years, or at the end of the project's expected life.

Access to electricity gave this barber, who occupies a space in one of the microenterprise centers, the opportunity to trade in his scissors for electric clippers, increasing his productivity—and his profits.

PV-powered lighting enables this classroom space to be used 'round the clock—for adult education classes and for a children's study space.

Clinic System



Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.

We took great care to address the technical, financial, and organizational aspects of sustainability. JAEF, structured as an "energy service company," owns all the project PV systems, and charges each user a small monthly fee to cover operation and maintenance expenses. These fees, which cover spare parts, technician wages, and administrative costs, also provide funds for equipment that needs replacement. In four or five years, when batteries start to fail, there will be enough funds to replace them. In most cases, the monthly fees, which range between US$3 to $5, are no more than what families were spending on kerosene for their lamps.

Two levels of paid JAEF technicians keep the systems operating. Technicians living in the villages perform basic maintenance tasks, such as checking and watering batteries, cleaning modules and lamps, or performing rudimentary troubleshooting. Another group of technicians with more education, experience, and PV training visit the villages monthly, overseeing the local technicians and handling more complex repairs.

JAEF was furnished with enough spare CF bulbs, lamps, controllers, and fuses to last the villages for about one year. In that time, enough fees will have been collected to order another batch of supplies. Each village was given a solar water distiller so that distilled water is always available to top off the batteries. Depending on sunlight and ambient temperature, the simple, passive distiller made by SolAqua produces 0.75 to 1.5 gallons (2.8–5.7 l) of distilled water per day, which is more than enough to service all the batteries in each village.

PV system design also plays a big role in sustainability. Because undercharging batteries (or overuse) contributes to premature battery failure, the system arrays were "oversized" compared to many systems installed in the developing world. Among other benefits, this allows a battery to recover to full charge after an extended discharge period, such as one caused by several days of cloudy weather.

In the larger systems, such as the microenterprise centers, multiple inverters and charge controllers were used. This is especially important in developing countries, where equipment is often subject to severe environmental conditions, such as extreme heat, dust, and insects, and where the frequency of failure can be much greater. Having multiple controllers and inverters provides an insurance policy of sorts—you can lose a component, do a little rewiring, and still have all or most of the system functioning until further repairs or replacements can be made. This insurance is particularly important to the microenterprise centers, where at least six families depend on the income from each center.

Progress & Growth

The PV systems have had a positive impact on the 8,000 residents of these villages. One village principal says that he is using his two lighted classrooms five nights per week. Adult education classes are being offered for the first time and are attended by 30 to 40 adults. The brightly lit classrooms are also open for children to work on their lessons.

SELF Systems Costs

System Type	Cost (US$)
Microenterprise center	$12,468.16
Village water pump	9,278.00
School	3,294.00
Irrigation pump	3,042.24
Clinic	2,949.00
Mosque	945.62
5-Light home	669.38
3-Light home	500.58
Streetlight	464.53

This PV array provides energy for a mobile solar irrigation pump. The cart, moved from field to field by two cattle, enables farmers to irrigate their crops during the dry season, providing food and income for their families.

The technicians for the project were a diverse group; some had technical backgrounds, some had university degrees, and some had barely handled tools before. Before the projects began, all attended a one-week training course at a nearby university, where they got a good handle on the basics of PV installation.

The health worker in one village reports that with lights, he now opens the clinic three to four nights per week. He also says that procedures, such as giving injections and starting intravenous drips, are now much easier and safer to do under decent lighting.

The illuminated areas below streetlights have become major gathering places for people socializing or doing business. In one village, some enterprising young women now sell prepared food under one of the lights—perhaps the first "fast food" in Jigawa State. In another village, streetlights now guard the entrances to the village, making people feel more secure.

Before the installation of solar pumps, people in these villages either drew impure water with a rope and bucket from an open well, or stood in long lines at one of two hand pumps that served hundreds of families. Government supplied diesel-powered pumps lay unused and rusting in most villages, due to a lack of funding for fuel and maintenance. Now, the PV pumps, connected to a distribution system that feeds a half-dozen or more spigots placed around the villages, are not only supplying plenty of clean water, but are saving people time and effort in gathering it.

The microenterprise centers have enabled the electrification of existing businesses: Barbers have switched from hand clippers to electric clippers, tailors from pedal-driven sewing machines to electric ones, and radio repairers from a heated metal rod to an electric soldering gun. We expect electrification to increase productivity and raise the incomes of these businesses. A microfinance program affiliated with the centers also has enabled people to start new businesses. Once these loans are satisfied, new loans will be available to help additional businesses.

For the same monthly amount this family paid for kerosene to fuel their lamps, they now enjoy clean, reliable, and nonpolluting solar electricity that provides energy for several compact fluorescent lights in the house.

Several spin-off benefits from this project have resulted. Jobs have been created for solar technicians. The women technicians trained for this project have modeled new roles in a culture where women are traditionally sequestered behind the walls of the family home. JAEF has greatly increased its experience and capacity to do similar projects. Outside the project villages, other communities are requesting their own reliable power supplies, making it likely that JAEF will start a PV sales division.

This project was a model of peaceful and positive cooperation between the United States and a Muslim society. The goodwill we've generated and the friendships made while working in these villages have been deep and profound.

A source of reliable (and clean) electricity supports several small businesses in this microenterprise center.

Moving Forward

Solar electricity is available as a powerful tool to help people who have been stuck in poverty with few opportunities and until now, with little optimism. Remote areas no longer need to wait years or decades for the national electric grid, nor do they need to rely on diesel generator-based microgrids. PV-based electrification can jump-start every aspect of development in impoverished villages. Rather than just addressing one area of development, such as health or education, solar electrification can enable improvements in all sectors.

This comprehensive project has provided a model for larger programs, and improved the prospects for people in some of Africa's poorest villages. Now, for these people, hope truly rises with the sun.

Access

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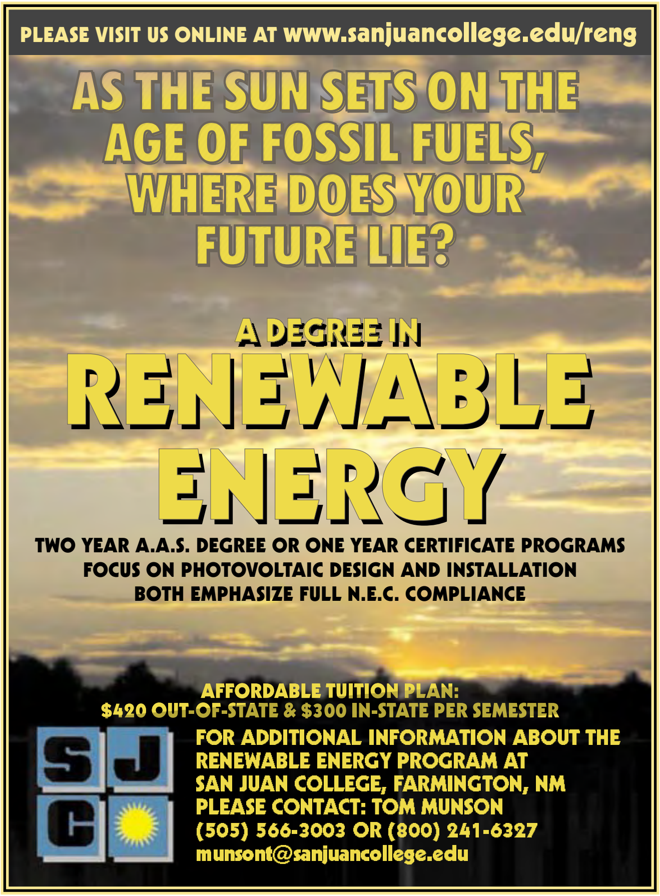
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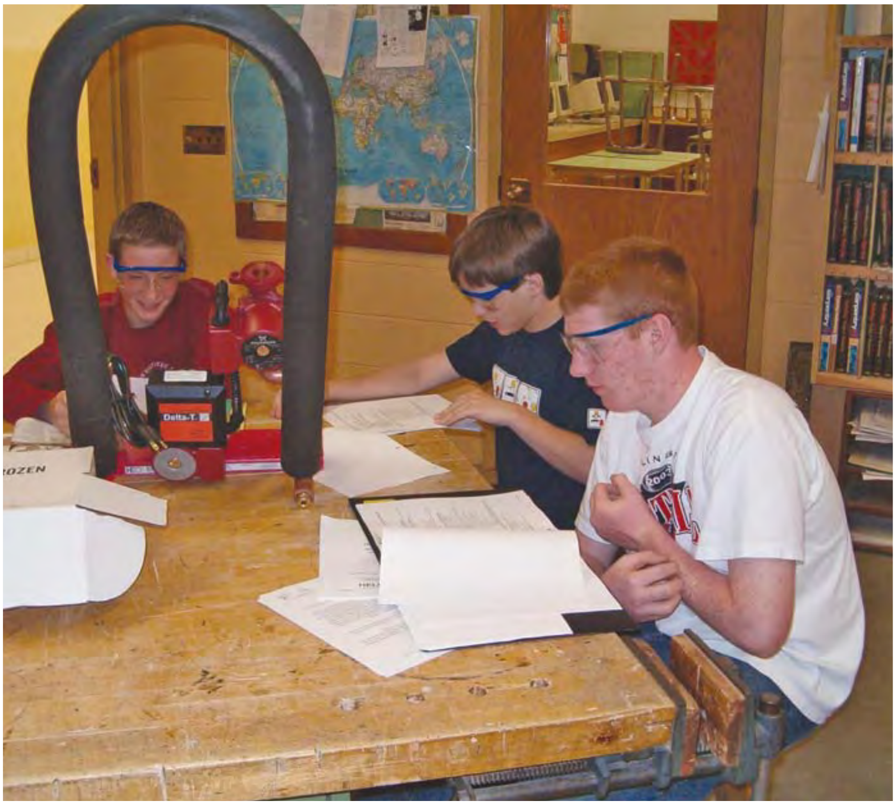
Real-World Solar Energy IN THE CLASSROOM

Dick Anderson



The SDHW project student engineering team—(L to R) Curtis Schulte, Andrew Skog, and Chad Allendorf—unpacks the equipment, inventories the parts, and studies the manual to become familiar with the system specifics.

Over the years, things have changed in high school "shop" classes. The days of squaring up a board by hand with a jack plane are over. Today, these classes are called "technology" classes, and they had better be interesting—which means being high tech, hands on, and light on theory. Although we still are required to teach specific shop skills, these skills are taught by using practical applications.

At Darlington High School in Wisconsin, where I teach in the "technology lab," we believe that the next generation will be expected to understand and use renewable forms of energy. We are designing and developing a "working" curriculum to give students real-world, hands-on experience with renewable energy (RE) technologies. Our projects have included wind and solar-electric systems, electric vehicles, and now solar domestic hot water (SDHW) systems.

Practical Application

In my classroom, I use RE systems as the bridge to teach my students basic shop skills. Complex in design and function, RE systems are useful for this purpose, and are great attention-getters. When students see other students working on a unique RE project, they ask questions. The result? The students doing the work get peer recognition, and the students asking the questions learn from their peers.

Most recently, my class put together a demonstration SDHW system. The students working on the project quickly came to understand that having basic skills, like measuring, leveling, soldering, and getting a good fit between pieces, are necessary to build a system. This teaching method also motivates students to study and learn the theories behind the skills, so they can apply them successfully to the project. And instead of relying on me for a grade, students quickly discover that their finished project is the ultimate measure of their skill mastery. Soldering water pipes, for instance, is a self-grading activity—they don't need a teacher to tell them that a joint leaks.

As the students work, and invest time and energy in a project like this, it takes on greater value to them. Their workmanship becomes a matter of pride, and they begin to see how much the wood, the pipes, and the wire are teaching them. The system and its components are demanding. "Just getting by" is not an option—it must work.

The students design the project, build it, and learn from it. I am their resource when they have questions. If they

SDHW Project Challenges

- Build a stable, portable platform
- Correctly size the hot water storage tank
- Accommodate the future addition of a second hot water storage tank
- Slope the collector loop adequately for easy draining
- Provide a means for filling and sampling water from the storage tank
- Incorporate a sight gauge to show the level of water in the storage tank
- Integrate a thermometer into the system to measure the temperature of the storage tank water
- Draw a schematic to show the operation of the system
- Design a data collection sheet to record the system's performance

need instruction on a specific skill, like operating a machine or soldering, I can give them a demonstration and advise them to practice until they reach a level of performance they feel will be worthy of the project. If they ask how I would solve one of the problems, I always answer, "What do you think?" Since there's usually no single answer to a problem, students work to find the "best" solutions—the project reveals if their solutions work.

System Specifics

This demonstration closed-loop SDHW system uses a counterflow, tube-within-a-tube heat exchanger to transfer heat between two separate loops of water—a solar collector loop and the storage tank loop. Each loop uses a 120 VAC pump to circulate fluid.

Sunlight strikes the 2-square-foot (0.2 m^2) Mini-Gobi solar collector, and heats the water–glycol solution in the copper tubes. A pump circulates this solution through the heat exchanger, where the heat is transferred, via conduction, to the circulated storage water.

The differential temperature control and sensors are the brains of the system. For this demonstration system, a 9°F (5°C) difference between the bottom of the storage water tank and the outlet at the top of the solar collector activates the pumps to begin circulating water. When only a 4°F (2°C) difference in temperature exists, the pumps turn off. Internal dip switches in the Delta-T controller allow the installer to field-set the differential, which would normally be 18:5 for a closed-loop system.

The Helio-Pak 16 unit came with the pumps, heat exchanger, expansion tank, temperature gauges, differential controller, and pressure relief valve, all assembled together. The students' job was to first build a portable platform for the system. Then they had to attach the Helio-Pak unit to the water heater inlet and outlet fittings, and mount and connect the Mini-Gobi collector. During the process of putting the system together, one student suggested that they make the collector adjustable to accommodate sun angles during different seasons. A removable pin in the front of the collector holds the panel in place after its tilt angle is adjusted. This adaptation also required using flexible reinforced polyethylene tubing between the collector and the heat exchanger. Permanently installed systems should always use copper tubing in the collector loop because of potential high temperatures.

The demonstration SDHW system offered students plenty of activities in various skill areas. The woodworkers got involved in the design and construction of the rolling base. The planning students got to make sketches and blueprints. The electrical students puzzled through the electronics of the differential temperature controller. Someone even had to read and figure out how to test and set the controller. And although the plumbing students had a big role in this project, they had to work hand in hand with the other students.

Andrew sweat-solders copper fittings.

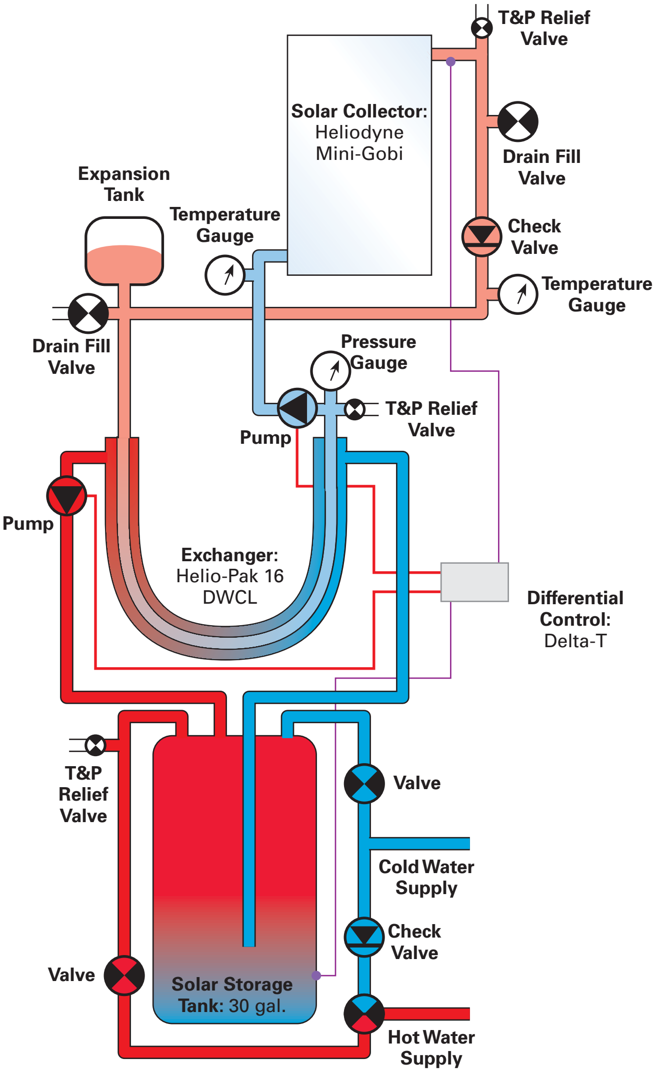
Bringing RE to the Classroom

To ensure students get firsthand experience with the actual components they'd handle with in the workplace, the relationship between a classroom model and a full-size system should be as real as possible. Like this SDHW system, many demonstration models can just be slightly modified, scaled-down versions of full-sized systems.

As a learning tool, the models should be portable, so that the system can be demonstrated almost anywhere. This exposes more students to RE, and makes the technology accessible to teachers who want to integrate it into their curricula.

Chad is learning to judge how tight pipe fittings must be while keeping in mind the alignment to other fittings, like elbows and tees.

Demonstration Solar Hot Water System



This and other RE projects can provide learning opportunities across the curriculum. Math students can make projections on the sizes of collectors and storage tanks needed for various domestic applications. Language arts students can write up installation and maintenance instructions. Physics students can use the model to study the concepts of heat transfer, radiation, conduction, and convection. Even geography classes can get in on the fun. Using what they've learned about longitude, latitude, hemispheres, and seasonal changes, they can determine the best placement of the solar collectors and predict how seasonal changes affect hot water production. Throughout the year, students can test their predictions, and determine their accuracy.

Demo SDHW System Costs

Description	Cost (US$)
Helio-Pak 16 SDHW module, prewired & preplumbed*	$1,500
Mini-Gobi solar collector, 2 sq. ft.*	200
Electric water heater, 30 gal.	130
Lumber & plywood for construction	36
2 Wheels, 8 in. pneumatic	16
Pipe, 2 in. by 8 ft. (for platform handles)	16
Dyn-O-Flo propylene glycol, 1 gal.	12
Misc. hardware	10
Total	$1,920

*Includes a generous educational discount from Heliodyne Inc.

Andrew tests the completed system under the sun—success!

As an instructor, I feel that these real-world projects give students a greater understanding and an appreciation of how energy is produced—and how it *can* be produced. I believe that RE will be the future, and that my students should be given the opportunity to learn about it today.

Access

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Solar Electricity

Saves an Endangered Campground

Paul Hanley & Ken Kelln

Tapping into solar electricity allowed the Narrows Campground in Canada's Prince Albert National Park to remain open and reclaim the park's natural serenity, while cutting their reliance on a fossil-fuel-powered generator.

A combination of citizen action and solar electricity has saved a favorite family campground in a remote area of Canada's Prince Albert National Park.

In 1999, high operating costs and budget cuts put The Narrows Campground in central Saskatchewan on the "endangered list," forcing the park superintendent to reluctantly announce plans to close the site. Today, thanks to a solar-electric (photovoltaic, PV) system and responsive park management, not only is the site open, but its operating costs are down and the campground is a demonstration site for the Canadian park system.

The story of the campground's near-death experience begins in 1995, when the Canadian government enacted sweeping budget cuts designed to eliminate a massive federal deficit. Looking for ways to cut costs, officials at Prince Albert National Park zeroed in on the high costs of operating an idyllic 87-site campground tucked into a pristine corner of the boreal forest park, 29 kilometers (18 mi.) from the nearest resort town and 19 kilometers (12 mi.) from the provincial utility grid.

The single highest cost at the campsite was the aging, propane-fueled generator used to provide electricity for pumping water, for lighting, and for operating the camp store and marina. The generator used about 10 to 15 liters (2.5–4 gal.) of propane per hour, or 45,500 liters (12,000 gal.) per year. At prices as high as 80 cents a liter (about US$2.76 per U.S. gallon), annual electricity costs were in the neighborhood of Can$37,000 (Can$1 = US$0.86). The power plant also required frequent and expensive maintenance, as well as 225 liters (59 gal.) of motor oil per season. It was both too expensive to bring in electricity from the grid, and environmentally inappropriate to run a transmission line through a protected forest near a pristine lake.

Initially, park officials tried to privatize the site, turning site services over to private operators. But these operators were ultimately unable to run the site to Parks Canada standards, which alienated many longtime camp users. By 1999, the only option left seemed to be to closing down the site entirely. When that decision was announced, the campers decided to get organized.

Campers Propose Sustainable Alternative

The Narrows Campground has been immensely popular with a group of families who have used the site every summer, some for as long as 40 years. It is typical for many families to camp for a week or two at a time.

"My dad started bringing us to The Narrows when we were kids, in the 1960s," says Barb Kachur, who took a lead role in organizing alternatives to the closure. "My five siblings and I still come here every year for a reunion, even though we're now spread out across Canada. We weren't about to see our gathering place close if there was anything we could do about it."

Kachur and other camp volunteers were able to get 1,800 names on a petition asking that the campground stay open, prompting the federal minister in charge of the national park system to direct the superintendent to collaborate with the campers to find a solution. Adopting a nonconfrontational approach, an ad hoc campers' committee met with the park superintendent on a monthly basis to come up with a cost-effective way to save their campground. Five different proposals were considered, including one to use solar electricity in the campground.

"It was quickly determined that solar electricity was the most appropriate way to power the campground," says Barb Kachur, "especially since the National Park is dedicated to sustainable alternatives. The only problem was that installing a solar-electric system of this size involves significant up-front costs—about Can$200,000—and the park didn't have any money to spare."

A solution was found when a federal government program to fund sustainable energy demonstration projects was identified. With half the capital costs coming from this fund, Parks Canada was able to come up with the rest of the money, recognizing that the project would eventually pay for itself through lowered annual costs. In 2001, an initial 4.1 KW solar-electric system was installed.

Advantages & Disadvantages

Advantages

Low operating and maintenance costs. The PV system saved annual costs of operating a propane-fueled generator, including fuel costs of approximately Can$35,000, oil costs of approximately Can$300, and significant maintenance costs. The panels are shatterproof, making them ideally suited for the park environment.

Elimination of noise. The previous system was noisy, which is inappropriate in a natural campground setting. The solar-electric system is silent.

Educational value. The solar-electric system provides a new attraction for the campground and the National Park, creating opportunities to educate the public and the travel industry about a sustainable electricity source.

Disadvantages

Initial costs are high. The initial cost of building the system was high, although it was much less than putting in a utility line from the provincial grid system.

Less energy available. Unlike a grid connection, the PV system will not supply enough energy for some applications that might be useful at the campground, such as heating water or operating a large number of freezers and refrigerators at the camp store.

Uni-Solar shatterproof panels were chosen due to the possibility of vandalism. The PV mounting system was designed to accommodate 80 panels.

Solar Electricity to the Rescue

Today, longtime visitors may not notice much of a difference at The Narrows Campground. They'll still find running water, lights, and other conveniences that make a rustic camping experience a little more comfortable. But anyone walking around the campground will soon come upon an impressive array of 64, 64-watt solar-electric panels, which now supply most of the electricity needed to run the campground.

Although the big propane generator has been replaced with a small, 7 KW one for backup, electric

Rear view of the array and electrical building. This building contains the batteries, inverters, back-up generator, and charge controllers.

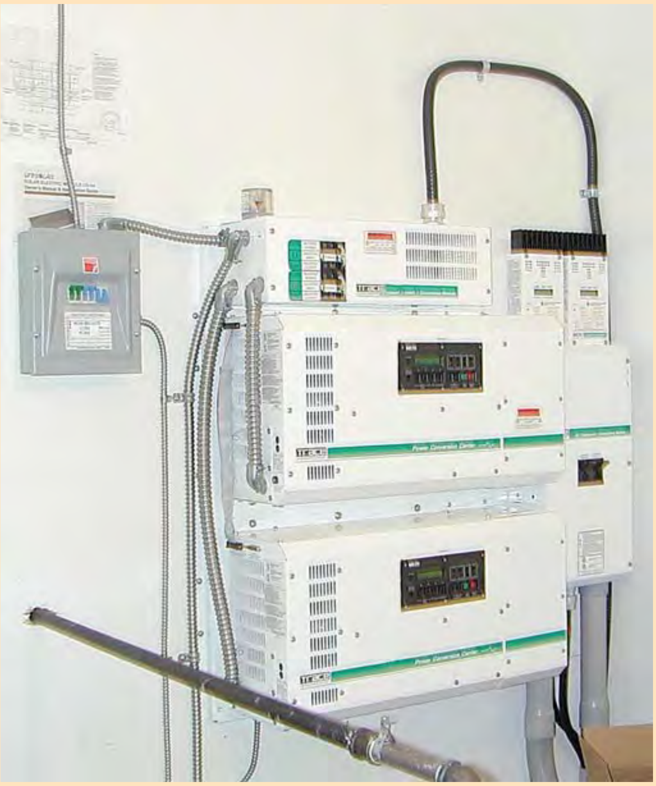
pumps continue to feed water sufficient for the six cold-water washroom facilities. An ultraviolet water-disinfecting unit is in place to ensure safe, potable water. There is a streetlight, all the buildings have electric lights, and the marina has a refrigerator and freezer. Everything runs, rain or shine, since batteries store a six-day energy supply.

The old system was noisy, required daily maintenance, and was expensive. In contrast, the solar-electric system is quiet, low maintenance, and once capital costs are covered, the electricity is free. A reasonable estimate of the payback time on capital costs from savings on propane and maintenance could be as short as two to three years. Lowered annual operating costs have meant no increase in fees at the campground due to the new electricity source.

Significantly, the solar conversion eliminates annual emissions of about 70,000 kg (154,000 pounds) of climate changing carbon dioxide, making it consistent with the environmental objectives of Parks Canada. The elimination of carbon-dioxide emissions also sets the trend for reducing greenhouse gas emissions as per the Kyoto Protocol, which Canada ratified more than three years ago. The solar conversion is also consistent with the objectives of The Narrows campers, who appreciate the opportunity to enjoy nature without doing it any harm. Thanks to their activism, The Narrows is now considered a model, low environmental impact campground.

"The use of solar electricity makes a lot of sense for Parks Canada," says Dale Redford, the park's front country manager. "It makes a lot of sense both ecologically and economically to invest in sources like solar energy. Even if initial capital costs are high, the payback time can

Two Xantrex SW4048 sine wave inverters provide 8 KW at 120/240 VAC. A 240 to 600 VAC step-up transformer enables long-distance, high-voltage electrical transmission throughout the campground.



Tech Specs

System Overview

Type: Off-grid, battery-based PV

Location: The Narrows Campground, Prince Albert National Park, Saskatchewan, Canada

Solar resource: 6 average daily peak sun-hours

Production: 480 AC KWH per month

Photovoltaics

Modules: Sixty-four, Uni-Solar US64, 64 W STC, 16.5 Vmp

Array: Sixteen, 4-module series strings, 4,096 W STC total, 66 Vmp

Array installation: Custom-made structural steel rack, south facing, 36-degree tilt

Energy Storage

Batteries: Eight Surrette 6CS25PS, 6 VDC nominal, 820 AH at 20-hour rate, flooded lead-acid

Battery bank: 48 VDC nominal, 820 AH total

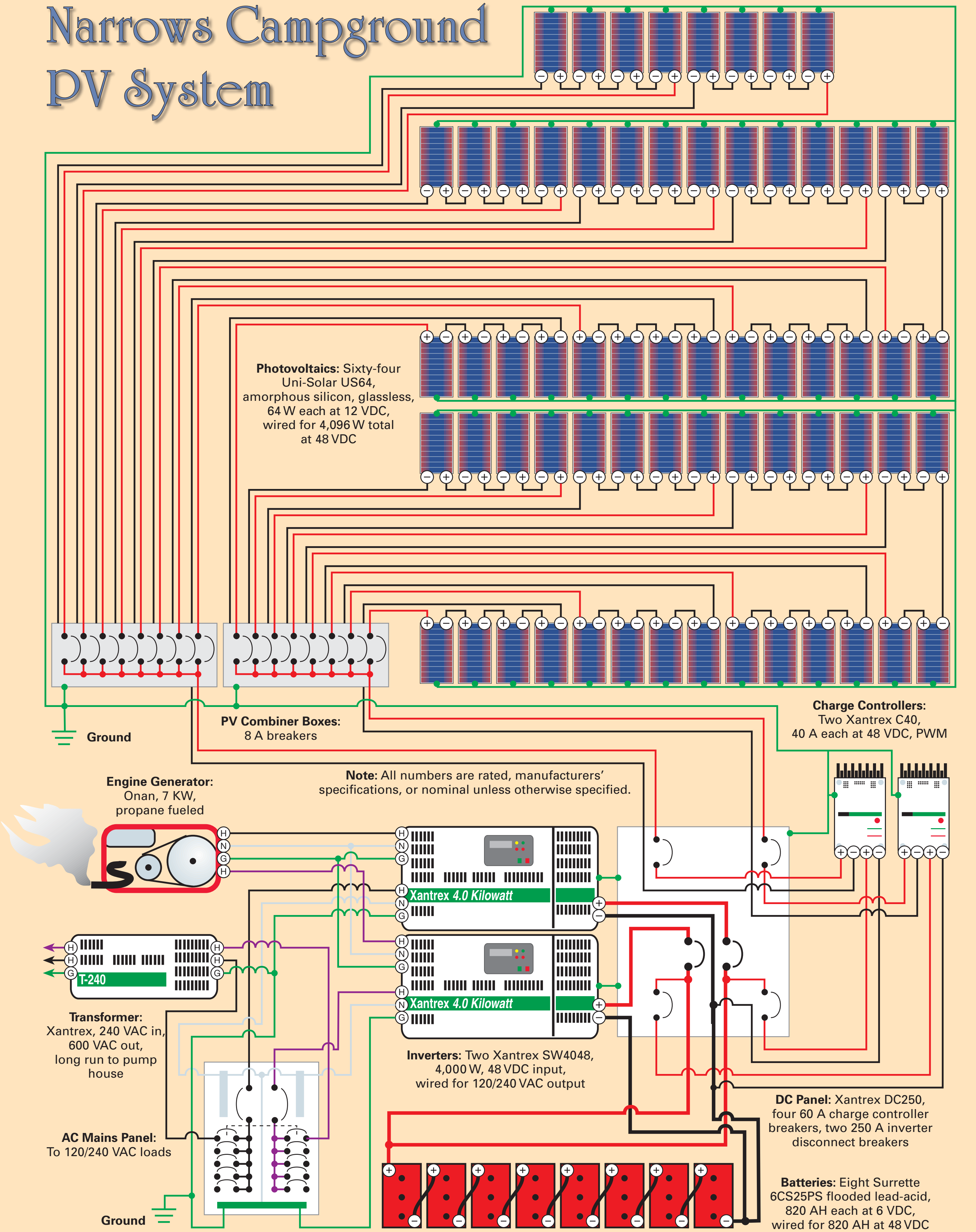
Balance of System

Charge controller: Two Xantrex C40, 40 A, PWM

Inverter: Two Xantrex SW4048, 48 VDC nominal input, 120 VAC output, stacked for 120/240 VAC

Transformer: Xantrex 240/600 VAC step-up

Narrows Campground PV System



PV System Costs

Item	Cost (US$)
64 Uni-Solar US64 solar-electric panels	$35,000
Installation, 400 person-hrs.	16,000
Xantrex Power Panel with two SW4048 inverters	14,000
Rack, custom galvanized; concrete pad & frost fence	13,500
Onan generator, continuous-duty propane, 7 KW, with fuel tank	10,500
Building, 10 x 12 ft.	10,000
8 Surrette 6CS25PS batteries	8,000
Module interconnects, waterproof with strain relief	1,000
Lightning arrestors, AC & DC	1,000
Direct burial armored cable to battery & inverter, each 100 feet #4, 2 conductor	800
Battery box	700
2 Splitter boxes	400
AC distribution panel & breakers	200
Total	$111,100

be long, given that national parks are meant to be here forever. In the case of The Narrows Campground, which is 19 kilometers (12 mi.) from a major utility line, on-site electricity generation from sustainable sources made even more sense because bringing in a transmission line is also expensive." The campground runs from the May long weekend to the September long weekend, a time when the solar energy is maximized.

Redford says Natural Resources Canada was interested in the project both to support sustainable energy sources and especially to showcase a northern solar electricity project for potential use in fly-in fish camps, which can be found throughout Northern Canada. "A lot of camps might be open to the solar option after seeing it operating at The Narrows," says Redford. "The North is particularly well suited to summer solar applications given the long hours of daylight."

How the System Works

The Narrows solar-electric system was designed by solar consultant and engineer Ken Kelln of Kelln Solar of Lumsden, Saskatchewan, and was built by a local solar contractor from Prince Albert. The first stage of the project was completed with the installation of 64, 64-watt panels.

The direct current (DC) electricity the panels generate is routed to a bank of deep-cycle batteries, which store the solar energy for use at nighttime or during cloudy weather. A pair of charge controllers regulate the output of the PV array and keep the battery bank from being overcharged. The stored energy in the battery bank is converted to 120/240 VAC by the inverters, and a 240 to 600 VAC step-up transformer enables high-voltage electrical transmission throughout the campground. Additional transformers step down the AC voltage to 120/240 volts to power electrical loads at their point of use.

The Narrows project incorporates a number of measures to reduce energy requirements. For example, the six washroom facilities had skylights installed to reduce the need for electric light. The campground lights are also activated by motion detectors, so they are only on when needed. And the 24 toilets at the campground were replaced with low-flush units to reduce the amount of water required.

Model for Parks

Parks Canada will be taking advantage of The Narrows Campground PV project as an educational opportunity. Asset managers from parks in Saskatchewan and other provinces have already attended a solar electricity workshop at the Park, and plans are underway to make northern outfitters aware of the solar option.

Other parks all over the country are impressed with the performance of the system, and are considering harnessing the sun's or wind's energy. Kelln Consulting Ltd. has designed and is in the process of installing a 9 KW PV system and a 50 KW grid-tied, wind-electric system for the information center at Fort Battleford Historic Park in Saskatchewan.

The Narrows Campground has become a haven for environmentalists, students, and campers, who come here to take advantage of Canada's first solar-powered campground located at the heart of Prince Albert National Park. As the load requirements have gone up over the years, Parks Canada officials are considering adding an additional sixteen photovoltaic panels, making it a 5 KW PV system, to keep up with the demand.

Access

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Paul Hanley, 2506 Ewart Ave., Saskatoon, SK, Canada S7J 1Y8 • 306-554-2962 • paulhanley@sasktel.net

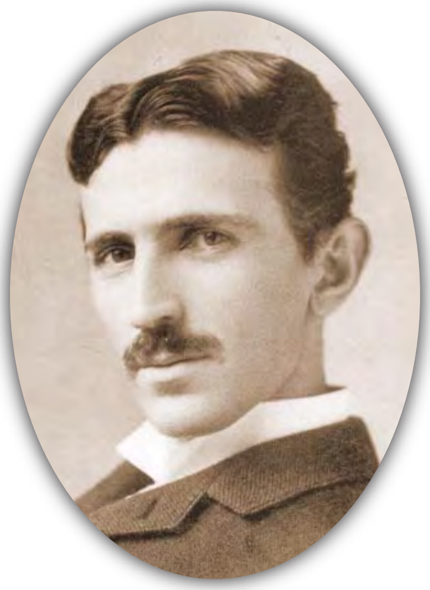
Prince Albert National Park, Box 100, Waskesiu, SK, Canada S0J 2Y0 • 877-255-7267 or 306-663-4522 • Fax: 306-663-5424 • panp-info@pc.gc.ca • www.pc.gc.ca/pn-np/sk/princealbert/index_e.asp

The Narrows Campground Users Web site • http://members.shaw.ca/narrows4 • Information about & photographs of the solar-electric installation

The War of the Currents

Thomas Edison

Courtesy U.S. Dept. of Interior, National Park Service, Edison Natl. Historic Site



Nikola Tesla

Courtesy Nikola Tesla Museum

John Cowdrey

Most of us don't give a second thought to where our electricity comes from, how it gets to the outlet, or the fact that it arrives as alternating current (AC). In fact, it's hard to believe that a battle was ever waged over whether to use AC or DC (direct current) electricity—why not just choose the best form? However, at the turn of the twentieth century, two powerful inventors battled over the future of electrical transmission. The outcome led to the interconnected power system we rely on today.

Early Electric Generation

First pioneered at the turn of the nineteenth century, the earliest sources of continuous electrical energy were batteries—DC devices. However, these batteries did not produce enough energy to economically run bright lights or powerful motors for any useful length of time.

In 1831, Englishman Michael Faraday invented the first electromagnetic generator or dynamo. But it wasn't necessarily these rotating machines (see the sidebar on opposite page) that sparked the revolution in widespread electricity generation and distribution. Rather, it was the simple need for light. In the early 1800s, homes and businesses relied on light from candles and kerosene lamps.

DC vs. AC

Direct current (DC) electricity comes from sources such as batteries, photovoltaic (PV) modules, and DC generators. DC voltage doesn't change polarity—the positive pole always has a positive voltage with respect to the negative pole. Since charges flow from a higher potential (voltage) to a lower potential, DC provides a constant, unidirectional flow.

Alternating current (AC) electricity is produced from rotating generators and can now be synthesized by inverters and variable-speed motor drives. The familiar AC voltage takes the form of a sine wave, with the voltage's magnitude constantly changing and reversing polarity. The current also changes constantly and reverses direction each cycle. (For more information about AC and DC electricity, see the two-part article in *HP52* and *HP53*, "Basics of Alternating Current Electricity," and *Word Power* in *HP85* and *HP86*.)

Later on, gas lamps, which used coal gas for illumination, gained popularity, especially in cities. However, gas lamps were dirty and smelly, and posed a fire risk.

Illuminating Inventions Lead the Way

Inventors had been working for more than 50 years trying to invent a successful incandescent lamp. In 1802, Sir Humphry Davy caused a platinum filament to glow when he connected it to the most powerful battery built in that time. Englishman Joseph Swan had some success by 1860, but eventually gave up on the project since his lamps burned out within a few minutes.

American inventor Thomas Edison also faced similar problems. He experimented with more than 1,600 different filament materials, including platinum, but his lack of success with the platinum filament did not stop him from telling reporters in 1878 that there was "no doubt" that he had already discovered a successful light. He showed reporters his platinum filament light, being careful to usher them out of the room before it burned out. "When I'm through, only the rich will be able to afford candles," said Edison.

A year later, in December of 1879, Edison was able to get a carbonized-thread-filament bulb to burn for 13.5 hours. In 1880, after a worldwide search for a more durable filament, Edison started manufacturing carbonized bamboo filament lamps that lasted 1,000 hours.

Edison realized, though, that to sell his lamps to the public he needed an entire system of electricity generation and distribution. So he bought an old building on Pearl Street in New York City and turned it into a power plant, filling it with coal-fired steam turbines and dynamos. On September 4, 1882, 800 lamps at the Drexel-Morgan Building, the *New York Times* headquarters, and other establishments were illuminated by Edison's power plant. After this remarkable success, the Edison General Electric Company was formed to build and sell electric power stations to cities and towns across the United States.

By 1887, Edison's DC system of generating electricity had become the industry standard, with more than 120 Edison power stations delivering DC electricity to its customers. But this method of producing and distributing electricity was not without its challenges. The low-voltage energy (240 V) could only be sent a short distance—usually one mile or less—before the electricity began to suffer extreme losses in voltage. Because of this, power plants had to be built close to users, which was a costly endeavor. And, to carry the high currents required

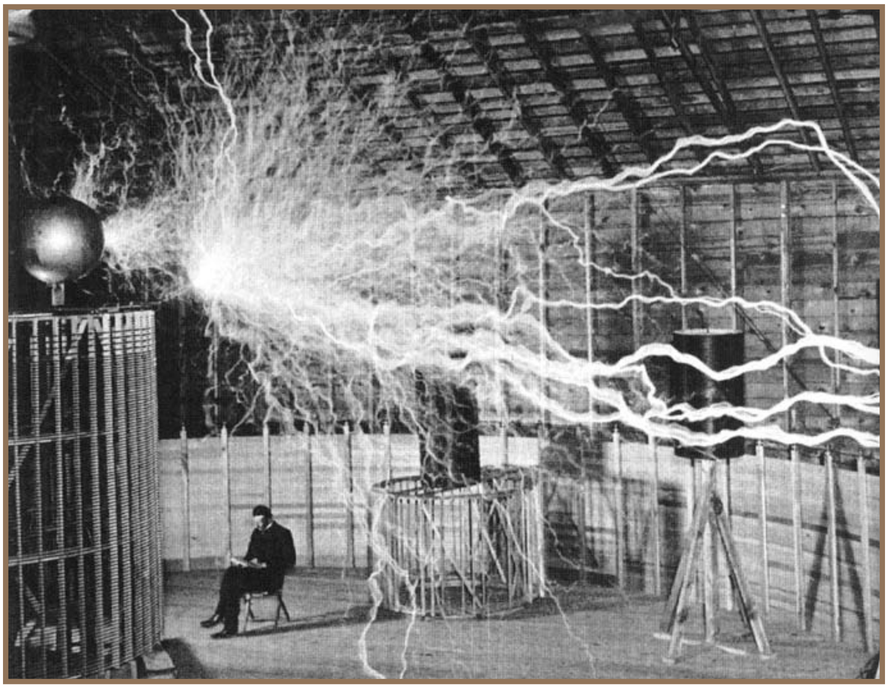
How DC & AC Generators Work

Both DC and AC generators use Faraday's principle of induction, which says that when a conductor moves through a magnetic field, a voltage is induced. A rotating loop of wire (armature) cuts and stretches the magnetic lines of force, as the conductors pass the field face, generating voltage.

At other times during the rotation, when the loop is traveling parallel to the magnetic lines of force, no voltage is generated. The polarity of the voltage induced in the left and right segments depends on whether they are traveling down through the field, and then traveling up a half-turn later. With each rotation, the voltage reverses, generating one cycle of AC.

When scientists first sought to generate electricity from machines, they wanted the same steady flow that batteries provided. American blacksmith Thomas Davenport invented the commutator, a mechanical device to make an alternator's current unidirectional. The commutator acts like a high-speed switch, switching the load just as the generator's voltage drops to zero, ensuring that the load's current and voltage do not reverse. Practical DC generators use many armature windings and commutator segments to minimize ripple in the output voltage.

A huge Tesla coil, part of Nikola Tesla's transatlantic experimentation in wireless communication and electricity transmission.



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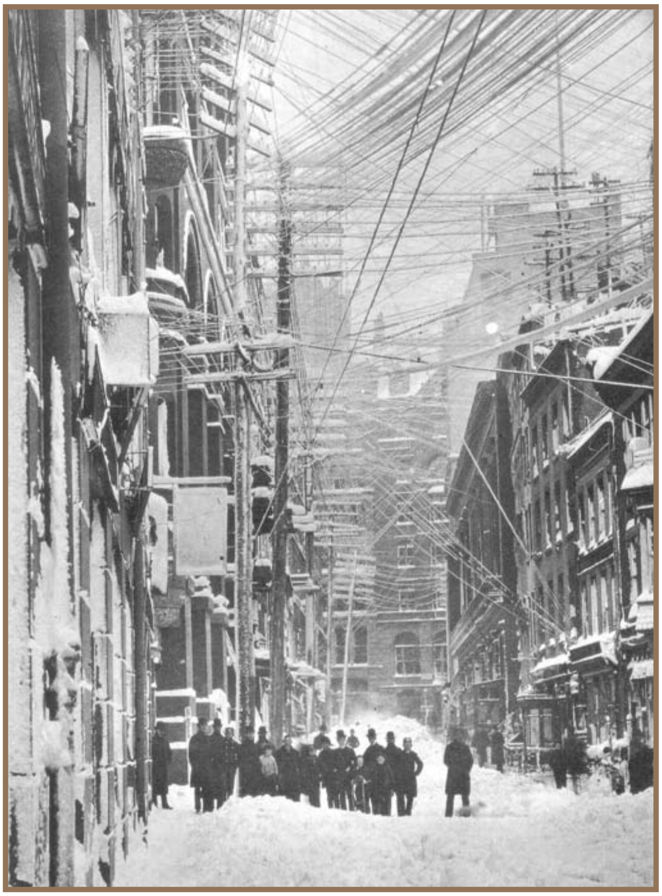


Brown Brothers

Edison buried his electrical lines due to the tangle of wires overhead.

to meet the demand of distributed load, expensive, large-diameter copper wire had to be used for cables and lines carrying the electricity.

Foreign Competition

Meanwhile in Europe, Serbian inventor Nikola Tesla was developing a different system. As a young man, he examined the early DC machines and decided that there was a way to eliminate the sparking commutator and just use AC directly. Tesla understood that a rotating magnetic field could be produced in a motor by two or more alternating currents of the same frequency, but which were out of step with each other. By this method, commutation was unnecessary. His idea was not only brilliant, but stunningly simple.

In 1884, Tesla arrived in the United States and went to work for Edison, although it was not the harmonious meeting of the minds that Tesla had envisioned. With little scientific training, Edison relied on his laborious trial-and-error approach to inventing. Tesla, by contrast, had great academic and engineering skills.

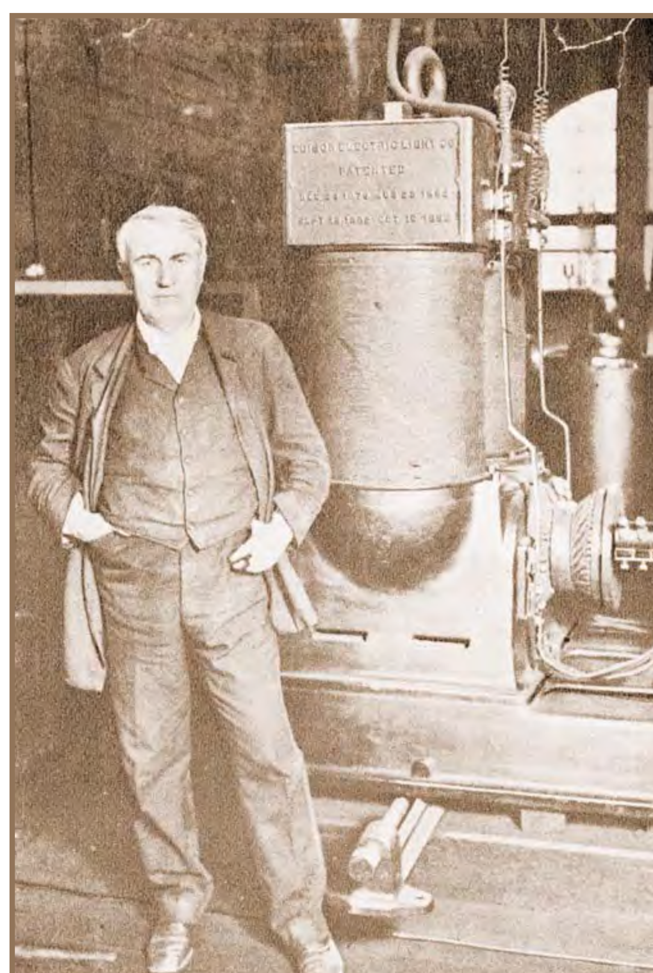
Given their very different personalities, conflicts arose. Edison brusquely told Tesla that he was not interested in AC—he asserted that there was no future in it and said that anyone who dabbled in it was wasting his time. Edison also believed that AC was deadly—he was convinced that people would be killed by the high voltages that can be produced with transformers and AC. Many historians speculate that part of Edison's opposition to AC may have come from the grudging realization that the Serbian genius who was working for him had designed a system that made his own DC system obsolete.

Tesla Takes Another Tack

In 1887, after parting ways with Edison over a bonus dispute, Tesla founded the Tesla Electric Company and began working on his AC alternators day and night. During this period, he not only constructed the machines, but he also formulated the basic mathematical theory and basis for our modern electrical system. His original version, developed in Belgrade, Yugoslavia, was two-phase electricity—two identical voltage waveforms separated by 90 degrees. While this system produced the rotating magnetic field he desired, it required four wires.

He progressed from this system to the three-phase system—three voltage waveforms, 120 electrical degrees out of phase with each other. This system requires only three wires, and was electrically balanced, since the voltages add up to zero. In 1883, Tesla had built his first working AC motor, producing motor rotation for the first time without a commutator.

Edison's inventors improved the early dynamo designs.



By 1891, he had acquired more than 40 patents for his "polyphase" system. Unlike Edison's DC system, in Tesla's system, voltage could be generated at two- or three-phase, stepped up for transmission, and then stepped down again to run lights and his polyphase motors.

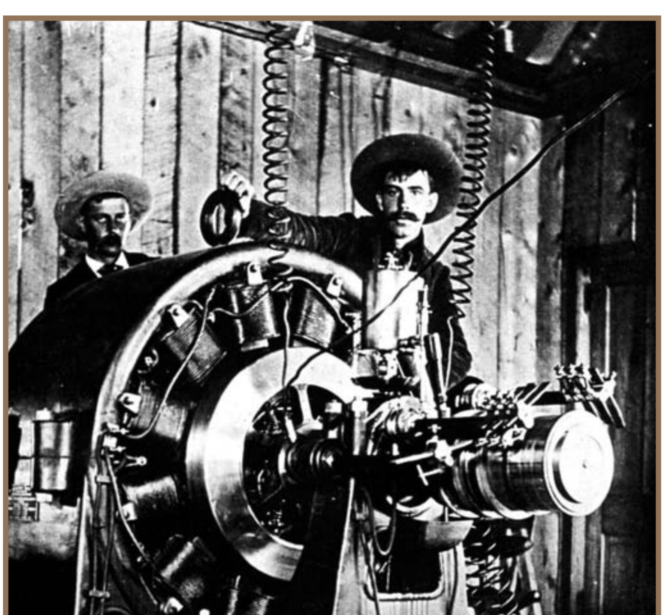
Westinghouse Transforms the Industry

Intrigued by the emerging electrical energy business, business magnate George Westinghouse had identified significant flaws with Edison's DC system. Due to the need for the rotating commutator, Edison's systems could not generate at high voltages, and due to voltage drop, his plants could only deliver energy over a radius of about one mile.

Westinghouse understood that a transformer would allow stepping up the generator voltage to high voltage and low current, permitting longer range transmission with low losses. With this in mind, he bought patent rights to the transformer invented by Frenchman Lucien Gaulard and Englishman John Gibbs, and hired American engineer William Stanley to improve the primitive design into one that was economical to manufacture. By using transformers, power plants would no longer have to be located in city centers. Instead, they could generate electricity where hydro or coal power was abundant, deliver the energy with low loss by high-voltage transmission lines, and step the voltage down to low voltages at the point of consumption.

In March of 1886, Westinghouse tested his system in Great Barrington, Massachusetts. A generator produced 500 volts AC, which was stepped up to 3,000 volts for transmission, and then stepped down to 100 volts to power electric lamps. But Westinghouse still had no AC motor. Tesla's patents were the key that Westinghouse needed for his vision. Westinghouse visited Tesla's lab and purchased his patents.

Ames Hydro operators gather around the big Westinghouse generator.



Courtesy Deep Springs College Archives, Dyer, NV

Transformers & Transmission

A transformer is an electrical device that transforms one voltage into a higher or lower voltage. The simplest transformer consists of two windings wrapped around a laminated steel core. AC current in one winding causes a changing magnetic flux in the core. This expanding and collapsing flux induces a voltage in the other winding. Each turn of the primary or secondary winding has the same voltage. The transformer is reversible—if there are more turns on the secondary winding, the voltage will be stepped up; if there are fewer turns on the secondary winding, the voltage will be stepped down.

A transformer does not produce electricity—it just changes the current and voltage levels. For a transformer, power in approximately equals power out (minus efficiency losses). Power ("P"), current ("I"), and voltage ("V") are given by the formula $P = I \times V$. If the voltage is stepped up ten times, the current decreases by the same factor of 10.

The ability of a transformer to step voltage up or down, coupled with low wire losses due to higher voltages, means that electricity can be transmitted and distributed over long distances. On average, the electricity you use at your household socket may have traveled as far as 300 miles (483 km) and passed through four to five transformers.

The Executioner's Current

By 1889, Westinghouse had built 870 central lighting stations, cutting into Edison's sales and profits. Edison was furious at the Westinghouse-Tesla encroachment into the business he had pioneered. His fortune was threatened and his personal pride was wounded. In retaliation, Edison Electric Light Co. published a book predicting the dire consequences if AC were used to generate electricity. And then, much to his delight, Edison was handed an opportunity to discredit AC.

The governor of New York appointed a commission to find an alternative to the gallows. When first approached by the commission, Edison was opposed to the idea of using electricity for capital punishment. But in a fit of inspired revenge, he changed his mind, telling the commission that 1,000 volts of AC from a Westinghouse machine would work well. To demonstrate AC's killing capacity, Edison's associate Harold Brown traveled from town to town, publicly killing old dogs, cows, or horses with AC. He even killed Topsy, a three-ton elephant.

Tesla also campaigned, but instead of leaving a trail of charred animals in his wake, he relied on dazzling demonstrations to counter fears of alternating current. One of his more outlandish demonstrations of AC's safety was to pass high-frequency current through his body to light a fluorescent lamp.

Despite Edison's efforts, the AC campaign continued. In 1891, Westinghouse built his first AC hydroelectric power plant for long-distance transmission of electricity in Ames, Colorado, sending electricity 2.6 miles (4.2 km) to power the Gold King mining camp. This was the longest distance that electricity had been transmitted in the United States.

The next year, Westinghouse won the bid to light the 1893 Chicago World's Fair—the first all-electric fair. Westinghouse had underbid General Electric by half, with much of the savings realized from using less copper. At night, 27 million attendees witnessed the illumination of 100,000 incandescent lamps—the most spectacular lighting display the world had ever seen.

The End of the Current War

In 1890, the International Niagara Commission had sponsored a contest to harness the energy of Niagara Falls. World-famous scientist Lord Kelvin chaired the Niagara Commission, which investigated proposals from around the world. Initially opposed to AC, he changed his mind after visiting the Chicago Fair, and awarded Westinghouse the contract in October of 1893. Kelvin recognized the advantages of the lower costs of an AC system and AC's ability to transmit energy over long distances.

When the power plant was successfully inaugurated in 1895, it was the largest electrical engineering project to date. To add insult to injury, Edison General Electric had to license the Tesla patents from Westinghouse to install the transmission and distribution lines from Niagara Falls to Buffalo, New York. After finally abandoning Edison's DC system, General Electric eventually removed Edison's name from the company's title.

And so the war was won. With the ease of long-distance AC energy transmission, four major highly interconnected grids evolved, with interstate transmission lines connecting many different utility systems. Today, we enjoy—and sometimes suffer—from this long-distance generation. Although most of the time our electricity is delivered to us quietly and without fanfare, brownouts and blackouts serve as reminders that a system of widespread distribution is still not without its own limitations.

Access

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Edison: A Biography, by Matthew Josephson, 1992, Paperback, 528 pages, ISBN 0471548065, US$24.95 from Wiley, 10475 Crosspoint Blvd., Indianapolis, IN 46256 • 877-762-2974 • Fax: 800-597-3299 • www.wiley.com

Tesla: Master of Lightning, by Margaret Cheney, 1999, Hardcover, 184 pages, ISBN 0760710058, US$20 from Barnes & Noble Books • 800-843-2665 or 201-272-3651 • www.barnesandnoble.com

Making the Utility Connection

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center
Sandia National Laboratories

More than 90 percent of new PV systems being installed throughout the United States are connected to the local utility with utility-interactive inverters. These inverters range in size from about 250 watts (rated AC output) to about 250 KW. Multiple inverters may be used at a single location to provide even higher outputs.

The connection requirements to the utility are established in various sections of the *National Electrical Code (NEC)*. Unfortunately, in many cases, these requirements are not fully understood or complied with. This article concentrates on the requirements of the 2005 *NEC*, Section 690.64, Point of Connection, as they apply to residential PV installations.

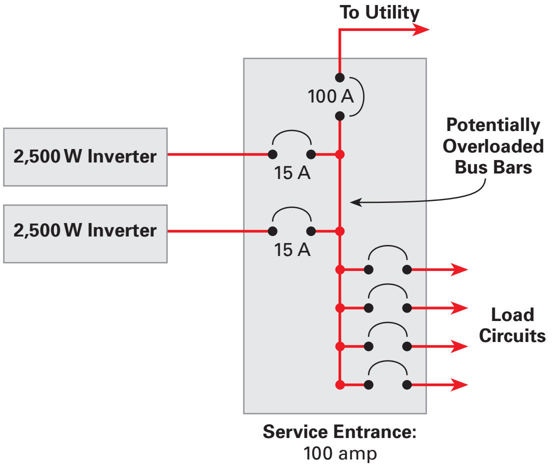
NEC *Details for Grid Connection*

Section 690.64 of the code allows the output of the inverter to be connected either on the supply (utility) side of the service disconnect or on the load (house) side of the service disconnect. Connections for dwellings are covered as an exception to the basic requirements of this code section, which deals with commercial, non-dwelling installations.

The requirements of 690.64(B)(2) are complex. Here is what the section (without the exception, which applies to residential installations) says:

The sum of the ampere ratings of overcurrent devices in circuits supplying power to a busbar or conductor shall not exceed the rating of the busbar or conductor.

Backfed breakers feeding a load center.



The key word is "supplying." In a load center or panel board, the main circuit breaker *supplies* power to the internal bus bars, as do any backfed circuit breakers *supplying* power from the PV inverters. The potential problem can be seen in the drawing below left.

The load center is rated at 100 amps, but the main circuit breaker can supply 100 amps to the bus bars, and at the same time, the inverters may add another 30 amps to the bus bars. If the loads were increased to 130 amps (for example, by increasing plug loads), no circuit breakers would trip, but the bus bars in the center of the panel, rated at 100 amps, would be overloaded, carrying 130 amps.

Exception for Dwelling Units

Now, examine the installation requirements for dwelling units. The exception for 690.64(B)(2) reads:

Exception: For a dwelling unit, the sum of the ampere ratings of the overcurrent devices shall not exceed 120 percent of the rating of the busbar or conductor.

With the exception, it's okay to add PV backfed circuit breakers to the dwelling (residential) load center with some leeway before having to change equipment. Normally, the main circuit breaker in a residential load center is rated the same as the residential load center. This exception allows the sum of the main circuit breaker plus the sum of any backfed PV circuit breakers to be 120 percent of the rating of the load center.

This additional 20 percent allowance is made because, generally, residential circuits are more lightly loaded (due to demand-factor calculations) than circuits in commercial buildings. If the loads remain below the rating of the busbar, the panel cannot be overloaded.

Where the main circuit breakers and panels have the same rating, the exception to 690.64(B)(2) allows 20 amps of backfed PV circuit breakers to be added to a 100-amp panel and 40 amps to be added to a 200-amp panel. Although these numbers translate to a 3,840-watt (AC inverter output) PV system on a 100-amp panel and a 7,680-watt PV system on a 200-amp panel, some people want to install bigger PV systems, which requires creative thinking. These limits include the normal 80 percent maximum continuous operating-current limitations on the circuit breakers.

Many common PV inverters are rated at 2,500 watts and 240 volts. The rated output current is 2,500 ÷ 240

= 10.4 amps. Using the *NEC*-required 1.25 multiplier (Section 690.8) yields a circuit breaker requirement of 13 amps, which rounds up to 15 amps as the rating of the backfed circuit breaker. On a 100-amp panel, with a 100-amp main circuit breaker, only one of these inverters can be accommodated. On a 200-amp panel, only two of these inverters may be connected, limiting the PV system to 5,000 watts and not the maximum potential of 7,680 watts.

However, the drawing at right shows a code-compliant way to add three of these 2,500-watt inverters to a 200-amp panel by using a subpanel. A subpanel is selected to accommodate the three, 15-amp backfed circuit breakers, one from each of the 2,500-watt inverters. The main circuit breaker on this dedicated (PV-only) subpanel has to have a minimum rating of 3 x 10.4 x 1.25 = 39 amps (rounded up to a 40-amp circuit breaker). This would also be the rating of the backfed circuit breaker in the main panel and, at 40 amps, would meet the code requirements for a 200-amp main panel.

Using a formula derived from the *NEC* requirements, the minimum size of the panel would be about 75 amps, which would round up to a 100-amp, standard-sized panel. The equation is:

(3 x 15) + 40 ≤ 1.2Y
Where Y is the panel size required

Solving for Y gives us: Y ≥ (45 + 40) ÷ 1.2 = 71 amps. So, if you want to install larger PV systems on residential services, using a supply-side connection [690.64(A)] can meet the code requirements.

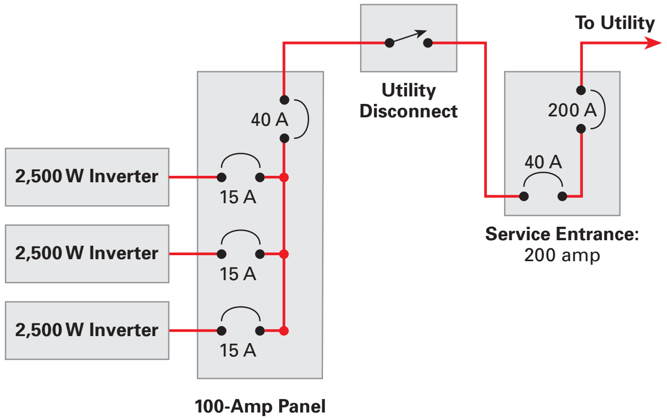
Line (Utility) Side of Ground-Fault Equipment—690.64(B)(3)

The code generally requires that all PV inverters be connected on the line (utility) side of any ground-fault protection equipment with an exception that allows backfed ground-fault protection (GFP) equipment when the protected circuits have ground-fault protection from all sources.

However, tests by SWTDI and Sandia National Laboratories on the typical 5- and 30-milliamp GFP circuit breakers have revealed that the internal sensing and trip circuits are destroyed when they are tripped while being backfed by a PV inverter. Conversations with manufacturers of the larger 100- to 800-amp ground-fault protection devices indicate that these devices may also be damaged when tripped while being backfed. Therefore, ground-fault protection equipment should only be backfed when it has been tested and listed for backfeeding.

Backfed Circuit Breakers—690.64(B)(5)

Although another section of the *NEC* [408.36(F)] requires that backfed circuit breakers be clamped, changes to 690.64(B)(5) in the 2005 *NEC* no longer require them to be clamped when connected to the output of utility-interactive inverters. Section 690.3 allows the 690 requirements to override the 408 requirement. A Fine Print Note explains that circuit



Inverter subpanel feeding residential service entrance.

breakers suitable for backfeeding are not marked with "Line" and "Load" designations.

Battery Backup, Utility-Interactive Systems—More Complexity

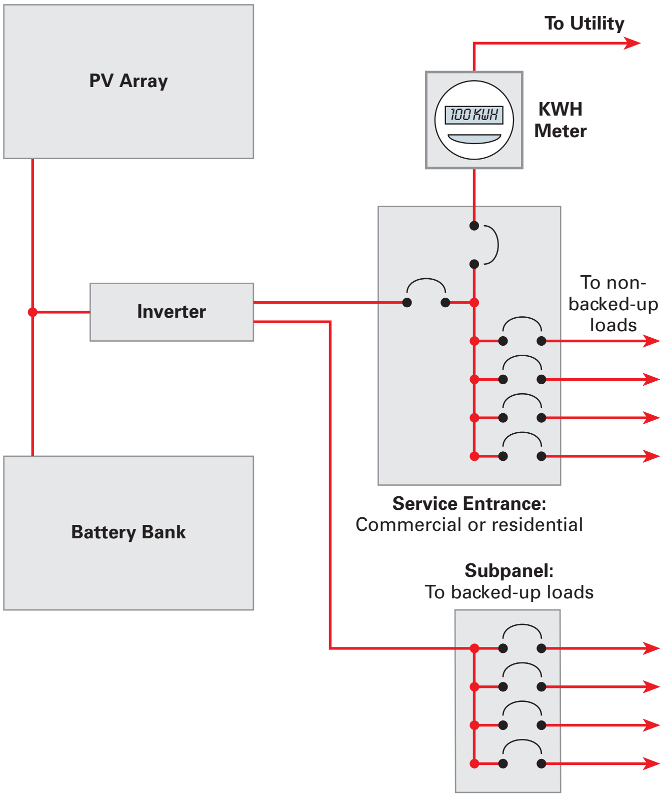
The specifications in Underwriters Laboratories (UL) Standard 1741 require that all utility-interactive inverters cease exporting power to the utility grid when the utility grid voltage and frequency deviate from very narrowly defined values. In blackout situations, the PV system and the standard batteryless utility-interactive inverter cease to operate and will not even supply power to local loads.

In areas where utility blackouts are a concern, some systems are being installed that have a battery-based energy storage system to provide local power during utility outages. The batteries are connected to a specially designed and listed utility-interactive inverter that, in the event of a utility outage, will disconnect from the utility system and provide a set of designated circuits with power from the PV system and the battery. All of these actions are done automatically with transfer devices built into the inverter. The drawing on the next page shows a simplified block diagram of a typical system. Several variations are possible.

Interfacing these systems with the utility grid and meeting 690.64(B)(2) requirements presents challenges for the system designer, the installer, and the inspector. Many of these inverters have internal transfer relays that are rated for 60 amps continuous duty, and that information is presented in the specifications.

This specification leads designers and installers to size the backup load subpanel for 60 amps and to use a 60-amp backfed circuit breaker to connect the inverter to the main load center where the utility connection is made. The use of 60-amp circuit breakers in both positions provides for best use of the internal 60-amp relay and appears to allow maximum loads to be connected to the backup subpanel. Unfortunately, the use of 60-amp circuit breakers poses two problems and code violations.

Inverters commonly used for grid-tied backup systems cannot source these high currents, but *NEC* Section 690.64 requires the load center to be sized based on the size of



Utility-interactive PV system with battery backup.

the breaker, not the rated output of the inverter in utility-intertie mode. Even though the inverter may be rated (and can be adjusted) to carry 60 amps, the external wiring and circuit breakers require the normal 80 percent continuous current derating. For a 60-amp continuous current, an 80-amp circuit breaker and conductors rated for at least 75 amps would be required.

Another option that will allow the 60-amp circuit breakers to be retained would be to adjust the inverter to not allow more than 48 amps of continuous current to be handled by these circuits. That adjustment is commonly available on most of these inverters, although there is some question about who has access to the adjustment (qualified or unqualified people).

Second, the 690.64(B)(2) requirements discussed above must be addressed. In a residential installation, a 60-amp backfed PV circuit breaker would dictate that at least a 300-amp main panel be used (60-amp PV circuit breaker + 300-amp main circuit breaker = 360 amps; 1.2 x 300 = 360). Residential load centers rated at 300 amps and above are available but not common. In a commercial installation, the existing load center would have to be replaced with one having at least a 60-amp greater rating than the original rating. In either case, a supply-side interconnection [690.64(A)] might be the more practical alternative. If the full 60-amp rating of the inverter is to be used, then, of course, 80-amp circuit breakers and 75-amp conductors should be used. The use of 80-amp overcurrent devices would require a 400-amp load center to meet *NEC* requirements.

In all cases, 120 percent of the load center rating must equal or exceed the sum of the main breaker and the 80-amp PV breaker. Some possible combinations would include a 200-amp panel and a 150-amp main breaker. A 300-amp panel could be used with a 240-amp main breaker.

To further complicate system design, many of these systems have an external inverter-bypass switch that is used if the inverter fails. This bypass switch, usually consisting of a pair of interlocked circuit breakers, is used to connect the backup subpanel directly to the main panel when the inverter fails. These circuit breakers are typically also rated at 60 amps and installed in a small 60-amp, three-position (three-phase) load center. Obviously, neither the circuit breakers nor the load center are rated to carry 60 amps continuously. The use of a larger load center and interlocked 80-amp circuit breakers would allow a full 60-amp rating for the inverter-bypass switch.

Some inverters have only 50-amp internal ratings. The ratings of the external overcurrent devices would have to be at least 70 amps and conductors would have to be rated for at least 63 amps. The load center would need to have a 400-amp rating unless a smaller main breaker could be used.

Summary

The requirements of *NEC* Section 690.64 can be met in nearly all installations. While the requirements, at first glance, are somewhat complex and sometimes overlooked, attention to these details in the design, installation, and inspection of these systems should help to ensure a safe, durable, and code-compliant installation.

Access

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Photovoltaic Power Systems & the 2005 NEC: Suggested Practices, a 145-page manual can be downloaded from the SWTDI web site • www.nmsu.edu/~tdi/photovoltaics/codes-stds/PVnecSugPract.htm

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

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

Growing Solar

Strategies for RE Success

Don Loweburg

Hailed as "America's Largest Business-to-Business Solar Event," the Solar Power 2005 conference was held October 5–9, 2005, in Washington, D.C. More than 1,300 attendees, and a record number of presenters and displays resulted in the largest conference to date. Julia Judd, executive director of Solar Electric Power Association, reported that attendance was greater than ever (exceeding last year's by 15 percent), and also was the most diverse. Companies represented everything from roof-integrated solar-electric (photovoltaic; PV) systems and domestic solar water heating to inverters and Web-based monitoring systems.

Increasing Solar's Exposure

Certainly, Solar Power 2005 was a trade show, with manufacturers and service providers vying for the attention of the attendees. New players and established manufacturers put on their best face, while information-hungry attendees cruised the aisles, collecting glossy brochures and chatting with manufacturer reps. Perhaps more importantly, though, Solar Power 2005 focused on addressing the question, "What's needed to grow the U.S. solar energy market?" Below is a sampling of ideas companies are investing in to move solar technology forward.

Sponsored Solar Thermal Systems. Solar thermal currently represents a small fraction of the total solar energy business, but this technology offers great potential for increasing the amount of renewable energy (RE) in the United States' energy mix. If the amount of thermal energy collected is quantified in kilowatt-hours (KWH), the installed cost of solar water heating systems is about US$1 per watt—an amount that's considerably less than the price of PV installations. Even accounting for the generous PV rebates offered by several states, solar thermal systems still deliver more energy for every dollar invested. And a new federal tax credit of up to 30 percent of the cost of a solar thermal system may help stimulate consumer interest.

German company KACO showcased their line of inverters.

At Solar Power 2005, Jeff Curry of Lakeland Electric, a municipal utility and Florida's third largest public power utility, described an innovative utility program for promoting solar thermal systems. In 1998, Lakeland started placing solar thermal systems on some of their customers' homes and then metering each system's hot water output. But rather than reporting the energy produced in British thermal units (Btu), the amount of energy produced is reported in equivalent KWH using a special meter. Customers are billed for KWH of electricity used and KWH for hot water delivered. The customer can then see what proportion of the total energy is used to make hot water. Jeff says that "customers love it because they get to use solar energy with absolutely no financial risk—no upfront [or maintenance] expenses—because Lakeland owns and maintains the system."

Besides actively increasing the use of RE in their system and creating revenue, Lakeland benefits by owning the tradable renewable energy credits (TRECs) generated. Lakeland can sell these credits, currently at a value of US$0.032 per KWH. This revenue, when combined with the metered charge in KWH for the hot water generated, covers the capital investment and maintenance of the solar hot water panels.

Lakeland's program of metering hot water production in KWH has an important additional benefit. Making solar hot water has been traditionally regarded as an energy efficiency measure or load reduction technology, but neither has had much impact on the widespread adoption of solar water heating in the United States. By explicitly treating solar hot water production as an energy generation technology, it may be possible to shift the public and bureaucratic mind-set.

Maximizing PV Performance. Bill Brooks of Brooks Engineering presented findings based on a PV system's performance-testing program—the BIPV Testing & Evaluation Project—funded by the California Energy Commission. Motivation for this project was based on consumers having too little to rely on besides the manufacturers' literature for judging performance and suitability of various PV products. And the literature often does not paint an accurate picture of performance because it doesn't factor in the interaction between the individual components. The end result of these sometimes overly optimistic reports can be a disappointed end-user, which can have negative consequences for the installer and for RE as an industry.

If high-efficiency components are mismatched or improperly installed, system performance will suffer. This project evaluated several professionally installed commercial and residential systems that used various inverter–module combinations. (The live data and project details are available on the Web—see Access.)

The project yielded two general conclusions. First, array string voltage should be as high as possible for any given inverter. Inverter manufacturers specify an input voltage window, but make the window as wide as possible to accommodate many module configurations and types. However, inverter performance is better when the array string voltage is well above the inverter's minimum operational value.

Second, the data showed that over time, sloppy or overly broad module power ratings will be the source of disappointing system performance. This point makes the case for more accurate module power ratings. Many modules sold in the United States have power ratings that are plus or minus 10 percent, while European and Asian markets often require tighter tolerance ratings.

Short-Supply Solutions. No modules, no problem? Well, not exactly. In his presentation, Matt Lugar of Sharp Solar presented several recommendations for weathering the solar-electric market. He says that due to a silicon shortage that may last another two years, PV modules are increasing in price and modules will be in short supply.

With the manufacturers in the driver's seat of this "seller's market," Matt's advice was directed primarily at installers and sellers of PV systems. He suggested that PV purchasers prepare for price increases, and advised installation companies not to get locked into specific module sizes, but to sell watts instead. That way, when "volatility" restricts the availability of a particular module, the installer–seller may substitute another module, while still maintaining the specified system watts. Matt also counseled installers to make monthly projections of future requirements (in watts) so that manufacturers can allocate production, and stressed the importance of communication with the module suppliers. He also emphasized the importance of keeping all accounts current and, at times, to consider prepaying for product.

Suntech, a company based in China, exhibited their PV modules.

Matt suggested that folks looking to break into the business focus on promoting solar hot water system installations, energy audits, and other energy efficiency measures. New companies can establish strong customer relationships this way and prepare for PV when the market improves. He also encouraged new business owners to use the current period of module constraint as an opportunity to get additional training, licensing, and certification to enhance their professional and competitive standing.

Future Forward

These innovative ideas and many others will be instrumental in moving solar energy into the U.S. mainstream. And this year, by taking advantage of the federal tax credits and state rebates for solar-electric and solar thermal systems, you can help renewable energy gain momentum too. (For more information, see the Database of State Incentives for Renewable Energy Web site at www.dsireusa.org.)

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Solar Power 2005/2006, 805 15th St. NW, Ste. 510, Washington, DC 20005 • 202-682-0556 • info@solarelectricpower.org • www.solarpowerconference.com • Solar Power 2006 will be held Oct. 15–20 at the San Jose Convention Center, San Jose, California. A CD containing all the presentations made at Solar Power 2005 is available for sale on the Web site.

Energy Movement

Michael Welch

In the last several months, the energy world has seen lots of interesting and mostly positive movement. The recently passed energy bill has provided a lot of impetus for the nonrenewable technologies, and some help in areas that *Home Power* readers are more interested in promoting.

But several other areas of movement are not as closely connected with the energy bill, and clearly reflect the public's desire for a renewable, cost-effective, and nonpolluting energy future. Greater public awareness of environmental problems that were mostly being ignored by politicians and the large energy companies is again becoming a factor in policy making.

Economically, it hasn't hurt the cause to have energy prices skyrocket from previous years as much as gasoline prices have (about 60% higher, supposedly from supply interruptions since Hurricane Katrina), and as much as home heating costs are expected to rise this winter (40% for natural gas and 27% for heating oil). Supplies are not expected to return to normal until the summer of 2006 at the earliest.

PV Demand

All facets of the industry have been impacted by a worldwide, hot market for solar-electric modules. And this is happening on many levels, from the home rooftop market to larger commercial installations to utility projects. As reported in *HP102*, the module shortage has resulted in substantial lead times for module shipments, and has been pushing up prices after literally decades of steady price decreases. I and many others felt that things would have changed by the end of 2005.

But module prices are continuing to go up, even though the industry has done a lot to try to keep up with demand. For example, solar cell manufacturers quickly ramped up production. But they were stymied when PV-grade silicon manufacturing could not keep up with the cell-producers' demand. Fortunately, these are all short-term problems that are naturally solvable within the economic framework of a demand-driven industry. Prices and demand are rising, so the industry wants to add production, and they will.

What has been surprising to me after watching this trend of increasing prices is that the higher costs have not seemed to slow demand much at all. The public's interest in the technology in the United States, where prices have gone up the most and incentives are far less than in high-sales nations, has continued despite higher per-watt installation costs.

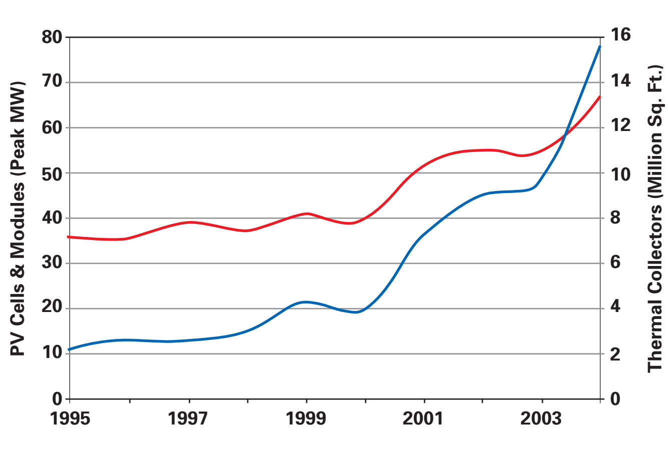
One thing that helps is that installed system prices are not going up at the same rate that PV module costs are increasing. This is because the PV modules normally make up 50 to 80 percent of the total system cost, leaving the rest to balance of system (BOS) parts and installation fees. The major BOS component is the inverter, and inverter prices have been holding steady for years, not even keeping up with increases in common price indexes. Installation costs have stayed pretty flat, with easier-to-install equipment and sharing of techniques among installers.

Solar Hot Water Resurgence

As the point person in a local nonprofit that deals with renewable energy, I have noticed an increasing interest in solar heating. In fact, 2004 statistics recently released by the U.S. Department of Energy bear this out. Solar thermal collector shipments increased by 23 percent over 2003 levels. The same report shows that solar thermal collector prices are decreasing at a pretty good rate, due to advanced technologies and manufacturing economies of scale. Prices are down 27 percent since 2000.

Besides the cheaper prices helping to increase the amount of installed solar thermal capacity, folks that I talk to are

Domestic Solar Panel Shipments



finally "getting it" that solar heating pays off with greater energy savings and greater environmental benefits than "sexier" solar electricity. Once again, fuel price increases are a timely nudge for folks to take a harder look at how they are making hot water and space heat. For sure, it is helping that *Home Power* and other RE magazines have been telling folks about the benefits of solar thermal systems for quite some time.

But media outlets are not the only ones passing this news on. The solar thermal cause is being taken up by municipalities, utilities, and nonprofits alike. The cause is even being reinforced by installing dealers of renewable-electric systems fearing for their jobs as they watch PV module prices increase and availability decrease.

This is a great thing for the industry in general. It helps put solar heating and solar electricity on a more equal footing, and helps consumers make more holistic choices about dealing with their energy use and supply.

Biofuels Boom

Because of post-hurricane fuel prices, public interest is up in both fuel-efficient vehicles like hybrids, and in alternative fuels for internal combustion engine vehicles. This greater interest is giving biofuel manufacturers and organizations more clout and more prominence as they try to work their way into the mainstream.

With this clout, these organizations are better able to stick up for themselves in spite of a government that is so extremely favorable to the fossil-fuel industry. For example, the American Soybean Association is gaining support in fighting the import of millions of gallons of biodiesel and vegetable oil from foreign countries. The ASA is trying to close a loophole in an incentive that was designed to increase U.S. production, but is also available to importers.

There is plenty of room for both domestic and imported biofuels. We are already unable to keep up with the demand for biodiesel in the United States. And other countries that have vegetable oil-based industries are throwing away millions of gallons of potential fuel, which could be placed in tankers and brought to the United States. Not only is this a potential fuel that could offset fossil fuel use and decrease air pollution, it is a potential revenue stream for developing countries and should be rescued from becoming an environmental dumping problem for those countries.

According to the ASA, 2005 biodiesel production is at about 30 million gallons, with projections for 80 million gallons in 2007 and up to 200 million gallons in 2007. But that seems to be a drop in the bucket compared to the potential for demand in the United States.

I know that several companies are looking at importing veggie oil for biodiesel. One, EarthFirst Americas, has already brought their first shipment into Florida from Ecuador, and expects to hit the 3 million gallon per month mark by spring 2006. This company is mainly in the business of liquid and solid waste removal, a great matchup. Another company is looking at shipping foreign veggie oil to the Northwest, and setting up local businesses to turn the oil into biodiesel.

It seems certain that we cannot completely replace fossil-fuel use in transportation in the foreseeable future, but at least we will start making a dent in it soon.

Oil Bucks

Another item in the news is the high profits that the oil companies have posted recently. In the third quarter of 2005, oil company profits were up by 46 percent over the same period the previous year, according to the *Washington Times*. But to hear the oil companies talk, you'd think it was about time, after so many years of nearly nothing. Fuel prices have been changing up and down, but the general trend is up, up, up.

According to the activist group Public Citizen, oil companies reported earnings of 22.8 cents per gallon of gasoline refined in 1999. In 2004, that amount was nearly double—40.8 cents. Public Citizen testified before Congress in September that the price increases and huge profits are not the result of Hurricane Katrina, as the oil companies would have us believe. The problem is more related to less competition in the marketplace—a result of the federal government's unwillingness to enforce antitrust laws that make it illegal to withhold commodities from the market to drive up prices.

Further, Public Citizen states that oil company mergers in recent years have consolidated too much power into too few hands. A decade ago, ten companies controlled 55.6 percent of refining capacity. In 2004, after mergers between already-giant companies, *five* companies controlled 56.3 percent of refining capacity.

Public Citizen's Tyson Slocum said, "We have every meteorologist in the country monitoring hurricanes, letting us know exactly when the next one is going to hit and where. But who is monitoring the companies that are jacking up gasoline prices for consumers under the guise of natural disasters?" He continued, "We need the government to protect us from dangerous weather, but we also need to be protected from price-gouging every day when we heat our homes, drive our cars, or fly somewhere."

Now Congress is asking the oil companies to invest in production and refining to make up for the Gulf hurricane losses. Others are suggesting that they help the poor and fixed income folks afford oil and gasoline. Still others are suggesting a windfall tax that would go toward renewable energy industry development, and are bemoaning the US$6 billion subsidy that the oil industry will be receiving as a result of the 2005 energy bill. Whatever happens, these oil industry problems are helping the renewable energy industry to gain appreciation among politicians and the public.

Brightening Up

This column touches on only a few of the many energy items we've been seeing in the news recently. Others include more interest in government incentives and a renewed interest in the administration's secret energy meetings with the fossil fuel and nuclear industry CEOs. For the world, and in spite of the mostly horrible energy bill foisted on the public last year, I see a future of possibilities.

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DC Receptacles & Plugs

Unsafe Connectors?

Ian Woofenden

Derivation: from Latin receptaculum*, to receive.*

For small electrical applications in boats, RVs, and cabins, direct current (DC) electricity can still make sense. Using DC can eliminate the need for an inverter, and the 10 to 20 percent efficiency penalty it carries. Unlike AC systems, though, high-quality, safe, and standard DC receptacles aren't yet available. Many types of receptacles are being used in DC systems, and various kluges have been the end result, with systems made up of poorly matched components.

DC systems use various connector types, such as Anderson connectors, spade connectors, or specialty connectors from the audio, professional lighting, electronics, or industrial fields. None of these has the convenience of a typical AC plug, and many of the robust receptacles that can be used for DC are quite expensive.

The most commonly used DC receptacle is the cigarette lighter receptacle, like those found in automobiles, recreational vehicles, and boats. These plugs and receptacles can be purchased in most hardware, marine, automotive, or RV stores. Many 12 VDC appliances come with this type of plug.

But these plugs have serious shortcomings. They are often not high quality. In many cases, both the plugs and the receptacles fail prematurely, and the cheaper ones frequently do not make good contact. Another drawback is their exposed electrified terminals. In a cigarette lighter socket, the DC positive terminal is at the bottom of the socket well, and within reach of fingers or metal tools. The DC negative terminal is the whole sleeve of the socket, and easily accessible, making for an ever-present shock and short-circuit hazard.

In the off-grid renewable energy world, installers and homeowners are in a bind—if we're using DC, we're faced with needing a safe and durable way to connect and disconnect appliances. If we reject the flimsy and unsafe cigarette lighter plugs, the next most common solution is to use standard 120 VAC receptacles. But besides the fact that many of these are not tested or rated for DC use, an even more important drawback is that you may accidentally plug 12 VDC appliances into 120 VAC receptacles or vice versa. I've seen older off-grid homes that rely on labels or even just the color of the receptacle to distinguish between 12 VDC receptacles and 120 VAC receptacles. This is not a good solution! Plugging in the wrong load can damage the appliance, the circuit, and you.

Cigarette lighter receptacles are the most common 12-volt DC receptacle, but they have multiple problems.

A better (although more expensive) solution, short of developing a universal standard receptacle and plug, is to use an unusual receptacle that's not commonly found in homes. Many choose a 240 VAC receptacle with one or both prongs perpendicular to the normal 120 VAC receptacle prong orientation; others use 240 VAC twist-lock plugs. This avoids any confusion about what plugs belong in what receptacles, unless you have friends who bring 240 VAC appliances with them when they visit.

I wish I could report that using these receptacles is the best answer. Unfortunately, it may be only a step along the way. I hope that at some point users, installers, and regulators come to an agreement on a safe, durable, economical, and approved connector for DC applications. I welcome your input and suggestions.

But after living with DC systems in my home for more than twenty years, I wonder if the answer for most renewable energy systems is just to switch to high-quality inverters and AC loads. While I still have a great love for the simplicity and efficiency of DC, having a single, AC distribution system with conventional, safe, and approved wiring and receptacles has a lot going for it.

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The Long Goodbye

Kathleen Jarschke-Schultze

In our lives, there is always someone who influences our course or direction. We don't always know this person personally, but still feel close to them because we identify with them. For me, it was a woman who wrote about how to live the life I wanted.

The first time I heard of Carla Emery was in the late '70s, when my friend Jean showed me her copy of Carla's book, *The Encyclopedia of Country Living*. At the time, I was living in a city, working as a psychiatric technician. I knew I wanted to live a different lifestyle, and my friend knew that too.

Jean's copy of the book was one of the first. She had lived in Kendrick, Idaho, when and where Carla's *Encyclopedia* first began. It was printed with a mimeograph machine and bound in a blue, three-ring binder. I loved it at first sight. I devoured Jean's copy, and went and found my own. By then, a publisher was printing it with a regular binding; it had been expanded and updated. I read every word.

It would be the truth to say Carla and her incredible book brought me to the place I am today. She has inspired my life and my writing. She wrote honestly about her life—the good and the bad, though always with humor. My first copy became tattered and stained. I loaned it to many people and finally it didn't come back. I couldn't remember whom I had loaned it to. I went out and bought a new one. It had been updated since my last copy, so I read it again.

Kathleen and Carla at the SolWest renewable energy fair, summer 2004.

The *Encyclopedia* is the reference book I have recommended to anyone moving to the country. It has something on everything—plants, animals, and common sense, along with how to do anything you need to on a homestead. All this knowledge is sprinkled liberally with autobiographical vignettes of Carla's life.

When I joined Bob-O as a "mail-order" bride (*HP22*) at Starveout, his mining claim in the remote Siskiyou mountains, I brought Carla's book with me. I used it all the time. I was constantly attempting things I had never done before. Carla guided me through it all.

It was one of the most thrilling moments in my life when I met Carla for the first time. She came to our county for one evening to give a lecture. I bought a new copy of the book and she autographed it for me. That book is still a prized possession.

Since I had the new book, I started loaning out my old copy, and soon enough it went on a "walkabout" and did not return. I don't loan my signed copy to anyone these days.

At the SolWest energy fair two years ago, Bob-O and I had our booth right across from Carla and her husband, Don DeLong. I sat in their booth and talked with her several times, always worrying that I was being a pest. I bought a book for each of my sisters and my sister-in-law. Carla autographed each one personally, and I was thrilled.

I told her how much my sister, Mary, loved the story about a very young Carla and her horse Shorty Bill getting lost in a blizzard on their way home from school in Montana. It always brings tears to Mary's eyes, but she loves the story.

I brought the books to our family reunion. Everyone there was ecstatic. The books sat on the picnic table, and were constantly picked up and read by all my relatives. Most conversations during that reunion started with, "Hey, did you know…?"

I saw Carla and Don again at the Midwest Renewable Energy Fair this last summer. I stopped by her booth several times to chat. It was great to visit with someone you admire so very much.

On October 18, 2005, I received a heartrending e-mail from Don, informing me of Carla's untimely passing. I was deeply saddened by his news. It read:

Carla Emery DeLong, bestselling author of The Encyclopedia of Country Living *and tireless crusader for the homesteading movement, passed away of complications from low blood pressure* *on October 11, 2005. She died in Odessa, Texas, on her way home from a national speaking tour, surrounded by her family.*

Carla's entire life was distinguished by her strength of character and her willingness to make her own way on her own terms. She will be remembered by thousands around the world for her writings on independent living, and for the doctrines of self-sufficiency and environmental stewardship she preached at speaking engagements across the United States.

Carla Emery DeLong was 66 years old. She was born Carla Harshberger in Los Angeles and raised on her parent's ranch in Montana. Before her birth, her father had lost his farm in Montana. Her parents went to California looking for work. Actress Dorothy Lamour employed them as chauffeur and cook.

The young family eventually worked its way back north. Her father worked as a logger in Oregon, then found defense work in the shipyards of Seattle. By saving everything they could, they returned to a new ranch in the mountains of Montana. That is where Carla's childhood memories began. She always considered herself a Montana farmer's daughter.

As an adult, she attended college in New York City. She met and married her first husband, Mike Emery, also country raised. They returned to the country in Kendrick, Idaho, where in 1969 she began compiling the *Encyclopedia.* Now in its updated ninth edition, it covers a multitude of topics and chronicles Carla's journey through life.

On Carla's Web site, Don writes that shortly before her death, she wrote down how she wanted to be remembered. "She was responsible. She loved a job. She loved being a wife, a mother, and a writer. She worked hard and did her best."

Here is what I believe. To impart practical knowledge that betters a person's lot in life, and builds self-reliance, health, self-confidence, and personal responsibility is one of the most wonderful things you can do with your time on this Earth. Another is to love and be loved. Carla embodied this idea and spent her life doing just that. Her passing is a great loss to us all.

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Carla Emery's Web site • www.carlaemery.com

The Encyclopedia of Country Living, Updated 9th edition, by Carla Emery, 2003, Paperback, 864 pages, ISBN 1-57061-377-X, US$30 (includes shipping) • PO Box 133, San Simon, AZ 85632 • 520-845-2288 • www.carlaemery.com

letters to HP

Thanks, Home Power!

Dear Mr. Perez, I would personally like to thank you for the magazine you run. When I first began reading it back in 1999 or 2000, I found it somewhat—well, hippie-ish! You know—"smoke dope, wear hemp clothes, hate the U.S.A."—that kind of thing. As I began researching solar energy, I found just the opposite. I found a great deal of independence in the pioneers of this field—the kind of independence that built this country.

The more I read the magazine and crawl into your head, and understand what you are really trying to say, the more I agree with you and your philosophies. Now I am using solar energy, and was one of the hundreds of homes on last October's solar tour.

Please forgive me for any criticism of your past ideas. At this point, not only do I understand them, I totally agree with them. Thanks for being there. I really mean this. Bill Mount, Tacoma, Washington

Solar Ambassadors

In the fall of 2005, the students of the Crested Butte (Colorado) Community School helped install a 1.55-kilowatt photovoltaic (PV) array, complete with a real-time data monitoring system. The students learned about renewable energy technologies in the classroom, and then the fifth, eighth, and tenth grades helped install the system right outside their classroom windows. This project couldn't have happened without the expertise, planning, and fundraising efforts of the Crested Butte Office for Resource Efficiency (ORE); the initial idea and a US$10,000 donation from Gunnison County Electric Association; and the educational execution of Solar Energy International's (SEI) Solar in the Schools program.

Students show off their new solar array at Crested Butte Community School in Colorado.

During the installation, the students were careful with panels, serious about their role in the installation, and filled with empowerment as they were given the responsibility to help make this project a success. All student participation took place on the ground, preceded by instruction from the SEI staff on job-site safety, tool and equipment safety and use, and an overview of PV panels and electricity. The assembled array (donated by BP Solar) was then lifted off the ground by a boom truck and placed on its pole. SEI staff finished up the final connections. The school hosted a successful solar fair the following week to showcase their new PV system and to further educate the public about renewables and energy conservation. Not only did the students sell more than 250 compact fluorescent bulbs that day, they also eagerly fell into the role of solar ambassadors—kids teaching their peers! Soozie Lindbloom, Carbondale, Colorado, Coordinator, Solar in the Schools • soozie@solarenergy.org

Solar-Electric Hot Water

I wonder if the output from a PV array could be sent directly to an electric water heater? A resistive load should heat up with DC electricity. With an output that varied with the prevailing sun, the system would not be efficient, but this might serve to preheat the water before routing it to a gas-fired water heater. Thanks in advance for any feedback. Fred Clarke • fbc3@copper.net

Hi Fred, Your concept will work. Many people have used a diversion heating element for preheating their domestic hot water with overproduction from their PV system. Many retail advertisers in Home Power *sell low-voltage water heater elements. One supplier reports that "AC water heating elements work fine for DC. You just need contacts that can switch the DC to turn the elements on and off. You can get a variety of 120- and 240-volt elements at anywhere from 500 to 4,500 watts. If you use a 240-volt element at a lower voltage, remember—every time you cut the voltage in half, the wattage drops by 75 percent."*

The low-voltage elements make sense for excess solar electricity, but a thermal system dedicated to heating hot water is more cost effective. This is due to the higher efficiencies of thermal collectors and the lower cost per square foot of collector/panel surface area. Cheers, Chuck Marken • chuck.marken@homepower.com

Developing World Need

Dear Sir, I'm a British member of a Catholic religious order of educators and have been working in the Peruvian Amazon for the past five years. I have founded an environmental organization here—the only one of its kind—since there are many problems due to the petrol companies and illegal timber work. In this town of 400,000, we also have a serious noise and pollution problem because of the transport system—basically 20,000 motorbike taxis.

I'd be very interested in seeing how your magazine's ideas could be incorporated into future public planning. We are already consulted by the local government as to better ideas for the future, and would like to see how we could benefit from renewable technologies. I'd be grateful for any info that you feel may be relevant for our town and the river villages. Sincerely, Paul McAuley • redambientalloretana@yahoo.com

Hello Paul, I'm sympathetic to your plight because of my own work in the developing world. The need is great, though funding and financing are always a problem, and there are serious issues with outsiders introducing technologies that may or may not be desired by the locals.

Many of the renewable energy technologies are probably very appropriate for your town in Peru. I'd urge you to study more, and especially recommend Solar Energy International's Renewable Energy for the Developing World workshop. This Colorado classroom-based workshop is full of examples of incredible work by a variety of organizations focused on the developing world.

As far as the specific question you mention, if there is utility electricity there, I strongly recommend that you consider using electric bikes and scooters. This would reduce your noise and pollution levels dramatically, and in the future, give people the option of making their own transportation energy with the sun, wind, and falling water. Perhaps you can bring in a sturdy electric bike or scooter and begin using it yourself, which is often the best way to interest others in new technology. Regards, Ian Woofenden • ian.woofenden@homepower.com

Technology Old & New

Last October, I was giving my dad a ride, and enjoying the fall foliage of northeast Pennsylvania. I knew where the local wind farm was, but never had seen it in person. I'm happy to report that at 87 years old, Dad knows just what it is and what it does.

Here's a photo of the scene (at right). In the foreground and sitting alone is a fine example of yesteryear's technology. Looming in the background, sitting atop a ridge at an altitude over 1,900 feet above sea level, were just a few of 40 modern wind turbines—quite the contrast in technology. These majestic machines owned by Florida Power & Light are scattered across an ancient five-mile-long ridge in the Appalachian Mountains.

In doing a little research on the wind farm before writing this letter, the first person I talked to in the area did not share my admiration for the wind turbines in her backyard. Obviously, she's just one more great example of a NIMBY (not in my backyard). I suspect she thinks the energy that comes out of her wall plug grows on lovely electricity trees planted in someone else's backyard. Glenn Ryerson • glenn@3cats.com

New Wind Technology?

I've been interested in wind power for some time, but it seems to not be cost efficient in my area because of lower wind speeds. However, I just read an article in the October 2005 issue of *Popular Mechanics* magazine and want to run it by someone, so I located you on the *Home Power* Web site. The article reports on a way to make small wind turbines 40 percent more efficient! I'm wondering if you've seen this article. If so, I'd be interested in your thoughts on it. If seems that they may be on to something that could spur the increase of small home wind power in this country. Please feel free to send me your thoughts. Thanks, Mike Woolen, Sullivan, Illinois

Hi Mike, I wouldn't get too awfully excited about this, though the general idea of electronically enhancing output at lower wind speeds has some merit. The basic problem is that there just isn't that much energy in low wind speeds. The power available in the wind varies with the cube of the wind speed, so a 4 mph wind has one-eighth the energy of an 8 mph wind. That means that designing a machine to be optimized for extremely low wind speeds is a low-return enterprise from the start. Turbines should be designed to capture the most prevalent and productive winds, which are generally in the 10 to 20 mph range.

A few manufacturers are playing with power electronics to match their turbines to the charging needs better, and that shows some promise. But overall, the technology we have works

In Pennsylvania, old meets new—a fossil-fueled jalopy in front of a field of modern wind generators.

fairly well, and I don't expect any amazing breakthroughs. The easy answer if you want more wind energy production is to put turbines on tall towers, where there is more wind. Even a few miles per hour difference in average wind speed can make a huge difference in output. For instance, the increase in output between 10 and 12 mph in average wind speed is more than 70 percent. Best, Ian Woofenden • ian.woofenden@homepower.com

Tax Credit

Your profile of the recently passed federal energy bill has inspired me to install a small PV system on our vacation home. I want to be sure everything is done to qualify for the 30 percent government tax credit promised by the energy bill, but I can't seem to find where the government is hiding the forms and other relevant information. Do you possibly have a link? Thanks! Jerry Borshard, Plano, Texas • jcborshard@fastmail.fm

Hello Jerry, The following link has pretty detailed information on the new federal tax credits for residential solar energy systems. There's an IRS contact listed as well. Just go to www.dsireusa.org and click on "Federal." You can also click on "Texas" for incentives specific to your state. Thanks for reading, and for using renewable energy! Best, Joe Schwartz • joe.schwartz@homepower.com

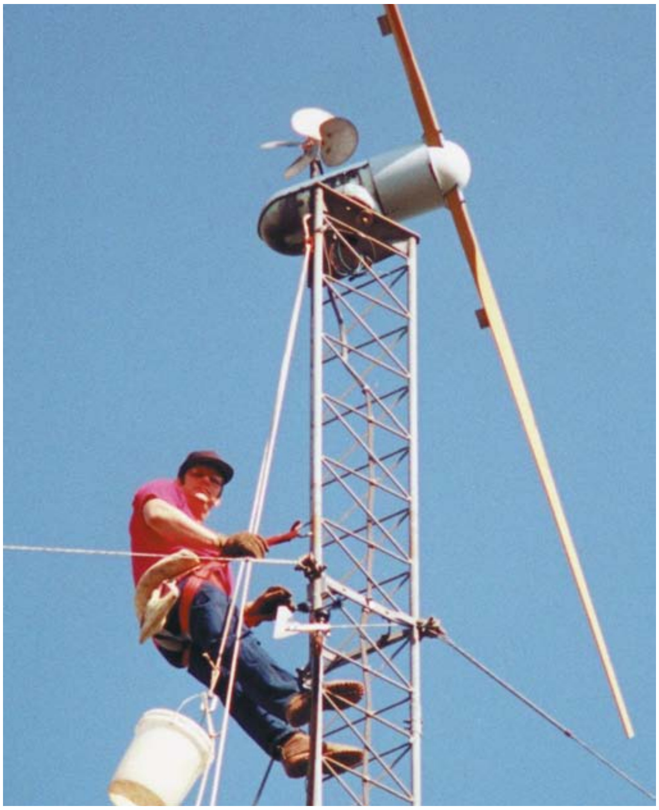
Wind Metering Correction

Hello *Home Power* crew, As a long-term owner of a grid-tied, wind-electric system, I would like to compliment you on the excellent article by Ian Woofenden, "Wind-Electric Systems Simplified" in *HP110.* However, I will call your attention to a small statement in the article that is rather misleading.

In the description of the kilowatt-hour meter, the article states: "A bidirectional KWH meter can simultaneously keep track of how much electricity you're using and how much your system is producing." I believe a more accurate wording would be: A bidirectional KWH meter can simultaneously keep track of how much electricity you're getting from the grid and how much electricity you're putting into the grid.

In most grid-tied RE systems, the amount of electricity we purchase is not the same as the amount of electricity our home uses. Part of the electricity we generate is used directly by our house and is not recorded on the bidirectional KWH meter. It is only when our PV panels or wind generator generates more electricity than the house is using that the KWH meter records the amount of electricity we are putting into the grid. This amount is very different than the amount of electricity our system is producing. Thank you for an excellent publication and (with this small exception) an excellent article on wind-electric systems.

As far as my own wind energy experience, we went online in October 1985, and it was the start of a twenty-plus year adventure with utility-intertied wind electricity (see *HP51*). A 4 KW Whirlwind generator tops a 120-foot guyed tower on our rural property outside of Buffalo, New York. It has been a challenge keeping the unit running when both the dealer who installed our system and the turbine manufacturer went out of business a short time after installation. With skills as a machinist, no fear of heights, and help from friends and family as ground crew, I am able to keep the twenty-year-old Whirlwind running. It has been through a number of rebuilds and I was able to locate some critical parts on the Internet. It has been great fun and I'm happy I went on this adventure. However, climbing the tower is not as easy as it was twenty years ago, and the time is near when the unit will be retired and I will move on to other projects. Carl Berger • csberger@earthlink.net



Carl Berger on his Whirlwind's tower.

Hi Carl, Thanks for your letter. Bidirectional KWH meters display a home's net electricity use. Two-channel KWH meters separately display electricity purchased from and "sold" to the grid. Also, many inverters measure and display their AC output instantaneously, daily, and cumulatively. An additional, user-supplied KWH meter can also be installed to independently track an inverter's contribution to a home's total electricity use if this metering is not built into the inverter. Congrats on your long history with wind energy! Ian Woofenden • ian.woofenden@homepower.com

Putting $100 Billion in Perspective

The oil shock of the last few months has revealed much about what American consumers are willing to pay for, and also what kind of impact the economy can withstand. The oil companies collectively made US$100 billion in profits over a period of three months. If this quarterly profit were annualized, it would represent, in profits alone, the dollar cost of moving half of the U.S. electricity industry to renewable energy. This is based on an assumption that renewable electricity would cost US$1 per watt (reasonably accurate with respect to wind turbines) and that current generation capacity is somewhere between 700 and 800 gigawatts (in other words, about one thousand, 800-megawatt power plants).

Hydroelectric dam operators use wind turbines to reduce water discharge when the wind is blowing. This is evident with Bonneville Power Administration and Hydro Quebec at the very least. Hydro Quebec has ordered 660, 1.5 MW turbines, which presumably can be used in conjunction with the James Bay and St. Lawrence systems, among others. Similar thinking can be used with natural gas and combined cycle turbines—use as much wind as is available and fill in with on-demand backups.

Renewable energy creates a conundrum. You would not expect to see wind turbines next to natural gas compressors. However, many gas wells are in remote locations, and depending on the value of the gas, wind power may leave more gas for the well operator to sell. The natural gas pipeline, in that respect, becomes a partial proxy for renewable energy. At some point, the investors in the well may notice that the renewable energy component of their system is lasting longer than the well, so perhaps investment in the RE makes more sense than poking another hole in the ground.

There is an enormous amount of money sloshing around the U.S. (and global) economy that doesn't know where to settle. Supposedly, the cash pile in U.S. companies runs between US$1 and $2 trillion. Utility-scale wind turbines are being sold at US$1 per watt, and photovoltaic cells cost less than US$2 per watt to manufacture (although retail prices range from US$3.60 to $4). Therefore U.S. corporations could secure the national electricity supply and have a few hundred billion left over.

Many of the utility workers local to San Antonio went to New Orleans following Katrina, only to return home in a week frustrated by a lack of utility poles. The Pakistan earthquake and aftereffects of Hurricane Stan in Central America show how, at some point, people willing to contribute money to disaster relief get overwhelmed. It takes time for government and relief agencies to get organized, and often they have to work their way into areas blocked by downed trees, washed-out bridges, or landslides. We've been reminded that it can take weeks for some areas to return to habitability.

Texas seems to be the homebuilding capital of the world right now. One can see some evidence of this by looking at historical and current satellite photographs of Houston, Dallas, San Antonio, Austin, and other regions along the major Texas interstates. Question: Where do the utility workers come from to maintain all of this infrastructure? City Public Service (the San Antonio power company) sponsors a program for hiring utility workers straight out of high school. A number of RE projects in Texas have been built because there is no other way to get electricity installed in a meaningful time frame.

Another scene you can get from the satellite photographs is the traffic jam of coal trains in Wyoming and Nebraska. One thing renewable energy installers and activists may have to address in the short term is that a significant base of users might well be traditional resource extraction industries. This would apply to mines and lumbering operations, as well as oil wells. The people in these traditional industries would like to simply hook up power from their local utility. Such utilities might be hard to find in the remoter reaches of Alberta and the Northwest Territories.

The energy situation is simply becoming more volatile, with 30 percent price swings in a matter of weeks. Anyone trying to plan investments in this environment would want to pool and spread their risks into a basket of energy technologies. Meredith Poor • mnpoor@idworld.net

Which Way Up?

Dear *Home Power* and Dr. Bernd Geisler, I just love the magazine. It has so many great examples. In *HP110*, "Efficiency Pays" was excellent, with many tips on saving energy. I live in a grid-tied, 1.8 KW solar-electric home with solar hot water, solar tube lights, Energy Star appliances, solar clothes dryer (clothesline), solar oven, and LED lights. Best of all, I have no gas or fireplace, just all clean electricity. I installed the systems myself, before there were incentives. My electric bills average US$20 to $30 a month. I live in a nine-year-old, 1,600-square-foot, three-bedroom home.

I have been checking into spray-on soy-foam insulation for my home renovation, with no luck. The suggestion in the article about using radiant barriers was a super idea I hadn't thought of before. The only part that confused me is the foil side put facing down. The picture shows it down and back to the attic-living area. Everything I have heard suggests that the foil should be placed facing the heat. In a hot climate like the example in Texas, that would be up, away from the attic and living space. I live in Arizona, so that's what I would do. In a cold area, it might be the way shown in the story. Which is correct? Jim Stack, Chandler, Arizona • jstack6@juno.com

Hello Jim, The manufacturer recommends installing the radiant barrier under the rafters with the foil facing down for retrofits, to reduce or eliminate dust buildup, which they fear could compromise the function of the foil over the years. Personally I think that dust cannot do much harm, because it has too little mass and therefore minimal specific heat.

I agree that the foil side facing up would probably lower the temperature of the radiant barrier a bit, because the heat would be reflected slightly earlier. But the paper layer is also very thin and has low specific heat capacity, so physically it really should not matter much which direction it faces. This may seem counterintuitive. Keep in mind here that the radiation involved is (invisible) infrared (IR), because the visible and UV parts cannot penetrate through the upper layers of the roof. Only the IR part can penetrate deep into the attic and heat it up. Even if the radiant barrier doesn't look like a mirror when you look at the paper side, for IR it still is.

By the way, I have used another method for my house. Since I had accidentally bought twice as much radiant barrier as needed, I placed a second layer of radiant barrier with the metal side facing upwards directly under the shingles when those had to be replaced after a severe hailstorm. My idea was that the earlier the

IR is reflected, the better. Because the attic temperature is usually hotter than the ambient temperature, heat flow by conduction will usually be directed out of the attic! Convective heat flow also rises out of the attic naturally (warm air rises), so the main problem is really blocking radiation from entering the attic, which is best done as early as possible.

I don't know which method works better, foil side upwards or downwards—that would be a nice research project. But my guess is it does not really matter. My combined method has definitely been very, very effective. Our August cooling bills were reduced by half compared to previous years' bills.

For the do-it-yourselfer, the method recommended in the article is probably the easiest and involves the least amount of trouble. That's why I mentioned it. Stapling the foil facing downwards also gives the attic a space-age look, which is attractive because people can see something special has been done here. It definitely looks much better than brown paper, and also makes the attic appear brighter, because of all the light reflection. But I would be intrigued to know what a company engineer would say about this issue. It is a very interesting question, indeed. Best wishes, Bernd Geisler • texregeninfo@aol.com

Compressed Air

I eagerly await each edition of *Home Power* magazine and read it from cover to cover. It has had a strong influence on my attitudes towards energy usage awareness. So, first up, I'd like to thank everyone at *Home Power* for the excellent publication. One of the strongest messages I've taken from my reading is what I call "the three great misuses of electricity," namely: for heating water; for all other forms of household heating and cooling, including cooking; and for almost all the motors you can find around your house.

Most articles in *Home Power* (and other publications) concentrate heavily on the first two areas. For heating water, an on-demand, gas-boosted solar hot water system seems the clear winner. Household heating/cooling requirements are best minimized by good design, the use of thermal mass, and the use of insulation, and are best boosted by heat pumps and nonelectric heaters. Cooking with electricity seems to be the least efficient method of all, and any other method seems preferable (a gas stove is my personal pick). I suspect that the electric motor great misuse is not looked at much because it is deemed too difficult or not worth dealing with. I'd like to make a few observations about this, ask a few questions, and propose a few ideas. I'd appreciate input from the people at *Home Power* and the readers out there as well.

When designing a renewable electricity system for your home, the sizing of the inverter is a decision to get right the first time. Of importance in this decision is both the "normal" load (power draw when things are up and running) and the "surge" load (power draw when things are starting up). Items that require a large surge load capability almost always involve an electric motor (such as fans, the compressor in your fridge, or the power tools in your shed). Electric motors are also pretty power-hungry even once they're up to speed. Finding an alternative to the electric motors in your life could mean you are able to significantly scale down the components in your home's renewable electricity system (I think).

With all this in mind, my interest was piqued when a friend recently converted his shed over to an air-tool system. All his electric motors are now run from a pressurized air reservoir that is filled via an electric compressor. The only surge load he now has to worry about is the compressor, which is lower than most of his tools.

So here (at last, sorry) we come to the crux of my letter. Two questions sprang to mind after the conversation with my friend. I'm interested in your comments in what is wrong with these ideas, and then I'd like your input into solving the problems you identify. My two questions are: Can I run an air compressor directly from a solar/wind-electric system? Can I convert any of my indoor appliances to use air-driven motors (my fridge would be at the top of the desired conversion list)? I believe that it is possible that producing, storing, and transmitting compressed air could be done much more cheaply than producing, storing, and transmitting electricity.

My limited knowledge about all things electrical/ mechanical leads me to think that it would be a struggle to run an air compressor directly from a solar-electric panel or wind turbine. So how about with a supercapacitor in between (I want to avoid the need for any kind of battery in this system)? If this would overcome the problem, can you publish a circuit diagram and parts list that would allow me to build such a system? What about an article about converting a fridge to use a hacked-up, cheap air tool, instead of an electric motor, to run its compressor? *Home Power* is better than many others because of the quality of its practical advice and the fact that many of its articles deal with things we can actually build. I'd really appreciate if it could turn its creativity to helping me solve my third great misuse of electricity. Chris Molloy • chris.molloy@allianz.com.au

Hi Chris, Thanks for your thoughts and questions. I'd like to start to answer your questions with a bit of historical perspective. The RE industry got its start largely with off-grid homes, many of them homes of "back-to-the-landers," including my own family's. We were poor, but eager to use natural energy as much as we could. Many of us started purchasing solar-electric modules when they were quite expensive, and we never seemed to be able to afford enough to do everything we wanted to do with electricity. This led us to some energy and economic compromises. It was simply financially out of our reach to power any significant heating loads with renewable energy. So we used wood, propane, or other fossil-based fuels for heating space and water, and we used fuel-fired generators to supplement our RE system output. Switching heating loads to other fuels became a basic strategy of RE system design.

But I'd like to point out that this was not because of some inherent mismatch between renewable electricity and heating. It was because of economics—we simply couldn't afford to power those huge energy loads with our RE systems. Propane became a common "enabler" (read: "crutch") for off-grid systems. But many of us had to ask if we had taken a real step forward to go off the electricity grid only to get onto the propane grid. Electricity generated at home is surely a more efficient and environmentally friendly plan than propane extracted from the ground hundreds or thousands of miles away and trucked in.

This is a long way to say that I think your "three great misuses" is a bit misguided, though there certainly is some truth in it. I would encourage you to think instead about the most appropriate way to accomplish each type of task, and find a way that is simplest, with the fewest energy conversions, and with the lowest economic and environmental cost. For space heating and water heating, passive solar design and solar hot water systems should be your first focus. But RE-based electric systems can be contributors in both of those arenas. This is especially true with hydro- and wind-electric systems, which are sometimes used for heating. This is usually with resistance heating, but recently a colleague has been experimenting with a heat pump run by his RE system, which promises to be a very efficient use of the energy.

As far as the compressed air idea, I think you'll find that you are using more energy to power tools this way than powering them directly with electricity. Every energy conversion has losses. When you convert from the rotational energy of the compressor's electric motor to the stored energy in the compressed air, there is a loss. When you convert from the energy in the compressed air to the rotational energy in your tool, there is another loss. As water pumping and wind guru Windy Dankoff points out, "In the process of compressing air, the temperature of the air rises, and the heat is lost. That's why compressors always have cooling fins to dissipate the heat. That heat represents about 50 percent of the energy that enters the compressor. If compressed air is the final desired medium of energy transfer, this is an inherent loss that must be accepted. Otherwise, electrical systems are more efficient."

Get high-quality, efficient motors for your large tools and you'll be saving more energy than by using compressed air. While it would be possible to drive compressors with wind turbines and hydro turbines directly, I doubt that you would see any overall gain over conventional RE electric systems.

Electricity is a wonderfully handy way to transmit and use energy. Put your efforts into using it as efficiently as possible, but don't start to think that there is something wrong with the form itself. Best, Ian Woofenden • ian.woofenden@homepower.com

Chris, I must agree with Ian on this one—compressed air, while excellent for transmitting very large amounts of mechanical power with simple devices over short distances (rotors and reciprocating actuators) lacks the efficiency and magnitude (not to mention the economics) of storage compared to that of electricity coupled with batteries.

Compressors, unless operating very slowly, will develop large amounts of heat (this is why the cylinder head has cooling fins and a fan on it). As Ian mentioned, this represents a loss (20% or more in home systems).

The storage of energy in compressed air systems, unless they are very, very large (as is done in Germany using underground caverns) is not only expensive in terms of the tank required but also disappointing when scaled down to home size. Here are some numbers: Let's say you can find a very large propane cylinder—the kind used for home heating at about 500 gallons volume (they cost about US$1,200 new). These tanks are rated at about 250 psi, but let's get crazy and run it up to 300 psi just to make the math easy. Using the universal gas law combined with a little physics, we find that the energy we can store in that tank amounts to something like 0.5 KWH. An ordinary Trojan golf cart battery costing US$60 can store the same amount of energy (this assumes a regular discharge of 50%)!

So for the price of the propane tank, you could buy more than twenty times as much storage capacity, not counting the cost of the compressor or the fact that I can use electricity for a variety of purposes (like typing this letter on my computer). I know, it really is depressing and I still find myself, regardless of having done this calculation more times than I would care to admit, redoing the calculation over and over again over the years—you should see the results for hydro storage if you want to get even more depressed!

Compressed air storage is a wonderful technique for large power devices operating intermittently (air hammers, impact wrenches, etc.). It is also very safe, since the danger of electrocution is eliminated. And while the efficiency of very large compressed-air installations can be quite respectable (up to 80% compared to batteries at about the same value), in most home situations, I doubt if you would recover more than 50 percent. Electric motors are cheap and versatile. They can be replaced very easily and maintenance is virtually nonexistent (you have to oil air-tools on a regular basis).

If you would like some more info on the analysis of compressed air storage, check out Dr. Bossel's paper on the subject from www.efcf.com/reports. Just click on it and look under the "thermodynamics of compressed air storage." Hope this helps. Dominic Crea • dom120@juno.com

Send your letters to Home Power *magazine at* letters@homepower.com *or PO Box 520, Ashland, OR 97520*

RE happenings

Coming Next Issue

Listings of training events for dealers.

INTERNATIONAL

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

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

AUSTRIA

Mar. 1–3, '06. Wels. World Sustainable Energy Days. Includes conferences on energy efficiency, green electricity, renewable HVAC & more. Info: O.Ö. Energiesparverband, Landstraße 45, A-4020 Linz • 43-732-772-014-380 • office@esv.or.at • www.wsed.at

CANADA

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

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

CHINA

Mar. 16–18, '06. Shanghai. New Energy 2006. Intl exhibition & conference on China's RE goals. Info: Coastal Intl Exhibition Co. • 85-228-276-766 • general@coastal.com.hk • www.coastal.com.hk

Jun. 28–30, '06. Beijing. Wind Power Asia 2006. Wind energy conf. & exhibition. Info: Unique Intl Exhibition Ltd. • 86-10-88-145-170 or 86-10-88-145-171 • sonya.xia@windpowerasia.com • www.windpowerasia.com

COSTA RICA

Jan. 23–29, '06. Rancho Mastatal. RE for the Developing World—Hands-On. Solar electricity, hot water & cooking; biogas & other RE technologies. Info: see listings for WA state.

GERMANY

May 16–19, '06. Hamburg. WindEnergy 2006. Intl trade fair. Info: www.windenergy.de

Sep. 4–8, '06. Dresden. European PV Conf. & Exhibition. Info: WIP-Munich • 49-89-720-12-735 • pv.conference@wip-munich.de • www.photovoltaic-conference.com

MONACO

Mar. 30–Apr. 2, '06. EVER Monaco. Conf. & exhibition on RE & ecological transportation. Incl. fuel cell & hybrid vehicles rally. Info: Philippe Napoléon, Gare de Monaco, 98000 Monaco • 37-79-775-421 • napoleon@ever-monaco.co • www. ever-monaco.co

NEPAL

Kathmandu. School of Renewable Energy Ltd. • 97-701-424-4003 • sre@nepalmail.com • www.sre.org.np

NICARAGUA

Jun. 30–Jul. 11, '06. Managua. Solar Cultural Course. Lectures, field experience & ecotourism. Richard Komp • 207-497-2204 • sunwatt@juno.com • www.grupofenix.org

SPAIN

Jul. 12–16, '06. Granada. Solar Cookers & Food Processing Intl Conf. For researchers & practitioners. Spread access to solar cooking, water purification & solar food processing. Info: Terra Foundation, Barcelona • solar@terra.org or Solar Cookers Intl • bev@solarcookers.org • www.solarconference.net

UKRAINE

Apr. 23–25, '06. Kyiv. Chernobyl+20: Remembrance for the Future. Intl conf. on the nuclear accident. Info: Tetyana Murza, Ecoclub • 380-362-237-024 • tanyam@nirs.org • www.ch20.org

U.S.A.

Info on state & federal incentives for RE. NC Solar Center • www.dsireusa.org

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

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

ARIZONA

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

CALIFORNIA

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

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

COLORADO

Carbondale, CO. Workshops & online courses on PV, solar pumping, wind power, RE businesses, microhydro, solar thermal, alternative fuels, green building & women's courses. Solar Energy Intl. • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

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

IOWA

Iowa City, IA. Iowa RE Assoc. meets 2nd Sat. every month at 9 AM. Call for changes. I-Renew • 319-341-4372 • irenew@irenew.org • www.irenew.org

MASSACHUSETTS

Mar. 7–9, '06. Boston, MA. Building Energy 2006 & Trade Show. Speakers, workshops & exhibitors. Northeast Sustainable Energy Assoc. • www.nesea.org

MICHIGAN

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

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV & more. Sage Mountain Center • 406-494-9875 • www.sagemountain.org

NEW MEXICO

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

Six NMSEA regional chapters meet monthly, with speakers. NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NORTH CAROLINA

Pittsboro, NC. RE, biofuels, green building, etc. Piedmont Biofuels Coop • 919-542-6495 ext. 223 • www.cccc.edu or www.biofuels.coop

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

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Cottage Grove, OR. Adv. Studies in Appropriate Tech., 10-week internships. Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Jun. 23–25, '06. Portage, PA. East Coast Alternative RE Fair. Exhibits, vendors & education on RE & sustainable living. ECARE • 814-736-8818 • info@ecarefair.com • www.ecarefair.com

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

RHODE ISLAND

Jun. 3, '06. Coventry, RI. Sustainable Living Festival & RE Expo. Exhibits & workshops on solar, wind, biofuels, alternative vehicles & building. Music & food. Info: Apeiron • 401-397-3430 • brad@apeiron.org • www.apeiron.org

TENNESSEE

May 10–14, '06. Summertown, TN. Solar installer course, incl. hands-on install. Info: see next listing.

Oct. 19–22, '06. Summertown, TN. Personal oil independence course. Grow your own fuels, put PV on your roof. Info: The Farm • ecovillage@thefarm.org • www.thefarm.org

TEXAS

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

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

WASHINGTON STATE

Apr. 1, '06. Guemes Island, WA. Intro to RE workshop. Solar-, wind- & hydro-electricity, solar cooking & hot water. Classroom & tours. Info: see SEI in Colorado listings • Local coordinator: Ian Woofenden • 360-293-7448 • ian.woofenden@homepower.com

Apr. 3–5, '06. Guemes Island, WA. Solar Hot Water workshop, with *HP* Solar Thermal Editor Chuck Marken. Classroom, tours & installation. Info: see above listing.

Apr. 7–9, '06. Guemes Island, WA. Utility Interactive PV workshop. Classroom, tours & hands-on installation. Info: see above listing.

WISCONSIN

Jun. 23–25, '06. Custer, WI. RE & Sustainable Living Fair (aka MREF). Exhibits & workshops on solar, wind, water, green building, alternative fuels, organic gardening, energy efficiency & healthy living. Home tours, silent auction, Kids' Korral, entertainment, speakers. Info: see MREA listing below.

Custer, WI. MREA '06 workshops: Basic, Int. & Adv. RE; PV Site Auditor Certification Test; Veg. Oil & Biodiesel; Solar Water & Space Heating; Masonry Heaters; Wind Site Assessor Training & more. MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

Send your renewable energy event info to happs@homepower.com

questions & answers

Refurbishing Solar Collectors

My brother and I recently picked up some older solar hot water panels in the junkyard at a bargain basement price. They are flat panel copper, but need to be reinsulated, repainted, and resealed. What products would you suggest, keeping in mind that we need to keep this project low budget? I've been told that common black barbecue/stove paint will work, but should be "baked on" to gas off the volatiles before assembling to avoid clouding the glass. Is there a common type of insulation panel that will work, or do we have to invest in spray equipment? Any help would be appreciated. Jim LaPointe • jlapoi2010@yahoo.com

Hi Jim, Use 1-inch insulating board like polyisocyanurate insulation (about R-7 per inch) on the back and sides of your solar collectors. If you can't find it, use stiff, foil-faced, high-density fiberglass insulation. You can also use low-density fiberglass (about R-3 per inch) if the enclosures are deep enough to allow at least a 2-inch thickness. Unless you know that the service temperature of spray insulation is around 400°F (204°C), don't use it or any other type of lower-temperature urethane inside a flat plate collector. Fiberglass is less expensive anyway.

Seal the collector with contractor-grade silicone. Paint it with barbecue paint if you wish. High-temperature, flat-black engine paint works well also. There will not be any out-gassing problem from the paint or silicone as long as the paint is dry and you don't hermetically seal the panels (very hard to do in a garage/shop operation). Solar collectors are better off if allowed to "breathe" a little. Consider taking some photos of your refurbishment and submitting an article about your budget-minded solar hot water project. Cheers and good luck, Chuck Marken • chuck.marken@homepower.com

Switched Outlets

I live in a solar-electric home. I wired wall switches for outlets wherever I thought I would have phantom loads. Unfortunately, I didn't foresee all the places switched outlets would be needed. Putting in switched multistrips isn't always a great solution, such as in the kitchen. The multistrip takes up too much room and is kind of ugly. Has anyone made a thin receptacle interface with a switch on the side to make it a switched outlet? Seems like it would be more readily used and wouldn't be bulky and unsightly. Gary Demos

Hi Gary, You were wise to prewire switched outlets in key locations in your home. But it's hard to predict everywhere that you'll need them. Here's a photo (at right) of two add-on switched plugs that I use in my office. They allow me to turn computer peripherals on and off, eliminating phantom loads when I'm not using the component. These are a bit more aesthetically pleasing and streamlined than plug strips. Another option is to buy a receptacle with an integrated switch. This only gives you one receptacle, but can be a good option for individual appliances. Best, Ian Woofenden • ian.woofenden@homepower.com

Venting a Battery Box

Forty years ago, a cinder-block pump house and generator room was built for an off-grid homestead in the mountains south of Santa Fe. There was no insulation. Thirty years ago, the place sold. The new owner put in a Jacobs wind turbine and some solar-electric panels. He installed the charge controller in the pump house and added a cinder-block addition to house the batteries. He put in minimal insulation that has fallen apart over the years (mice love fiberglass).

Nine years ago, my wife and I bought the place. We were finally able to build our house and move in a year and a half ago. Last winter was our first winter. Our carefully calculated (by-gosh and by-golly method), four-day surplus of energy in the batteries turned into two days during the cold New Mexico winter months. *Ouch!*

So I'm rebuilding the battery and inverter rooms. I'm removing the old, gabled (facing east/west) roof and replacing it with an R-30 insulated, shed-style roof that faces south (for future solar-electric array expansion). I'm adding 4 inches (10 cm) of rigid foam insulation to the outside of the cinder blocks for R-20 walls that I'll stucco. I'll rebuild the doors, and add sun tubes for daytime light and LED lighting for nighttime. All is well so far.

What I'm worried about is the venting for the batteries. I *do* want to vent any hydrogen, but I *don't* want to lose all my hard-earned heat. What type of vents do I need? I'm sure you've written an article on the subject, but I seem to have missed it. Thank you, Grey Chisholm • www.chisholmclan.com/the-land/power/index.html

Hi Grey, This is always a conundrum. The best solution is to use a powered battery exhaust fan, such as the Zephyr (www.zephyrvent.com). They have a simple back-draft damper, and only run when the batteries are charging/gassing. They can be run automatically off one of the auxiliary relays in your inverter or charge controller. Let me know if you have any additional questions or ideas. Best, Joe Schwartz • joe.schwartz@homepower.com

Using switched plugs can eliminate phantom loads.

Pumping Dilemma

I'm a subscriber to *Home Power* and would appreciate your insight into our water woes. We are off grid in rural New Mexico, with a 24 V system that includes five, 140 W BP panels, Trace C40 charge controller and SW4024 inverter, and sixteen deep-cycle batteries. We are starting an organic farm and are finding that our water needs of six hours per day are heavily taxing our system. The well pump is 1/2 hp, 120 VAC, and delivers about 10 gallons per minute (0.6 l/s) to our 80-gallon (303 l) pressure tank. We have been advised to put in a 240 VAC pump or to make our water system stand-alone, powered strictly by DC. Other advice has contradicted this. Our pump house is only 50 feet (15 m) from our utility room, batteries, etc., and it was recommended that we just change to a bigger well pump and pressure tanks, and continue to use AC. What are your thoughts about this situation? Thanks very much for your help. Ted Silk • easilk@yahoo.com

Hello Ted, I'd remain 120 VAC for pumping. Your distance is short, and with solar electricity, there is no rush to do the job quickly. Increase the size of the pump if you wish, but I'd recommend going with more storage and pumping (with your existing pump) for a longer duration. An aboveground storage tank (the larger, the better—1,000-plus gallons; 3,785 l) will allow you to store water for when the sun is not shining. A bigger pressure tank will allow for less operating time on the pressurization.

Since water pumping is discretionary, you can choose the time to pump. Do it when the batteries are full and when the sun is shining. You will need to get the increased energy from somewhere, so increase the size of your PV array (I'd say at least double it) to meet the increased water pumping demand. You should not need to increase the size of the battery or the inverter. Richard Perez • richard.perez@homepower.com

Solar Thermal Plumbing

Hi Chuck, Just a quick one for you. What kind of pipe should I use to connect my hot water tank to my solar hot water panels, which are mounted on a south-facing roof on a shed 80 feet (24 m) away from my house? I used plastic PEX (cross-linked polyethylene) tubing. But one day, the water got too hot and the compression ring connections all got loose because the plastic got soft. Not good. With its oxygen barrier, and the way it holds bends and is easy to connect, PEX is so nice to work with. But do people normally use copper? Thanks, Paul Melanson • meshach@allstream.net

Hi Paul, Yes, copper tubing is almost always used on collector loops. The collector loop fluid can easily be more than 180°F (82°C). I believe this is the maximum service temperature recommended for PEX tubing. Other options that have been used are silicone and Teflon tubing, and high-temperature hoses (radiator hose), normally with barbed fittings. I'm not surprised that this happened, and I think it might be of interest to many Home Power *readers who are considering a solar water heating system. Cheers, Chuck Marken • chuck.marken@homepower.com*

Flywheels

Can you give me any information on flywheels suitable for replacing battery systems in houses? I am the principal of an eco-village where all the houses are powered by solar electricity, using lead-acid batteries for energy storage. Flywheels could be an alternative storage medium. In the houses, we estimate 25 KWH of storage would be enough.

In the village, we reckon a 250 KWH system may be worth exploring. We also have a winter creek that over five months delivers 1 billion liters (more than 264 million gallons) over a 6-meter (20 ft.) fall from a dam spillway. Thanks for your assistance. Warwick Rowell • warwick.rowell@bigpond.com

Hi Warwick, I've been excited for a number of years about the idea *of flywheels for energy storage. But every time I get an update on the products on the market, I'm disappointed. The idle losses are too high (not to mention the cost), and the capacities are often too low. The flywheel systems I'm aware of are designed to be continuously spun using grid electricity, so they are available during short-term utility outages to supply electricity for telecomm applications. See www.beaconpower.com for one prominent manufacturer. I would love to see this technology mature into something that is useful for the renewable energy industry, but at this point, the efficiency, cost, and idle losses of lead-acid batteries look pretty good by comparison. Meanwhile, you should tap into your hydro resource! Regards, Ian Woofenden • ian.woofenden@homepower.com*

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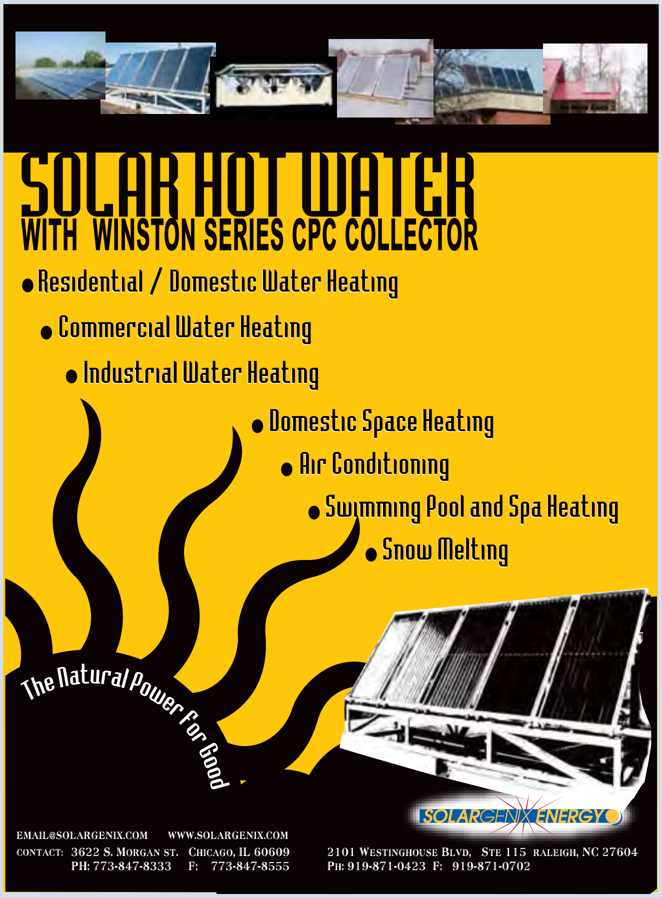

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