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Features

Photos, left to right: Tom Minczeski, istockphoto.com/ tforgo, Bill Hoffer, Randy Richmond, Current Cost, Bill Hoffer

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On the Cover

Brad Berman refuels his 2012 Nissan Leaf with renewable energy at his California home.

Photo by Tom Minczeski

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In Back

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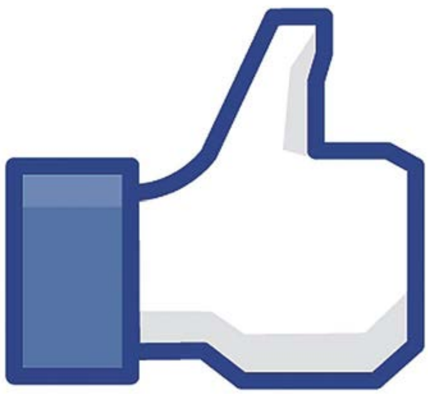
Continuing the Conversation

Although it may sound funny, in *Home Power’s* 25-year history we’ve rarely found it in the readers’ best interests to use “professional” authors. Instead, we invite experienced RE pros and readers to write our articles, passing along their knowledge to those seeking it. That’s precisely how and why the magazine was started.

But a magazine is not ideal for providing *all* of our readers with the opportunity to share their energy insights—there are only so many pages for only so many contributors, and the lag time for information sharing between contributors and readers can be large.



Home Power has long provided a range of opportunities for readers to be heard, including letters, surveys, and, more recently, social media. One challenge has been how to bridge the virtual gap between how you’re reading the magazine (whether in print or digital format) and how you can respond to what you’re reading (the HomePower.com website). That is, we’ve wanted to provide an easy method for you to continue the conversation in an open forum.

With this issue, you’ll now find a small graphic near the beginning of each feature article that includes a unique Web address. Consider this your invitation to widen each article’s scope *and value* by sharing your own experience, comments, and questions. If something stirs you to respond or dig deeper, just click on or enter that address into your browser to post your comments and engage with other *Home Power* readers, authors, and staff. You may even find your comment published in the next edition of the magazine!

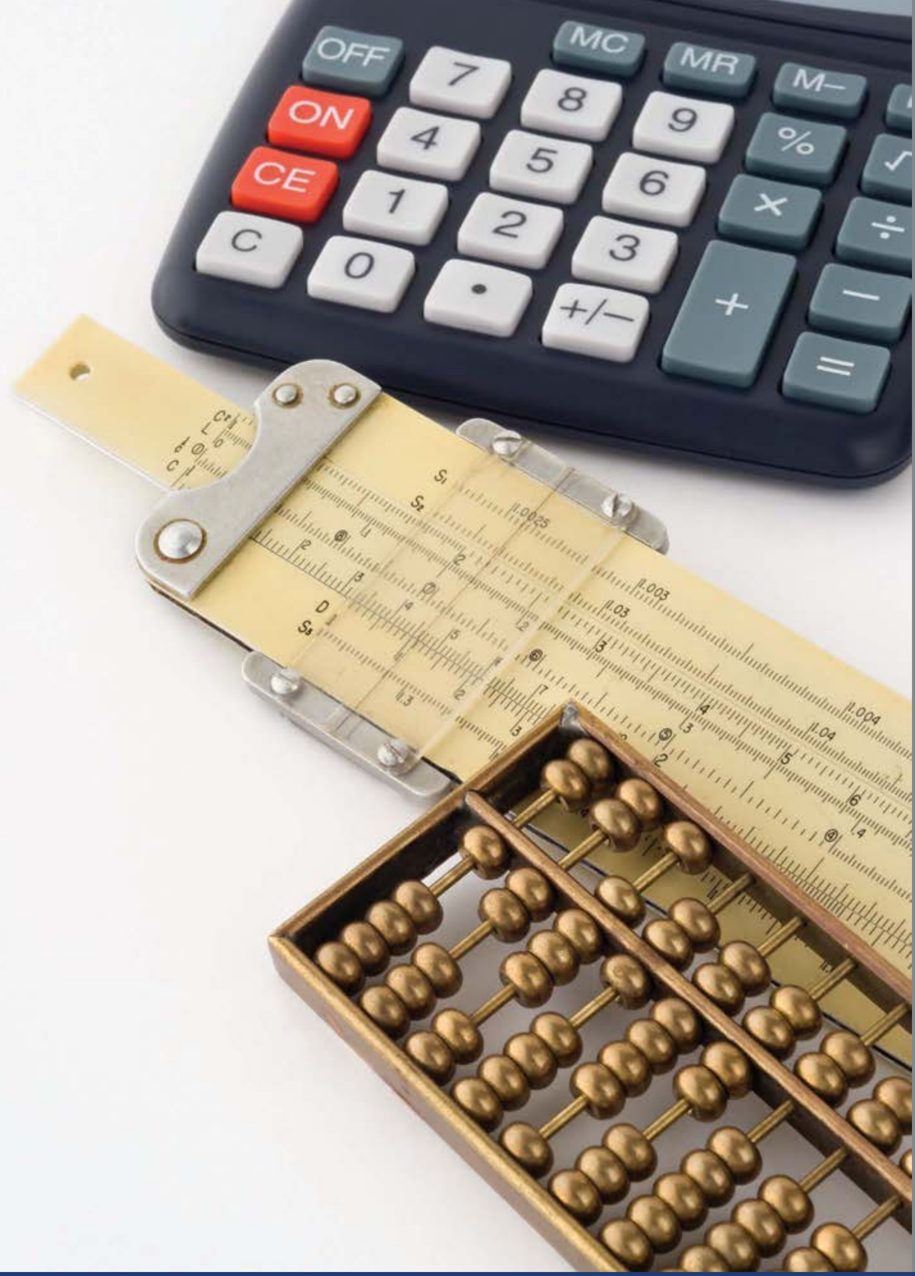
While you’re expressing your ideas, you’re also helping tailor the magazine to your tastes. These online discussions help our editorial staff spot gaps in our topical coverage and identify potential new contributors from among our learned audience. This satisfies our ultimate publishing goal of completing and repeating the knowledge-sharing loop. Follow a feature article link in this issue. We look forward to hearing from you.

—Scott Russell, for the *Home Power* crew

Think About It...

Social networks aren’t about Web sites. They’re about experiences.

—Mike DiLorenzo, NHL social media marketing director



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Mercury & Fluorescent Lights

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Although it's a necessary chemical in some industrial processes and products—including fluorescent lights—mercury is best avoided. You won't likely ever get a dose to make you "mad as a hatter" (hat makers once used mercury to make felt), but mercury pollution and poisoning are serious concerns.

Elemental mercury (Hg) enters the environment primarily from the burning of fossil fuels, especially burning coal or petroleum to make electricity. When released into the environment, bacteria in soil and water convert elemental mercury to methylmercury (CH_3Hg), which is far more toxic than the toxic-enough elemental mercury. Methylmercury concentrates as it moves up the food chain, which is why health authorities recommend limiting consumption of some foods like certain fish. Fetuses and children are especially vulnerable to methylmercury.

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Fluorescent lights, including compact fluorescent lights (CFLs), contain small amounts of elemental mercury vapor. As electrons are driven through the tube, ultraviolet (invisible) light is generated that excites the phosphor (fluorescent) coating on the tube to emit visible light. The amount of mercury in fluorescent lights has declined due to better manufacturing practices. Fluorescent tubes with green end-caps contain 3.5 to 4 milligrams of mercury rather than the typical 8 to 14 mg. Older CFLs contained about 4 mg of mercury, while new ones can have as little as 1 mg. (For perspective, older types of oral thermometers contained about 500 mg of Hg.)

New Federal Trade Commission labeling requirements for all lightbulbs require CFLs to reveal that they contain mercury and points consumers to the government's CFL gateway web page: epa.gov/cfl. When their useful life is over, fluorescent lightbulbs need to be properly recycled. In fact, many jurisdictions *require* recycling instead of discarding them.

Energy Star says that "even though CFLs contain a small amount of mercury that could ultimately end up in the environment, that amount is significantly less than the amount of mercury avoided as a result of energy savings." But what about the risk of mercury exposure in the home due to a broken fluorescent lightbulb or tube? While the risk of breakage is very low, accidents happen. To minimize breakage risk, make sure the bulb is cool before you remove it and twist from the base, not the bulb. Also, don't overtighten when installing.

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"Even though CFLs contain a small amount of mercury that could ultimately end up in the environment, that amount is significantly less than the amount of mercury avoided as a result of energy savings."

In 2007, the Maine Department of Environmental Protection measured mercury contamination from broken CFLs under various ventilation and cleanup strategies. Their worst-case scenario—designed to put the most mercury vapor in the air—resulted in an initial increase that exceeded the Occupational Safety and Health Administration permissible exposure level of 0.1 mg per cubic meter, spiking at 1 foot above the floor level. At 5 feet above the floor, it was only 18% of that amount (about where a standing adult breathes). After one hour, the concentration at the 1-foot level was about one-fifth of the spike.

However, most of the mercury in a broken CFL is not released in vapor form, but remains attached to the broken components and phosphor powder. If the bulb is broken, the vapor released into the surrounding air is between 0.001% and 0.007% of the total amount of mercury in the bulb. If you break a CFL in your home, don't panic, but do take precautions (see sidebar).

Of course, you can eschew mercury in your lighting altogether by switching to LEDs, which contain no mercury, last far longer, and are coming down in price and going up in quality. Also mercury-free is the Vu1, with its electron-stimulated luminescence technology. Either option is more expensive initially than a CFL or an incandescent (which are increasingly not an option), but will result in a good energy savings payback.

—Andy Kerr

CFL Cleanup

Before Cleanup

- Vacate people and pets from the room.
- If you have central forced air heating/air-conditioning system, shut it off.
- Air out the room for five to 10 minutes by opening a window or door to the outdoors.
- Collect materials needed to clean up the broken bulb:

  –Stiff paper or cardboard

  –Sticky tape

  –Damp paper towels or disposable wet wipes (for hard surfaces)

  –A glass jar with a metal lid or a sealable plastic bag

During Cleanup

- Use disposable gloves.
- Do not vacuum, which could spread mercury-containing powder or mercury vapor. Vacuuming is not recommended unless broken glass remains after all other cleanup steps have been taken.
- Be thorough in collecting broken glass and visible powder.
- Place cleanup materials in a sealable container.

After Cleanup

- Promptly place all bulb debris and cleanup materials, including vacuum cleaner bags, in an outdoor trash container or protected area until materials can be disposed of. Avoid leaving any bulb fragments or cleanup materials indoors.
- Next, check with your local government about disposal requirements in your area. Some localities require fluorescent bulbs (broken or unbroken) to be taken to a local recycling center. If there is no such requirement in your area, dispose of the materials with your household trash.
- If practical, continue to air out the room where the bulb was broken and leave the heating/air conditioning system off for several hours.

For more info

Environmental Protection Agency **bit.ly/CFLcleanup**.
Locate fluorescent and other recycling centers and drop-off points at **bit.ly/CFLrecycle**.

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Golden Gate Green

Electric vehicle drivers can recharge their cars—for free—at The Crissy Field Center's car charging stations.

Part of the Golden Gate National Recreation Area, San Francisco's Crissy Field is situated directly beneath the majestic Golden Gate Bridge. The urban park's shoreline promenade, sand dunes, and long grassy field are ideal vantage points to gaze at clouds sweeping in from the Pacific, across Marin's mountains, and past the landmark bridge. As of February 2012, the park has become a destination for EV drivers to recharge their cars while they enjoy the picnic sites, hiking and jogging trails, wind surfing, and wildlife viewing.

Powered in part by solar-generated electricity (with minimal contributions from three small vertical-axis wind turbines), and completely free to EV drivers, the Crissy Field charging station started with a spark of an idea from Adopt a Charger (AaC), a nonprofit created to provide free, accessible car charging in prominent locations. "If you look at a map of where EV charging has been placed, it wasn't serving the most attractive and interesting places for EV drivers to go," says Marc Geller, vice president of AaC.

Location, Location, Location

Most public charging stations have logically been placed near municipal buildings, in underground parking garages, and at shopping malls. But at this early stage of the electric car movement, says Geller, half the value of public charging is educational—to demonstrate EV charging locations being utilized by the public. Geller and his colleagues had been searching for a showcase spot to put its first sponsored charging station. The group provides expert advice and raises the funds—commonly between $15,000 and $20,000—to cover the costs of equipment, installation, and the three years' worth of electricity for car charging. "The national parks are an obvious place," says Geller.

A 28 kW PV system helps offset electricity use at The Crissy Field Center, an urban environmental education center.

Courtesy Bradley Berman (2)

AaC approached Laura Castellini, sustainability coordinator for the Golden Gate National Recreational Area, which encompasses places like Muir Woods, Alcatraz and the San Francisco Presidio, as well as nearly 60 miles of bay and ocean shoreline. "When Marc first came to me in spring 2011, it was an exciting idea to install

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Courtesy Bradley Berman

The Crissy Field EV charging project was a collaborative effort. The primary players included (from left to right): Neal Desai, associated director of the National Parks Conservation Association; Laura Castellini, sustainability coordinator for the Golden Gate National Recreational Area; August Goers, co-owner and vice president of engineering at Luminalt; and Marc Geller, vice president of Adopt a Charger.

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a free public EV charging station," says Castellini. "We had been talking about electric cars for our own fleet. And it just so happened that, at the time, the Crissy Field Center was working to install wind turbines."

The Center—a partnership of the Golden Gate National Parks Conservancy, National Park Service, and Presidio Trust—is a 7,500-square-foot urban environmental education facility that showcases recycled and reclaimed materials, solar water heating, natural lighting, and a rain catchment system. The buildings also had a 28-kilowatt grid-tied photovoltaic system and five vertical-axis wind turbines.

Timing Is Everything

Soon after Geller presented the idea of EV charging to Castellini, she received a fortuitous visit from Neal Desai, associated director of the National Parks Conservation Association (NPCA). NPCA had been working on a four-year project with the national parks that included a nearby display about rising sea levels, another one about global warming at Alcatraz, and a climate change brochure for the parks. "Neal mentioned that the conservation association had some funds left over from a previous project," says Castellini. "I put two and two together."

"National parks are perhaps the best place in the country to educate visitors. They can see the beauty of the places they're trying to protect," says Desai. "In this case, it was teaching them about clean technology. It's great for what it does for allowing pubic charging, but it's also a great demonstration."

August Goers, co-owner and vice president of engineering at Luminalt, a San Francisco-based RE installer, also recognized the educational power of the idea. The 28 kW PV system is the out-of-sight "silent workhorse" of the facility, according to Goers, but the 30-foot whirring windmills and EV charging stations are front and center.

However, wind guru Paul Gipe believes that the vertical-axis wind generators at Crissy Field are little more than architectural elements—calling them "kinetic sculpture"—and that their energy output is "severely overrated." It is well-accepted in the wind industry that turbine towers must be tall in order to take good advantage of whatever wind resource is available. *Home Power* wind editor Ian Woofenden also has his doubts about VAWTs. "Perhaps some day we'll see a successful VAWT in the marketplace for more than a matter of years. Perhaps we'll see one that is durable and productive. I remain open to this possibility, but remain guarded about the claims." (See "VAWTs & HAWTs" in *HP143*.)

Return On Investment, Multiplied

The final piece of the project is the completion of a Web-accessible monitoring system that tracks on-site energy generation "You will be able to see a chart of the combined output of the turbines, each turbine individually, as well as wind speed, temperature, irradiance, and solar output," says Goers, "and how much energy is being used by the electric cars. The project will answer questions about how effective solar is in foggy San Francisco, and which of the types of vertical-axis wind turbines produce the most energy under various wind conditions."

Since the Crissy Field EV chargers were installed, the Golden Gate National Recreational Area has added two Nissan Leaf electric cars to its fleet as part of a federal pilot project. Castellini says that five more will soon be added via the Department of Energy's Clean Cities program.

"We're exposing renewable energy technology and electric cars to people who may otherwise have never seen them," she says. "It's accomplishing the purpose we set out, to create a snowball effect and to create positive change."

—Bradley Berman

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Silicon Energy
Cascade PV Module


Courtesy Silicon Energy

Silicon Energy (silicon-energy.com) has released its next-generation Cascade PV module. Like its predecessor, this module has a glass-on-glass construction, which allows about 10% of the light to pass through, making the modules useful for building projects such as awnings and carports. The Cascade modules have an integrated mounting structure with an enclosed wire raceway, and a frameless design to easily shed water, dirt, and snow. The new modules are about 3 pounds lighter than their predecessors, and the mounting system requires one-third fewer roof penetrations. Other enhancements include an antireflective coating on the front glass and high-current Amphenol connectors.

Because the manufacturer is based in Marysville, Washington, Silicon Energy modules qualify for higher in-state incentive payments through the Renewable Energy Cost Recovery Incentive Payment program.

—Justine Sanchez

Helios Solar Works

SolSimple AC PV Module

Courtesy Helios Solar Works (2)

Helios Solar Works (heliossolarworks.com) offers its SolSimple AC module with a factory-integrated Exeltech microinverter (and no exposed DC wiring). These 60-cell monocrystalline modules are rated at a maximum of 216 watts at 120 VAC. The CEC inverter efficiency is 94.5%. These modules, manufactured in Milwaukee, Wisconsin, can be specified to be 100% "made in the USA," and come with a 25-year performance and a 10-year workmanship warranty.

Module-level monitoring is available via the HelioSentry data interface. One HelioSentry can accommodate up to 20 modules. Options include the ability to collect additional data, such as irradiance, temperature (module and ambient), and household electricity consumption, from supplementary sensors.

—Justine Sanchez

Report Card on State RE Policies

If you are an RE enthusiast who lives in California, Delaware, Maryland, Massachusetts or Utah, consider yourself lucky. These states received A's for excellence in both net-metering and interconnection policies in the 2012 edition of *Freeing the Grid*.

The report—produced by Interstate Renewable Energy Council and Vote Solar Initiative (VSI) in partnership with the North Carolina Solar Center—grades all 50 states on the effectiveness of their net-metering and interconnection practices in promoting rooftop solar and small-scale renewable energy technologies. While each state regulates the process under which a consumer can plug into the grid, interconnection rules vary. In some places, net metering is still not available.

"We saw improvement in many states that were already leading our nation's solar market," says Adam Browning, executive director of VSI. "Once they got a taste of what solar power can do, they decided they wanted more. *Freeing the Grid* provides a roadmap for all 50 states to be able to do the same."

In its sixth year, the report is available in an interactive version that allows you to monitor your state's progress toward improving their net metering and interconnection practices. Find the full report and articles about best and worst practices in RE policies (and see how your state measures up) at freeingthegrid.org.

—Kelly Davidson

Making the Grade

Net Metering: The District of Columbia, Minnesota, and New York improved their grades since 2011. Net-metering best practices have evolved to include virtual net metering, meter aggregation, and other innovative community-shared models. New Jersey and Maryland added a bonus point to their already-stellar A's in net metering for allowing meter aggregation. While California as a whole shines for its practices, the report awards a "worst practice" to one of the state's major utilities, San Diego Gas & Electric (SDG&E), for its proposal of a network use charge (NUC), since it could have had a negative impact on the otherwise thriving local rooftop solar market. The California Public Utilities Commission rejected the NUC proposal in January 2012.

Interconnection Procedures: Eight states received A's this year, a significant improvement from five in 2011 and none in 2007. Hawaii leapt from an F to a B for interconnection: In November 2011, the state adopted simplified interconnection rules for small renewable systems that streamline the previously arduous review process.

Net Metering

Interconnection

Courtesy freeingthegrid.org (2)

Extreme Conditions Demand Quick Mount PV

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Helps Light the Night

While visiting Namibia on a consulting job for the World Wildlife Fund, attorney Doug Vilsack recognized the need for renewable-powered lighting, especially in the rural areas, where most households have no access to the grid and must burn candles, kerosene, or wood for light. It was only after a law school acquaintance gave him a BoGo (Buy one, Give one) solar flashlight that he realized what he could do to help.

He collected $10 donations from his Facebook friends, and quickly raised enough money to buy 50 BoGo flashlights. On his next consulting trip to Namibia, he distributed the BoGos to game rangers, who used the lights to startle and scare away crop-destroying elephants that, in a few hours, can decimate a family's entire year's food supply.

Inspired by the rangers' success stories, Vilsack wanted to do more and launched Elephant Energy (EE), a nonprofit whose mission is: "Light in every home, clean air in every kitchen, power in every hand."

ELEPHANT ENERGY

Elephant Energy founder Doug Vilsack (far right), with friends in Namibia.

Courtesy Elephant Energy

"I pushed forward because of the clear impact that these lights had on people's lives," says Vilsack. "Plus, the economics made sense—people spend $5 to $6 each month on kerosene and could reinvest these funds in solar technologies."

Under Vilsack's direction, EE is establishing a network for distributing renewable energy products to rural areas throughout Namibia. Vilsack and a small team of volunteers travel from village to village to sell the products to rural shop owners and entrepreneurs.

EE then acts as the supplier, providing the goods at wholesale prices that allow shop owners to sell the lights at fair prices and still earn a good profit. If necessary, EE will subsidize or provide financing for the first batch of products—after that, shop owners must reinvest their profits to replenish and grow their inventory.

"Subsidizing is not sustainable—for our organization or for the Namibian people," Vilsack says. "We are there as an incubator for the first push of these products."

Early on, seed money for projects came largely from social funding campaigns, but the nonprofit group adopted a unique "for-profit mentality" to ensure its staying power. "We did not want our longevity as an organization to be at the mercy of grants and donations. Instead, we take a market-based approach and derive our funding from retail sales. That gives us a sustainable income to continue helping people," says Katie Murphy, the group's Africa program director. "Our goal is to be unnecessary in this equation."

After gauging the response to the initial batch of solar flashlights over several months, EE raised the funds to distribute and market lights to nearly 1,000 households in two conservancies (a bounded area of communal land governed by its members). Sobbe

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Conservancy purchased flashlights at a subsidized price and distributed them to members, while Wuparo Conservancy sold lights directly to its members for $7—the amount a family would normally spend on candles each month.

The solar flashlights spurred local interest in other solar-powered products, driving EE to open a shop in Katima Mulilo, the capital of the Caprivi Strip. In the first two months, the shop sold more than 250 items.

The products—hand-crank radios, solar-powered lights, and cell phone chargers, ranging in price from $10 to $60—are supplied by companies based in the United States, United Kingdom, and Australia, but manufactured in China. "I'm often asked why we aren't teaching the people how to make the products locally. The reality is that, if we built them in Africa, they'd be four times more expensive and no one could afford them," Vilsack says.

To extend its reach and keep costs down, EE also relies on existing distribution channels—including a network of 26 rural bike shops established by Bicycles for Humanity (bicycles-for-humanity.org). In addition, EE provides products through eight energy shops established by the Namibian government and the Polytechnic University of Namibia.

This year, EE quadrupled its sales, distributing 2,000-plus items to an estimated 10,000 users (about one product per household with an average of five people), creating upwards of $3,500 in revenue. Bulk sales have increased as well, including the sale of 240 solar-powered lights to World Wildlife Fund game rangers.

Eagle Energy

Closer to home, Doug Vilsack is providing solar lights to the Navajo Nation in New Mexico, Arizona, and Utah. Dubbed Eagle Energy by the Najavo, EE is working to bring renewable energy options to rural Navajo families—many of which do not have access to the electricity grid, and still rely on wood and kerosene. To learn more, visit **elephantenergy.org**.

Despite such impressive strides, EE is still a long way from making its exit. The primary obstacle is geography, according to Tim Weiss, a volunteer with EE in Namibia. "Most of the people we serve get their income in a variety of ways and at very inconsistent times," Weiss says. "This volatility in their income requires us to develop creative, flexible financing solutions, or have products available at the exact right time and place, which means we must go to the customer. This is very challenging because of how remote these villages are and how far apart they are from each other."

"Affordable small-scale solar technology is a perfect fit for many of these people because it fills their fundamental energy needs while actually saving them money," he adds. "When I travel through rural villages at night and see people either using candles, kerosene, or just living in darkness, it motivates me—all people should have access to light that is clean, safe, affordable, and bright."

—Kelly Davidson

Courtesy Elephant Energy

RESIDENTIAL SOLUTIONS
1.8 TO 15KW

REAL WORLD SOLUTION:
Magnani Residence

Size: 5 kW

Installer: solarflair CLEAN ENERGY SOLUTIONS

Location: Framingham, MA

Products: PVI 5000

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– Matt Arner, President and Certified NABCEP PV Installer, SolarFlair Energy, Inc.

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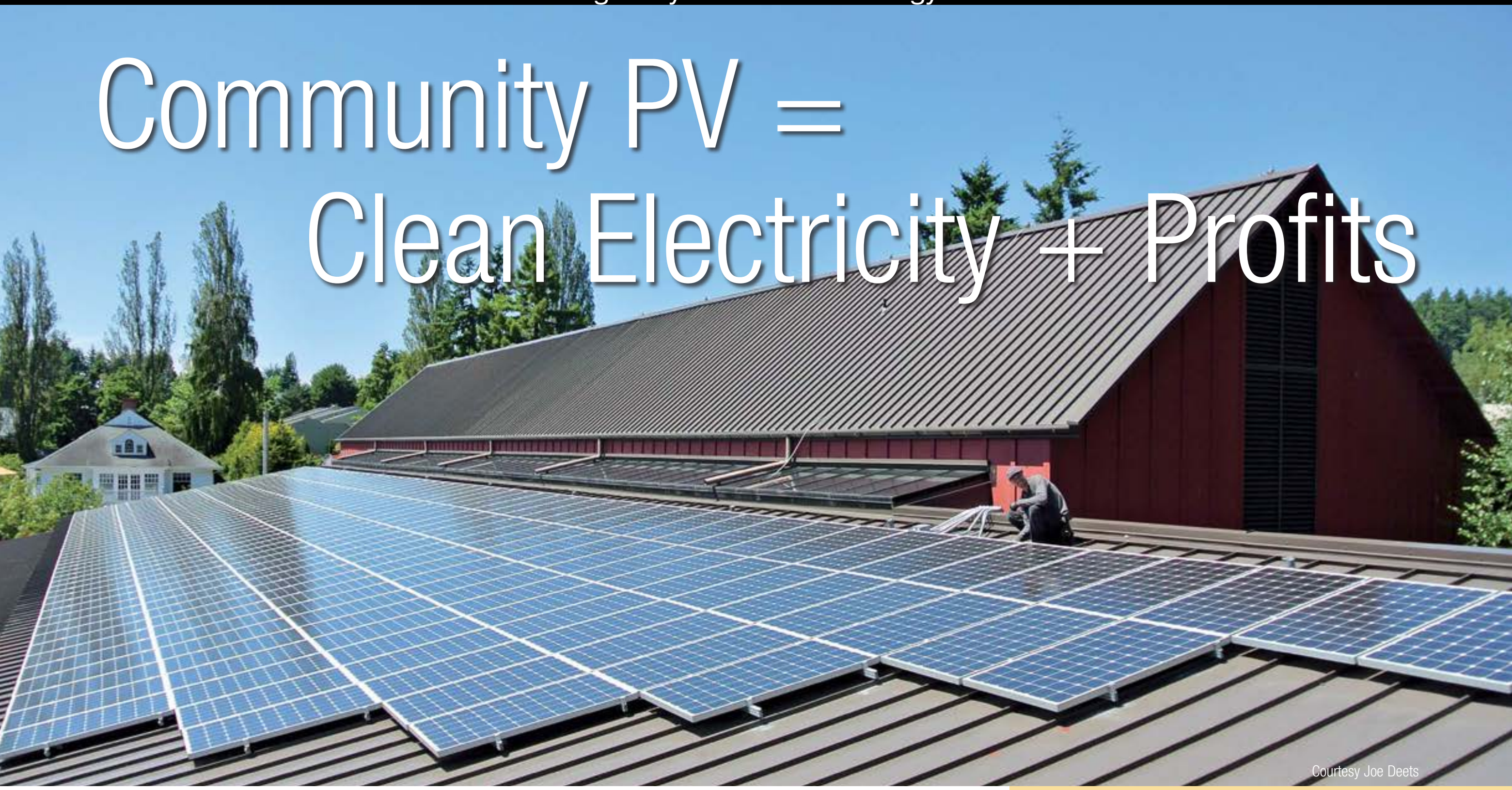

Courtesy Joe Deets

The number of modules used on the project was dependent upon the amount of funds contributed by investors. With enough investors, the roof space was fully utilized.

The city of Bainbridge Island, Washington, has long been a progressive community with its efforts to preserve green spaces and control overdevelopment. Here, you'll find solar-powered trash compactors, solar awareness campaigns sponsored by local residents, and even a net-zero neighborhood, with buildings that generate as much energy as they consume. Now, the city has another project to be proud of—a 71-kilowatt community PV installation.

The array came online in August 2012, and was seven years in the making. The idea took root at a solar energy forum at City Hall in 2005, where several attendees expressed interest in investing in solar-energy systems, but weren't able to do so on their own property.

"People were saying, 'I'd love to go solar, but my house is surrounded by trees,' or 'I'm not a homeowner,' or 'my roof is pointed the wrong way,'" says Community Solar Solutions (CSS) president Joe Deets, who was also in attendance that day. "There were all of these barriers." Then someone asked about the possibility of using the roof of city hall for a community PV project.

While the interest in the project was widespread, there were a few obstacles to overcome before planning could begin. One was challenging a Washington State law prohibiting community-based systems. "At that time, leasehold prohibitions denied community solar projects," Joe explains. "Putting solar somewhere other than on your property—and getting compensated for the energy it produced—was not allowed."

However, state Senator Phil Rockefeller was also in attendance at the Bainbridge forum, and sat on an energy committee in the state senate. He contacted Deets about collaborating on legislation to permit for-profit community PV installations. After three legislative sessions and three years, Senator Rockefeller's bill finally passed.

Another positive outcome of the state's growing involvement in renewable energy law was the Renewable Energy Cost Recovery Incentive Payment Program. This performance-based incentive pays its largest incentive if Washington-manufactured modules and inverters are used. Combined with federal incentives, it created a profitable and secure local investment opportunity.

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Overview

Project name: Bainbridge Island City Hall Community Solar Project

System type: Batteryless grid-tied PV

Installer: Sunergy Systems

Date commissioned: August 2012

City: Bainbridge Island

Latitude: 47.7°

Average daily peak sun-hours: 3.83

System capacity: 71.3 STC kW

Average annual production: 69,000 kWh

Average annual utility bill offset: 18%

Equipment Specifications

PV modules: 297, Itek Energy IT240, 240 W ea.

Inverters: 30 Itek (Exeltech) XLGT1800, 1.8 kW

Array installation: S-5! attachments, Sunmodo racks on south-facing standing-seam metal roof

Array azimuth: 180°

Tilt: 10°

Courtesy Brian Pettepiece

To qualify for the state's highest production incentive, both the modules and inverters had to be made in-state. Since no commercial-sized inverter manufacturers are Washington-based, smaller string inverters assembled at a Washington manufacturer (Itek Energy) were used.

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Kathleen O'Brien hadn't been able to install a PV system at her property due to shading issues, but this project gave her the opportunity to directly participate in—and profit from—a renewable energy project. "This particular approach makes it accessible for people who normally wouldn't invest," Kathleen says. She already had a personal interest in solar, but when she saw the investment return numbers, it was an even easier decision.

In the end, the project attracted 25 investors. The investment levels ranged from $7,000 to $28,000 with the rate of return for each investor dependent upon their initial investment. Any excess energy produced by the array is monitored by the utility. Under the city's lease agreement, a check is then issued to CSS from the utility. But the lion's share of the investor's dividend comes from the federal and state tax incentives. Instead of the utility writing a check to the state for taxes, a check is instead written to CSS. CSS is tasked with distributing all dividend funds to investors. In November, the project received a U.S. Treasury grant, a federal program that allows owners of qualifying projects to receive up to 30% of the eligible project's cost. The funds from this grant were distributed directly to the investors with the amount each received dependent upon their investment level. This single grant put them well on their way to recouping their initial investment amounts.

CSS and the investor group co-own the equipment and lease the roof space from the city. That lease expires, along with the state's production incentive program, in 2020, so the project participants have to recoup their investment within that time frame. After the lease expires, the city can either purchase the array from CSS at fair market value or request that it be removed from the roof. If removal is requested, CSS and the investors would be responsible for that expense. But until then, the investors will continue to receive dividends from both the electricity production and tax incentive programs.

—Brian Pettepiece

Four Steps to Community-Based Solar

Find a host site. There may be many suitable rooftops (public or private) for a project—talk to building and property owners. Familiarize yourself with available incentives.

Network. The funding needed for the Bainbridge Island project (nearly $500,000) wouldn't have been possible without private investors.

Work out the details. The city has a Schedule 150 rate and net-metering agreement with the local utility. At the end of the year, the net is calculated and a payment is made to CSS and the investors directly from the utility, along with all the production incentives for the year.

Have patience. Expect some obstacles. Community systems don't happen overnight. Be prepared for lengthy negotiations between the involved and their attorneys before an agreement is reached.

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Sizing Equipment Grounding Conductors

In this issue's *Code Corner*, Ryan Mayfield discusses equipment-grounding conductors (EGCs) required in PV systems. Here, we show two PV system examples—a batteryless grid-tied and an off-grid system—for determining the wire gauge required for the EGCs of the DC circuits.

Batteryless Grid-Tied

Consider a 4.8 kW PV array of twenty-four 200 W modules (Voc = 57.8, Isc = 4.69). The array has three, eight-module series strings (aka the "PV source circuits") wired to a combiner box, which is integrated with the inverter and contains three series fuses each rated at 10 A. Because the combiner box is integrated, there is no "PV output" circuit wiring that needs to be sized.

NEC Table 250.122 tells us that our 10 A fuses require #14 AWG, the minimum size allowed for copper EGCs for our PV circuit (i.e., array to inverter). The PV module frames are bonded to a #6 AWG EGC per *NEC* 690.46.

Off-Grid

Let's say we have a 3.6 kW PV array of eighteen 200 W modules (Voc = 36.2, Isc = 7.67). The array has six three-module series strings wired to a combiner box containing six 15 A breakers. Again, the *NEC* table 250.122 dictates that the copper EGC for the PV source circuit be #14 AWG minimum.

Technically, the "PV output circuit" runs from the combiner box to the battery bank. But this installation uses a pre-assembled power panel that includes all required disconnect, overcurrent, and ground-fault protection between the combiner box and the battery, and thus where the "PV wiring" terminates. An 80 A breaker in the power panel protects the wiring between the combiner box and the charge controller, and thus dictates our EGC to be #8 AWG minimum between the combiner box and the power panel.

If the battery cables are routed through metallic conduit, a grounding/bonding bushing is commonly used to attach a short EGC to the ground bar in the power panel. Just like with PV circuits, the breaker protecting the wiring between the battery and the inverter (commonly rated for 125, 175, or 250 A) will dictate this EGC size, per table 250.122.

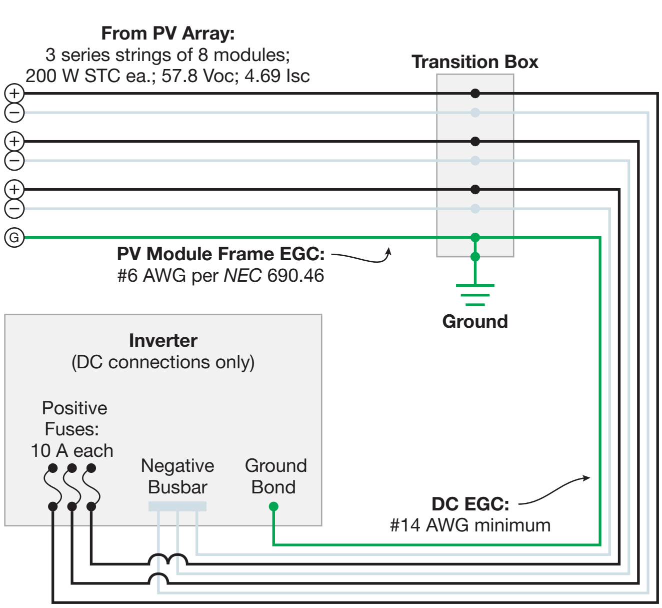
—Justine Sanchez

Minimum Size Equipment Grounding Conductors *NEC* Table 250.122

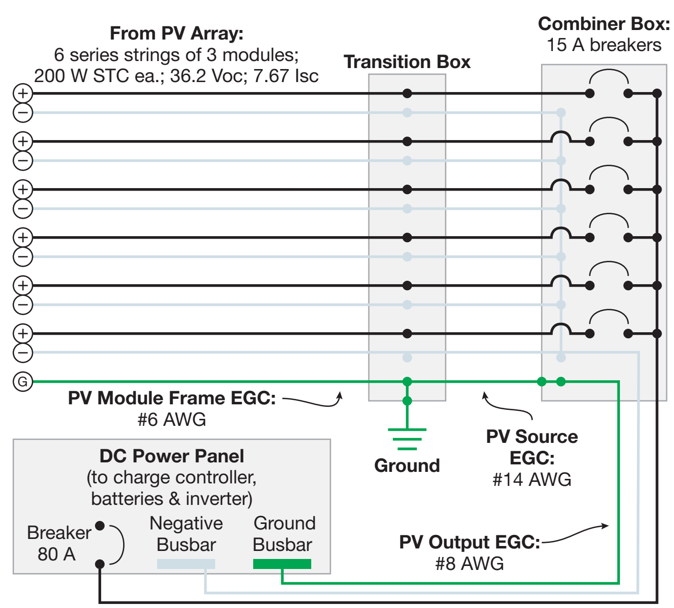
Overcurrent Rating (Amps)*	Size (AWG) Copper	Size (AWG) Aluminum or Copper-Clad Aluminum
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1

*Setting of automatic overcurrent device in circuit ahead of equipment, conduit, etc., not exceeding (amperes)

Batteryless Grid-Tied EGC Sizing



Off-Grid EGC Sizing



Micro-Solar Project

Using a 15-watt solar-electric module and four small "computer" fans, I built a simple exhaust system to keep the crawl space under my house dry. Projects that are simple, low-cost, and easy are the kind I like, and this could not be less complicated. The goal was to exchange damp, stale air with dry, fresh air. When it is dark and rainy, or damp outside at night, you don't want the fans to operate; when it is bright and sunny, you want the fans to operate, exchanging the air in the space. This is a perfect application for solar electricity.

If you have experimented with solar projects, you probably have a fair amount of "stuff" you may not be using. Better crawl space ventilation was what I needed. Using an old 12-volt, 15-watt PV module was the perfect start. It didn't put out a lot of power, so low-power fans were required. Four 12-volt DC muffin fans ($3.50 each) fit the bill. Each 4-inch-diameter, 0.1 amp fan can move about 50 cubic feet per minute. I used four fans for 200 cfm. My 1,200-square-foot house has a 3-foot-high crawl space—that's 3,600 cubic feet of air. So when the fans are running, the air exchanges every 18 minutes. Larger (120 mm) computer fans would work, but you'd need to be mindful of the total amperage—they need to be less than 0.8 A for a 15-watt module.

The 4-inch fans are mounted on two 1-by-6 boards with 4-inch holes. The two boards were then mounted inside the crawl space at the existing air inlets. I covered other air inlets and left two exhaust outlets, since you want the air to flow completely through the space.

I originally disconnected the fans in the depth of winter, since you don't want freezing air in the crawl space. What I needed to make this a perfect project was to add a thermostat. I built a Cana Kit (CK112; $25) electronic thermostat, which is also available assembled (UK112, $30). This thermostat uses only 0.1 A and has a built-in voltage regulator and a 3 A SPDT relay. I mounted the thermostat on one of the fan boards. When the temperature drops below 40°F, the fans don't operate.

I have had this in operation for about two years, and the fans and temperature control are working fine.

Roger Clery • Murfreesboro, Tennessee

Great idea, Roger. Cana Kit also has an assembly of four muffin fans with guards, already mounted on a plate, which could be attached directly to a vent screen.

Radiant Kudos

Wow! What an awesome article on hydronic heat! I wanted to know more, but didn't even know what questions to ask. Within the next four years, I will be building my house and expect to use radiant heating. This article covered a lot of the major things I was wondering if I would need to do differently to optimize a radiant floor system for solar heating. Perfect balance of explaining the basic concepts, yet providing extremely useful, specific information, such as the optimal temperature ranges. Thank you, thank you! Keep it up!

Sondra Winters • Portland, Oregon

continued on page 36

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Courtesy Michael Welch

continued from page 34

Letter & Comments from Facebook

I've set up an 18-module system, but purchased 20 PV modules to get a pallet discount. I sold one of the remaining modules to an RV owner, but the other is still sitting idle in my basement. I thought long and hard but could not come up with a good use. Due to the disadvantages of batteries, I don't think charging a battery and using the battery power is a smart solution. So my question is, what can I do with one 135-watt PV module?

Jakob Speksnijder • Glen Mills, Pennsylvania

Save that module for when you break one. In a few years, 135s will not be that easy to find. Carefully store it; it was smart to get extra.

Chip Mefford

Light your chicken coop, run some lights for your shop, add a night security light—so many things.

Brian Mather

Do you have fans in your attic? An attic gets very hot in the summer. Also, all year-round, the attic traps moist air from the bathroom that seeps up through the ceiling. Why not purchase two 12 VDC attic fans, and have the solar module power them? (I have two attic fans operated with two 20-watt modules.) Put the module to use. If one of your current 135s does break or go bad, you can replace it with this one. Don't let this potential extra energy go to waste!

Danno-Dad Allgrove

Let's see—you could power attic fans, security lights, light up the dog house, charge your zombie taser, and our favorite: supply power for your secret bunker where you store all your Home Power *magazines.*

GV2 | The Powerhouse

That's exactly what I would do! Death to zombies, LOL.

Rych Farnsworth

While tasing zombies would definitely be more fun, I'm with Chip on this one. Store the module so it's available in the future. Think down the road 10 years-—even if a module in the array happens to fail and it's covered under warranty, there's no guarantee that the manufacturer will have a replacement module with the same physical dimensions and electrical characteristics.

Joe Schwartz

Here's another idea: turn it into a community education project, like a solar fountain to take to schools. Kids make a wondrous connection between sun hitting the PV module and the work it can do.

Home Power

You could use the module to power a small water feature in your back yard.

Brian Coonrod

I'll take it to Africa to power a family's hut with light for the very first time! Life-changing experience.

Laura Jaecks

We have assorted spare old modules (even some of those original old Arcos—must be close to 50 years old now)! List of odd uses: attic fan, greenhouse fan, solar fountain, pump for 30-year-old solar hot water Sunspool system that works like a charm, power for guest house, power for camping. Have fun!

Simmons Natural Bodycare

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Solar Biodiesel

I just finished the article on "Solar-Powered Biodiesel" by Laura Mezoff Christy (*HP148*). I was quite impressed by the installation. How can one get 200 gallons of 185°F water from flat-plate collectors? I have not installed solar hot water collectors because for years I have been told that flat-plate solar collectors will not produce temperatures greater than 125°F.

I heat my house and domestic hot water in the winter with 150°F water from an outdoor wood burner. The water piping goes underground to a heat exchanger, and then to cast-iron radiators. If I could get a couple hundred gallons of 185°F or even 150°F water per day, in conjunction with the wood burner, I'd be golden.

Ed Lowe • Assonet, Massachusetts

Flat-plate collectors are easily capable of heating water above 125°F. Systems using flat-plate collectors can overheat (exceeding 180°F) if the daily use of hot water decreases or the collectors are oversized. However, the collectors are less efficient at elevated temperatures due to more heat being lost to the surrounding air. As the operating temperature of the collectors exceeds the ambient temperature, the collectors' output is diminished. Extra collectors are needed to overcome the heat loss of higher operating temperatures.

In most of the United States, a simple sizing rule used in solar-heating water is to use 1 square foot of collector per every 1.5 gallons of water to be heated. On sunny days, this configuration can heat a tank of water to between 120°F and 150°F, depending on the local groundwater temperature and, to some extent, the season. Using this simple rule, about 100 square feet of collectors are needed to heat 150 gallons of water to 125°F or so. In southwestern Colorado (and the Southwest in general), the sizing rule is 1 square foot of collector per every 2 gallons of water to be heated (so about 100 square feet of collector area will heat 200 gallons of water to 125°F). But the oil for biodiesel production needs another 60°F to meet the required 185°F. The extra six collectors are more than enough to make up for the heat lost to the ambient temperature at the elevated operating temperature.

Another factor is that oil is being heated, not water. Water has a specific heat of 1—it takes 1 Btu to heat 1 pound of water 1°F. Canola and other vegetable oils have a specific heat of about 0.45, which means it takes 0.45 Btu to heat 1 pound of oil 1°F. Additionally, the oil is only about nine-tenths as dense as water. This fact, combined with other system specifics, means that it will take about half as many Btu or, in this case, about half as many collectors, to heat the same volume of oil as it would take to heat water. Volume, temperature rise, specific heat, and density are all factors in calculating the amount of heat needed to raise a given liquid to a certain temperature. It is not surprising that the nine collectors are presently supplying enough heat for 100% of the almost 200 gallons of oil per day production. The 270 square feet of collector surface area may be adequate to keep up with their future requirements.

Chuck Marken • *Home Power* solar heating editor

The standard, cast-iron radiators that you are using with your wood boiler system are designed for high temperatures, like steam-heat. You might be able to use lower-temperature solar hot water by switching to radiators designed for lower temperature operation. See "Renewable Hydronic Heating" in *HP152* for more details.

The *Home Power* Crew


Solar-Powered BIODIESEL

This facility in Colorado uses solar thermal to heat canola oil for biodiesel, which is used in the county's road maintenance machinery.

by Laura Mezoff Christy
photos by Laura Mezoff Christy/Luke Christy

The remote and tiny enclave of Mesita, at the southern edge of Colorado's San Luis Valley, is not the sort of place where you'd expect to find a pioneering renewable energy facility. But at the edge of this isolated outpost sits Costilla County Biodiesel (CCBD), producing biodiesel from local crops—while part of the plant's energy is produced with sunshine.

CCBD is unique not only because of its remote location, but also because it is one of the few medium-scale biodiesel production facilities in the country. In 2010, my company, Solar Gain Services (SGS), designed and installed a solar thermal system to help the plant reduce its reliance on utility electricity—thus using renewable energy to power the production of a renewable fuel.

Raising Renewables

CCBD was conceived in 2001 by County Commissioner Joe Gallegos, who was looking for ways to create local economic development. Gallegos recognized that he needed to build upon the only strong private industry in the county: agriculture. He searched for a way to add value to local crops, and also studied whether this could be combined with the burgeoning growth of the RE industry. A feasibility study brought the idea of a biodiesel plant to the forefront—the county government consumes roughly 100,000 gallons of diesel annually to maintain its nearly 3,500 miles of roads. Though canola wasn't being grown locally at the time, a study showed that the crop was ideally suited to southern Colorado's climate, and was similar to seed crops that farmers were already accustomed to growing. Additionally, Gallegos discovered that the biodiesel process would churn out a nutritious by-product that could be sold to local ranchers for livestock feed.

In 2004, Project Manager Ben Doon procured a $150,000 USDA Rural Development grant to purchase equipment. Costilla County erected the building, and production began in 2006 with basic equipment.

"It was definitely *not* a turnkey facility," says Doon. "A lot of our small-scale production equipment was gathered from around the globe, where similar facilities exist. The equipment was procured piecemeal, and we had to figure out how it worked, often making modifications. Slowly, we tied all the equipment together to create a semi-automated production line. But in the beginning, everything was run by

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These nine collectors provide ample heating for biodiesel processing at this Colorado-based plant.

The Dankoff Solar Force piston pump.

Shallow-Well Pump

The recent drought conditions in Eastern Ontario, Canada, are forcing my well pump to work overtime, which overloads my four 6 V batteries (550 Ah), wired for 24 volts. Normally, my water supply for this off-grid country home is supplied by an artesian well that flows by gravity to the cabin. That well is running too low due to the drought, and I am forced to pump from our lake. This pump is a standard 3/4 hp shallow well pump. The lift is about 22 feet and the run is 80 feet.

If the pump runs five to six times at night, the battery system is deeply discharged. What pumps could you suggest that would alleviate this problem?

Tom Windle • via email

A well pump that runs five or six times per night seems excessive for a single home. Motor-starting surges are wasteful and hard on your batteries. I recommend you use a 40-gallon pressure tank (or larger) to reduce the pump start-ups. If your tank is that big, test its pre-charge air pressure to make sure that it is set properly. Only then will it store all the water it can between pump cycles (one-third of the tank's volume). It's OK to add a second pressure tank, and they need not match in size. A modern "captive air" tank is always best. You will recognize it by the tire-type air fitting on top.

But before you change anything, check the system performance as-is. Watch the pressure gauge while the pump is on. To observe its full cycle, run some water *only* until the pump turns on, and keep your eye on the gauge. The pressure should rise steadily without any sudden dip or spike until it reaches the maximum pressure—when the pump stops (the "cut-out" pressure). A dip or spike in the reading indicates improper tank pre-charge. If the pressure gauge just hangs there and takes "forever" before the pump stops, that indicates a worn or inadequate pump. You can find instructions on the Internet for adjusting pressure switches and tank pre-charge—it's easy if you're handy. For professional help, I recommend hiring a pump technician, since most plumbers are not trained to service pump systems.

You also might consider reducing your water pressure. Do you need to open any of your faucets to the max to get the flow you desire? If not, reducing the water pressure may satisfy your needs and will save energy. I have reduced some pumps' daily run time by as much as half this way! To reduce the pressure setting, loosen the larger of the two adjustment nuts in the pressure switch, let water out until the pump starts, then observe the reduction of cut-out pressure. When you're satisfied, reduce the tank pre-charge per normal instructions (with water at zero pressure) to minimize cycling.

On to pump alternatives: I assume you have a standard AC shallow-well jet-pump. The efficiency of those pumps is quite low, and the waste is compounded by a typical 10% inverter loss. A more efficient approach would be to use a 24 VDC shallow well pump that is made specifically for off-grid applications. Such pumps use about 40% of the energy used by a standard jet pump and inverter.

Two classic DC pumps are the Flowlight Booster Pump and the Solar Force Piston Pump by Dankoff Solar Pumps (dankoffsolarpumps.com). (Although I am recommending products from my old company, I no longer have any commercial interest in it.) A low-voltage pump requires larger wire than you would normally use. If it is difficult to run new wiring, you can get an AC version (using about 50% of the energy of your jet pump, with a much reduced starting surge). Another possibility is to use a DC/AC high-efficiency submersible pump. The Grundfos SQFlex pumps are efficient and have a soft-start motor that eliminates the starting surge (grundfos.com). A submersible will never freeze and does not need priming.

In conclusion, if your present system is not performing properly, make any adjustments, repair, or improvements that seem economical. If your water use is low, that may solve your problem. The greater your water consumption, the more economical it will be to get a more efficient pump, especially considering your northern climate and the modest size of your battery bank. I suggest you contact an experienced supplier of off-grid solar power and water systems to help you decide.

Windy Dankoff • Founder (retired), Dankoff Solar Pumps

Voltage Drop

Is there a different voltage drop calculation for direct current (DC) as opposed to alternating current (AC)? I have a project that will take my solar-electric module string wires about 300 to 400 feet, carrying 9 amps at 480 volts DC. What size of wire do you recommend, and how do I calculate that?

Rance Macdonald • Denver, Colorado

There is not a different calculation for AC versus DC voltage drop. Voltage drop is a function of voltage (regardless of DC or AC), amperage, distance, and the resistance of the wire.

This equation calculates voltage drop by percentage:

$$\%\ \text{voltage drop} = \frac{\dfrac{2 \times \text{distance} \times \text{amps}}{1{,}000\ \text{ft.}} \times \dfrac{\text{Ohms}}{1{,}000\ \text{ft.}^*}}{\text{volts}} \times 100\%$$

*This can also be written: 1 Kft., which equals 1,000 ft.

By rearranging the voltage drop equation, you can solve for a specific ohms/Kft. value. Then, you can use the *National Electrical Code (NEC)* Chapter 9, Table 8, to find the wire size having an ohm/Kft. value that does not exceed the calculated ohms/Kft. value.

$$(\text{Ohms/Kft.}) = \frac{\%\ \text{Vdrop} \times \text{volts} \times 5}{\text{amps} \times \text{feet}}$$

Resistance Table for Stranded Uncoated Copper Wire

Size (AWG)	Ohms/KFt.
14	3.14
12	1.98
10	1.24
8	0.778
6	0.491
4	0.308

Let's say you are aiming for a maximum voltage drop of 2%. Assuming 480 V, 9 A, and 400 ft., you have:

$$\text{Ohms/Kft.} = \frac{2 \times 480 \times 5}{9 \times 400} = 1.33$$

On the *NEC* table, we find that #10 AWG stranded (uncoated) copper yields 1.24 Ohms/Kft., less than 1.33. This means we can use #10 AWG or larger diameter wire and not exceed a 2% voltage drop.

Justine Sanchez • *Home Power* technical editor

Ham Radio Interference

I was recently asked by a local ham radio club to speak about renewable energy, since I have designed and built several RE systems, both for myself and for others. This group is especially curious about how much radio frequency interference (RFI) there is with components of a solar-electric system, especially inverters.

John Faughn • KD0CAC

I'm a ham (KC2FSW) and host a two-meter repeater (147.045, with the same call letters) that is powered by a 150-watt off-grid PV system. Early on, the first issue I had was interference from a pulse-width-modulation (PWM) type charge controller. We were not able to run that controller in PWM mode, due to a high level of RFI. I changed repeater radios around that time and the controller did not affect the new radio. Unfortunately, the new radio had a tendency to burn out controllers—four of them, all different types from various manufacturers. From what we could gather, it was stray radio frequency (RF) coming in from the repeater antenna via the solar-electric modules that was burning out the charge controller front ends. Bob Gudgel, a fellow ham (and electronics designer) from MidNite Solar, sent me a Classic controller to see if we could blow that up, but it's still running after three years—and there have been no RFI issues with this controller.

As for inverter RFI, some are worse than others. The OutBack inverters tend to interfere at the lower HF frequencies, but rarely on the two-meter or higher bands. The interference from inverters on the AM broadcast band is legendary in the RE business. Feedback from other hams suggests that torite cores on the inverter and radio DC cables work well. They need to be large enough to fit around both the negative and positive conductors. These can be found at electronics supply houses. Capacitors are also used to filter out RFI.

Snap-around ferrite bead.

The best defense against RFI is distance—the farther your radio is from the inverter, the better!

Our county's emergency management office and the National Weather Service both love my repeater because it never goes down in an outage. This repeater has seen frequent use over the past 10 years by these agencies to pass weather, health, and welfare traffic. 73!

Roy Butler • Four Winds Renewable Energy, Arkport, New York

Saving Oil

Can you recommend an efficient electric heater that could pump out some real heat *and* be run off energy generated by an off-grid (battery-based) solar-electric system? I'm looking for a system to supplement traditional oil heat in my home—anything to keep the fuel oil bills down.

Michael Drombell • via email

While heat from the sun is a fine idea, the losses and costs associated with converting sunlight to electricity, storing the electricity in batteries, and then converting it to heat are prohibitive. As there are fewer sun-hours in the winter, the battery bank (not to mention the PV array) would likely be as big as a house to provide space heating.

Home Heating Costs

Heater Type	Fuel Type	Efficiency or COP	Fuel Cost	Operating Cost per Million Btu
Hydronic Heat Boiler	Heating Oil	83%	$3.50 per gal.	$31.03
Pellet Heater	Wood Pellets	80%	250.00 per ton	18.94
Air-Source Heat Pump	Electricity	2.25	0.15 per kWh	19.94
Ground-Source Heat Pump	Electricity	3.00	0.15 per kWh	14.95
Central Furnace	Natural Gas	90%	1.25 per therm	14.17

Source: buildinggreen.com/calc/fuel_cost.cfm

Have you insulated everywhere you can? Have you sealed all the air leaks? Have you invested in highly efficient windows and doors? (A $1,500 federal tax credit can help offset these costs). Many jurisdictions or energy companies offer energy audits—and they are often free. Even if they aren't, they are worth the cost..

After you've reduced your demand for heat, look for a new source of heat. While the fuel cost of solar energy (be it solar electricity, solar hot water or heated air) is zero, capturing solar energy requires systems that cost money. Given the high cost of oil heat, such investments may pencil out financially.

If your hot water also comes from the oil-fired boiler, consider installing a solar hot water system (incentives vary by state and utility, but can be very generous). It also may make sense (not to mention cents) to remodel your dwelling to incorporate passive solar.

If you absolutely must continue with oil, newer oil heaters are more efficient than older units. But they aren't as efficient as the best natural gas and propane furnaces (98%).

To systematically evaluate your options, I highly recommend two books: Alex Green's *Your Green Home* and the American Council for an Energy Efficient Economy's (aceee.org/consumer) *Consumer Guide to Home Energy*.

Andy Kerr • *Home Power* contributor

Heat Pump in Garage?

In colder climates, could an air-source heat pump be put in an attached (insulated, but not heated) garage as a way to improve its operating efficiency?

James Carrow • via email

Air-source heat pumps (ASHPs) work by extracting heat from ambient air and need an ample supply to work effectively. Installing an ASHP in your garage would suck out all of the warmth from the air captured there, effectively turning that space into a freezer, colder and colder until it would be impossible for the heat pump to extract heat effectively. Installing an ASHP inside a garage can void your manufacturer's warranty and may cause permanent damage to the unit.

So while you want to avoid installing the ASHP in an enclosed space, installing one to replace an existing inefficient heating system, such as a furnace or boiler, can be a very good investment. I live in upstate New York, where many people are finding it harder to afford to heat their homes, especially with electricity, oil, or propane.

In my area, minisplit, hybrid, and geothermal heat pump systems are popular. Minisplits are the least expensive and easiest-to-install systems. A hybrid system is an air-to-air heat pump installed with

Heat-pump compressors, like the one for this minisplit unit, belong outside, not inside a home or garage.


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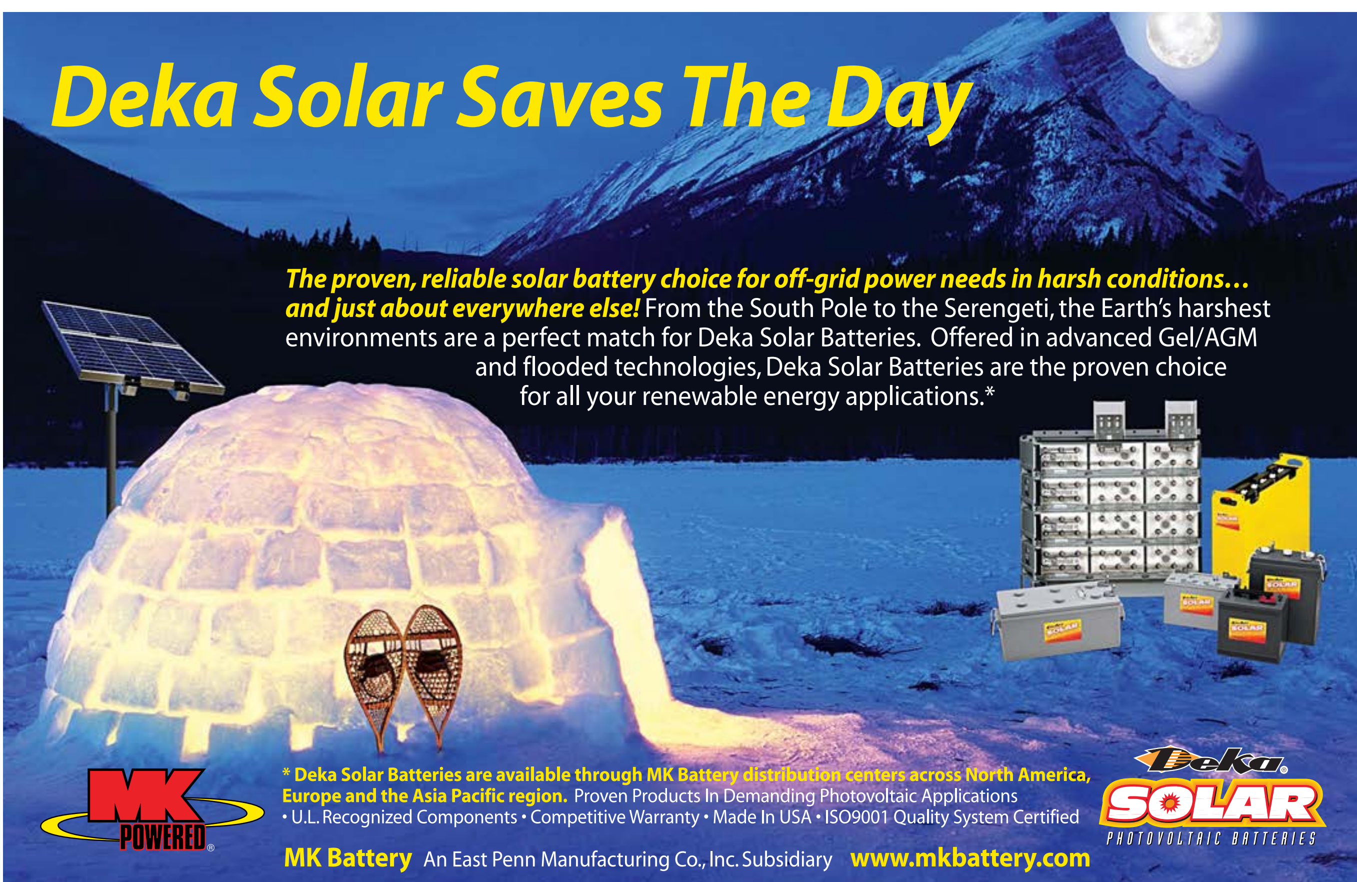
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a 92% or higher efficiency propane gas furnace. Geothermal heat pumps have the highest installed cost, but offer the greatest savings. Ground- or water-source heat pumps qualify for a federal tax credit of 30% of the installed cost.

Keep in mind that installing any heat pump is not a typical do-it-yourself project. Some manufacturers do not honor any warranty on equipment installed by homeowners or purchased on the Internet—so even though the online price may look great, you may end up paying a lot more to repair or replace equipment if it's not properly sized and installed.

If you heat with electricity, oil, or propane, you should look at heat pumps as a way to reduce your heating cost. It would be wise to make energy-efficiency improvements before upgrading your heating equipment.

Bob Zima • Certified Radiant Professionals Alliance radiant heat instructor

Grid-Tied Inverter Approval

I'm setting up a 2,600-watt grid-tied, battery-based solar-electric system (using SunPower 320-watt modules). The guy I talked to at the electric company said he was not familiar with the inverter that I'm using—an old Trace SW4024. Is there a way of getting a list or some kind of information on electric companies that have approved Trace inverters?

Martin Mladenka • via email

Electric utilities take the safety of grid-tied power systems very seriously. Any such inverter must meet UL 1741 and IEEE 1547 standards, which are intended to protect utility workers from electric shock as they repair power lines during a blackout, and also protect a homeowner's equipment and appliances from damage due to power quality fluctuations. To meet the standard, inverters must:

- Immediately disconnect from the grid if power quality falls out of specifications.
- Detect and prevent "islanding"—feeding electricity to the grid when the grid source is no longer present.
- Wait for five minutes of clean power from the grid before trying to reconnect.

In your case, it's likely that your utility simply isn't familiar with your inverter because the Trace SW series was discontinued a few years ago. The SW4024 inverter was first introduced in 1994, and thousands of them are still in use for both off-grid and grid-tied applications. The SW series has gone through many different hardware and firmware versions since then, and most of them meet UL 1741 standards.

Some utilities think UL 1741 isn't stringent enough. They may require that all grid-interactive equipment be chosen only from their list of approved models, which may also specify only certain model years or firmware updates. In other cases, it is the state utility commissions that determine allowable equipment. Unfortunately, I don't know of any master database of inverters approved by different utilities,

A Trace SW inverter.

though many provide that information on their websites or will mail it to you upon request.

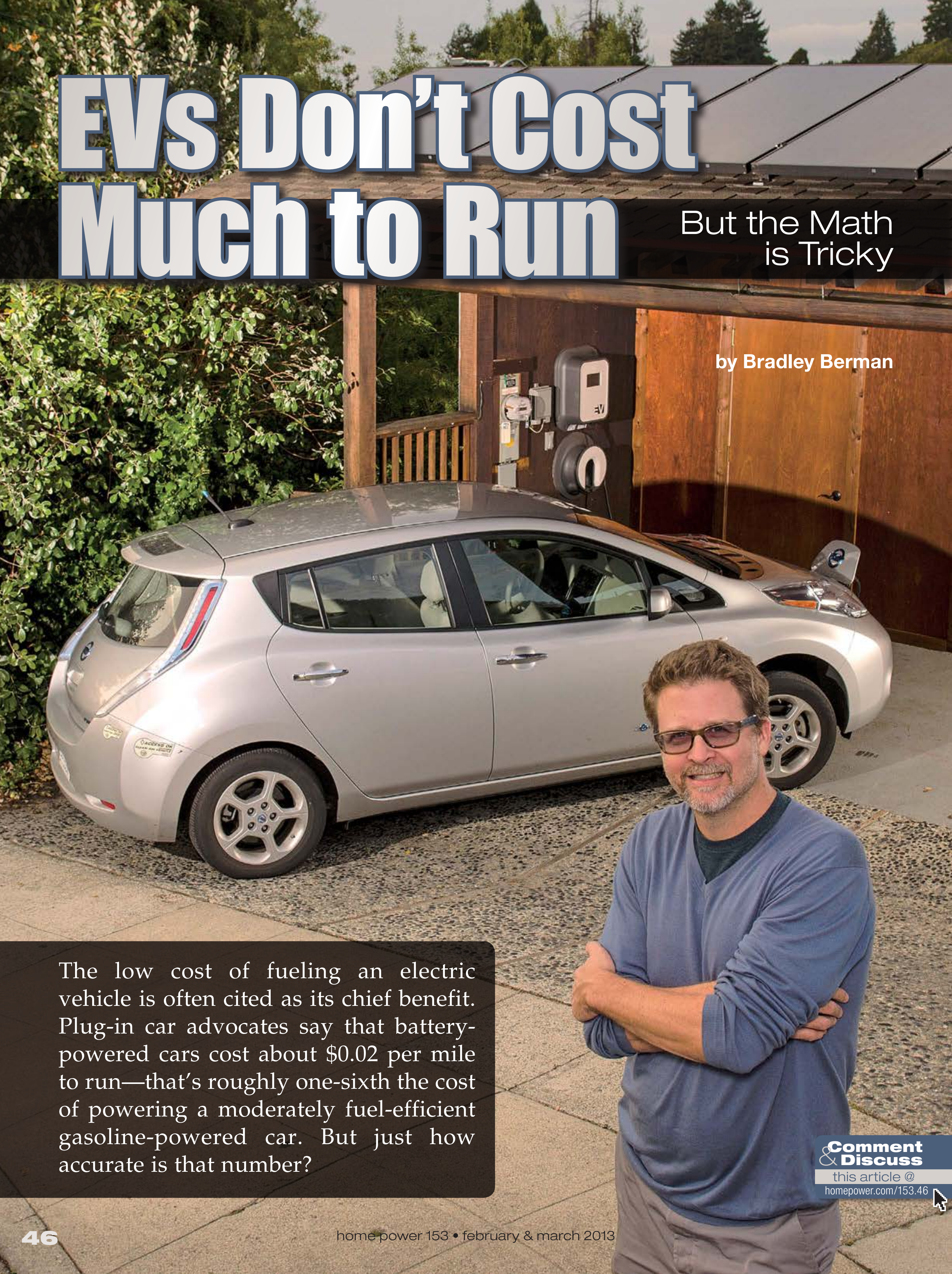
Utilities and electrical inspectors like to see new installations that are tidy; contain modern, new equipment; have ample documentation and schematic drawings; and were designed and installed in a professional manner. That puts the do-it-yourself homeowner with old equipment at a disadvantage. Your vintage Trace SW inverter is an old workhorse that will likely continue to perform for years to come—but is best placed into service in an off-grid situation.

Dan Fink • Buckville Energy Consulting

write to:

asktheexperts@homepower.com

Published letters are edited for content and length. Due to mail volume, we regret that unpublished letters may not receive a reply.



EVs Don't Cost Much to Run

But the Math is Tricky

by Bradley Berman

The low cost of fueling an electric vehicle is often cited as its chief benefit. Plug-in car advocates say that battery-powered cars cost about $0.02 per mile to run—that's roughly one-sixth the cost of powering a moderately fuel-efficient gasoline-powered car. But just how accurate is that number?

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Electric car drivers don't typically monitor their EV's electricity use—their home and car's energy consumption often get lumped together. Whether metered separately or not, the price of electricity can vary depending on the time of day, time of year, and the overall monthly electricity consumption, making quantifying EV electricity use even more complicated. All details, such as your local rates and type of electric car, could shift the numbers one way or the other.

Refueling an electric car is easy—just plug it in to recharge the batteries.

Two Typical Months

It would be a fool's errand to try nailing down a single price for all EV drivers across the country—or even in one town. Instead, I'll focus on what I paid during two specific months in 2012—February and May. The "test case" is my all-electric 2012 Nissan Leaf plugged into Pacific Gas and Electric's (PG&E) grid in the San Francisco Bay Area. A 3.3 kW grid-tied, net-metered PV system offsets some of my household's electricity and provides some charging electricity for the Leaf.

PG&E offers special EV residential electricity rates, and with its seasonal and usage tiers, the price for 1 kWh of electricity (in the high season—summer) ranges from $0.037 from midnight to 7 a.m. to as much as $0.54 per kWh—almost 15 times as much—during a summer afternoon.

I determined my EV's charging usage through reports provided by Blink, the charging network that tracks how much electricity flows through my home charger (which they document as part of The EV Project, supported by the U.S. Department of Energy—see sidebar).

In February, I used 385 kWh to recharge the Leaf—out of the total of 954 kWh I purchased from PG&E. In May, I bought a lot less electricity (461 kWh), since my PV system was generating more electricity, but the EV still used almost as much juice—342 kWh.

Using onboard tools helps Nissan Leaf drivers plan their cars' refueling for times when electricity rates are cheaper. The dashboard also displays the vehicle's energy use.

Tom Minczeski (4)

The hardware on the wall, known as electric vehicle service equipment (EVSE) is a networked supply of 240 V electricity. This EVSE—Blink, provided by The EV Project, monitors and transmits charging patterns to a central database. The Blink charger also has a small monitor that allows users to track charging.

Tom Minczeski

Figuring It Out

Are PG&E's current EV electricity rates confusing? Extremely. If I begin a four-hour charge at 10 p.m. in the winter, the first two hours of charging cost $0.09 per kWh. But at midnight, the price is cut in half to about $0.045 per kWh. Let's assume that charging energy use is steady for the entire four hours, even though the energy flows a little faster during the first few hours and tapers off as the battery fills up. And for simplicity, let's say that I charge exactly the same amount every day of the month, since averaging helps calculate the impact of a tiered pricing structure.

In February, for the first 10 days of usage, I paid $0.046 per kWh. On the eleventh day, I reached the baseline for Tier 1, which then pushed my rate up 40%, to $0.0645. By May 19, my rate for daytime peak electricity jumped to a whopping $0.54 per kWh. Utilities rightly discourage EV charging and other energy use during the day in the summer, when most air conditioners are running.

In February 2012, I used 385.12 kWh to recharge my Leaf. Of those, 243.31 kWh were during off-peak hours, costing $28.93. The other 142 kWh were during partial-peak hours—weekday mornings. For the first 49 kWh of those partial-peak

Some utilities offer attractive time-of-use rates for electric car owners, providing them with a financial incentive (i.e., cheaper electricity) to charge their vehicles during times of typically low loads—for instance, late at night and very early in the morning, when overall grid electricity demand is lower.

Making these EV rate structures (and monthly bills) easy to understand enables EV owners to figure out how much it costs to fuel their vehicles. Unfortunately, some utilities add unnecessary confusion by applying tiered pricing to EV rates.

Residential TOU Rates
(Standard & EV-Specific)*

	Standard ($ per kWh) (CA Rate Schedule E-6)			EV ($ per kWh) (CA Rate Schedule E-9)		
Summer**	**Peak**	**Part-Peak**	**Off-Peak**	**Peak**	**Part-Peak**	**Off-Peak**
Baseline usage	$0.27883	$0.17017	$0.09781	$0.30178	$0.09876	$0.03743
101%–130% of baseline	0.29640	0.18775	0.11538	0.31994	0.11692	0.05559
131%–200% of baseline	0.44653	0.33788	0.26551	0.50036	0.29734	0.15808
More than 200% of baseline	0.48653	0.37788	0.30551	0.54036	0.33734	0.19808
Winter***						
Baseline usage	–	$0.11776	$0.10189	–	$0.09864	$0.04680
101%–130% of baseline	–	0.13533	0.11947	–	0.11679	0.06495
131%– 200% of baseline	–	0.28546	0.26959	–	0.29721	0.15808
More than 200% of baseline	–	0.32546	0.30959	–	0.33721	0.19808

*PG&E Southern California Edison rates for 2012; **Summer (typically): Weekdays, 1–7 p.m. = Peak; All days, 9 p.m.–10 a.m. = Off-peak; Other hours vary between off- & part-peak; ***Winter (typically): Weekdays, 5–8 p.m. = Part-peak; Other hours = Off-peak; Total additional daily charge for meter: Standard = $0.25298; EV = $0.21881

A 5.89 kW batteryless grid-tied system helps offset utility electricity use for the home and car-charging. This subsystem of nine modules sits on the carport roof.

Tom Minczeski

142 kWh, I spent $4.82. But because of tiered price structure, the final 44 kWh of the month cost $14.83—more than three times the cost for fewer kWh. The total for partial-peak charging was $30.65. The combined off-peak and partial-peak for February's EV electricity bill was $59.58. That's an average rate (across all times and tiers) of $0.1547 per kWh.

Comparing to a Gasoline Car

According to my Leaf's onboard stats, I am a moderately efficient driver at 3.3 miles per kWh. (EV drivers who are light on acceleration and good with coasting can get 4+ miles per kWh.) But for me, those 385 kWh provided 1,270 miles of travel.

If I had been driving a 40 mpg gasoline-powered car, the cost for those 1,270 miles would have been $127, at $4 per gallon. So the cost savings in the electric car in February was $67.41. If all of my charging would have been during off-peak hours, I could have added another $14 to that savings.

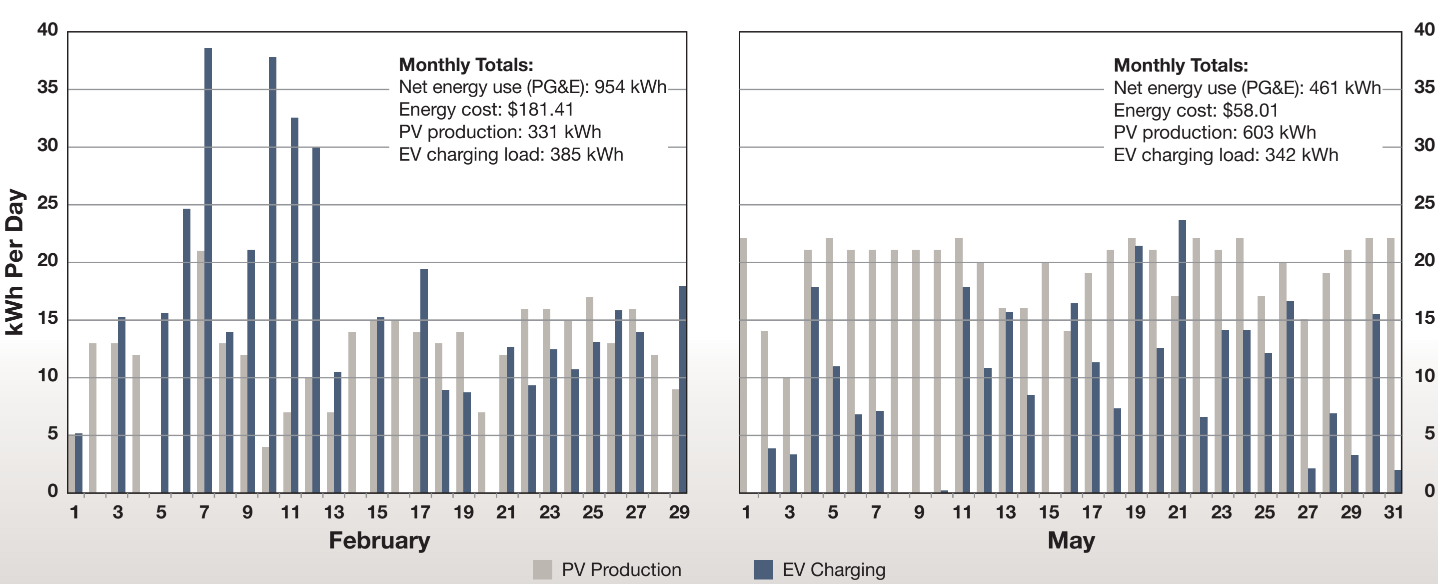
Solar Adds Savings

In February, my PV system produced 331 kWh that I would have otherwise had to purchase from PG&E. That represents about 85% of my EV charging for the month, which at my average per-kWh price for charging ($0.1547) would have meant another $50 of electricity. Without the PV-generated electricity, the charging cost would have been higher, since our overall electricity usage would have climbed into higher (and more expensive) tiers. In fact, the incremental cost of charging the EV would have made all of my electricity more expensive, but my PV system essentially erases that penalty.

There are so many numbers and extenuating factors and circumstances, but for the sake of argument, nearly all of my EV's fuel costs could be considered offset by PV-generated electricity. This decreases the payback period on my PV system—just as the cheaper electricity decreases the payback period of purchasing an electric car.

Continued on page 52

Daily PV Production & EV Charging (Feb. & May 2012)



The EV Project: Capturing Data

With the recent reintroduction of mainstream manufactured electric cars, the big question has been about users' real-world car-charging needs—and how utilities and municipalities can support these needs.

In 2009, Ecotality, an electric transportation and storage technologies company, received a $99.8 million grant from the U.S. Department of Energy (DOE) to study the experiences of EV charging at home, work, and public charging stations. Additional funds that more than doubled the original grant allocation were supplied by project partners—including automakers, local governments, equipment suppliers, and retailers.

"The EV Project," says Colin Read, Ecotality's vice president of corporate development, "is really a data collection project. We deploy infrastructure and recruit vehicle owners to help give us that data."

The EV Project is the largest evaluation of EV infrastructure ever conducted. By November 2012, more than 6,300 drivers—nearly all owners of either the Nissan Leaf or Chevy Volt—had signed up to participate. They all received free home charging equipment and, in most cases, a large enough credit to pay for the installation, which ranges from $1,500 to $2,500.

In exchange, participants agree to give The EV Project access to their charging data. The Blink charging equipment, manufactured by Ecotality, uses wireless technology to transmit charging information to a central database.

"In some locations, it can be three or four weeks to get certified to install a charger," Read explains. "But in other places, it's an over-the-counter 24-hour thing." The EV Project is located in major metropolitan areas across the United States.

The EV Project has logged more than 1 million electric car-charging events. Forty million miles of electric driving have been documented, revealing these patterns:

- EV drivers are clocking about the same number of miles on average as the typical American motorist. In the third quarter of 2012 (the latest data available), Nissan Leaf owners drove an average of 30 miles per day. According to the U.S. National Highway Traffic Safety Administration, drivers of gas-powered cars average 28.9 miles per day.

Courtesy The EV Project (2)

The Blink home charger logs and transmits EV charging data.

- Owners of the Chevy Volt—which has a gas engine to extend driving range—drive even more miles and charge more frequently than Leaf owners. On average, Volt owners drive 41.2 miles per day and plug in 1.4 times per day, while Leaf owners charged, on average, 1.1 times per day.

  Although Volt owners can fill up at a gas station to extend driving distance, the experience of driving on electrons—and avoiding the use of hydrocarbons—is addictive. More frequent charging, while not absolutely necessary, allows Volt owners to manage nearly all of their driving *without* using gasoline.

- EV drivers drive longer distances and use public charging stations more often the longer they own their cars. "Either public charging is becoming more ubiquitous, or EV drivers are becoming more familiar with where chargers are located," says Read.

on Electric Car Charging

- Economics matter. The lion's share of EV charging takes place at home—in the third quarter of 2012, 67% of charging for Nissan Leaf owners took place at home. (That's down 11% from the 78% of home charging that took place a year earlier.)

Charging patterns at home are greatly affected by the rate plans offered by utilities. In many locations, utilities offer special rates to EV drivers based on time-of-use metering. Under these plans, the cost for a kilowatt-hour of electricity can be two or three times higher during peak hours—mostly during the middle of the day—as opposed to the wee hours of the morning.

Utilities offer the cheaper rates because steady demand helps the power plants run more efficiently, helping mitigate the need for upgrades or repairing overtaxed transformers. "The last thing you want to do is add the equivalent of a household of power load—the EV's 3.3- to 6.6-kilowatt draw—during the peak periods of the day," says Read. "If EV users can charge during off-peak hours, there's a benefit to the grid and to all rate payers." It also further reduces the cost of electric fuel, which, per mile, is already half the cost or lower compared to gasoline.

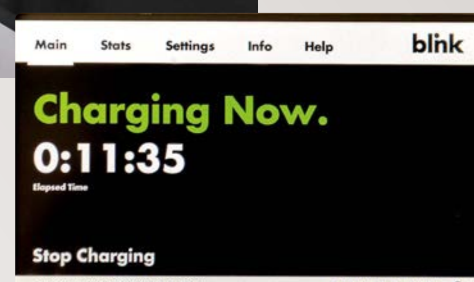
In places like Tennessee, where electricity rates are low and there's no time-of-use rate, people charge around the clock. "In California," says Read, "where there is a higher average utility price, those time-of-use rates have a large effect [on charging behavior]."

This insight can help utility companies prepare for a time when millions of electric cars roam U.S. roads. The first million plug-in vehicles are expected by about 2017.

The EV Project's deployment of charging equipment, on both residential and commercial fronts, is about two-thirds complete. The project is slowly working through the reservation queue as it adds the last thousand or so participants.

Courtesy The EV Project

In addition to home chargers, Ecotality manufactures the 480 VDC Fast Charger, capable of a full recharge in less than 30 minutes. With some user programming, home charging equipment (below) allows EV drivers to monitor cost, charging status, and estimated CO_2 savings from the equipment's touchscreen.



Tom Minczeski (3)

The number of public EV charging locations is rapidly expanding. Today, there are more than 10,000 charging spots across the United States—about 2,600 of which are powered by the Blink Network. By 2020, the number of publicly accessible charging stations is expected to reach 400,000, according to Pike Research.

web extra

For more on The EV Project, visit **TheEVProject.com.**

The savings are greater during May's sunny days—that's when my PV system's output jumped to 603 kWh (nearly double February's production). I also stopped running my heating system, which uses a lot of electricity to power its fan. Most of May's EV charging was during off-peak hours, which range in price from $0.03 to $0.198 per kWh. Only about 15% of the time did I succumb to charging during the peak times of 2 to 9 p.m. By the end of the month, these prices had shot up to more than $0.50 per kWh.

In May, with greater PV production, our adjusted electricity use, which factors in PV production and utility consumption, was 461 kWh. My driving in May also eased off to 341.76 kWh, down from 385.12 kWh in February. In May, the total cost for the 1,128 miles of EV driving was $47.40—an average of $0.139 per kWh.

In May, if I had exclusively charged the EV between midnight and 7 a.m., I could have reduced costs from $47.40 to $30.64. Still, the $47.40 is nearly one-third of the $113 gasoline bill I would have had fueling a 40 mpg gas car at $4 a gallon.

The PV system generated 603 kWh in May, helping charge my Leaf (which used 341.76 kWh) and offset at least one-third of my home's electricity use during that month. Without the PV system's contributions, the portion of my electricity usage in the higher tier would have been greater, driving up the overall cost of recharging the Leaf.

Tom Minczeski

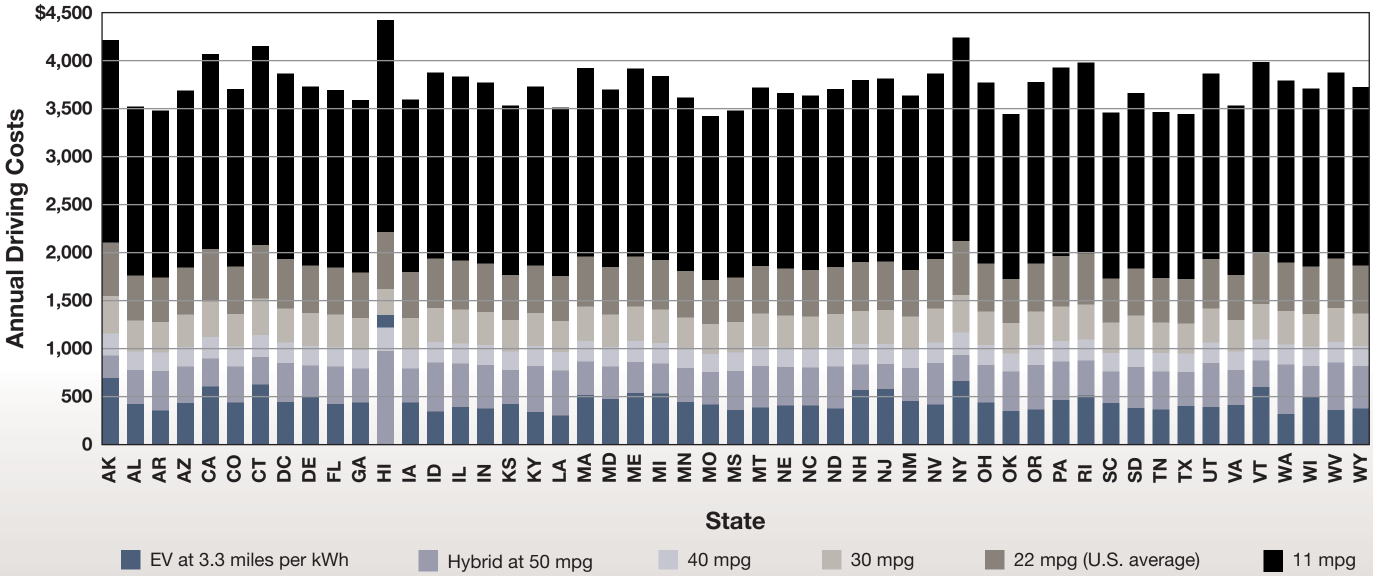
In many locations, a 2.5 to 3.5 kW batteryless grid-tied PV system can provide sufficient energy to offset common EV driving patterns.

Big Picture Savings

How does all this stack up to the $0.02-per-mile value that gets tossed around? In February, my EV fuel costs were $0.047 per mile. In May, they were $0.042 per mile. That compares to about $0.10 per mile for a 40 mpg gasoline-engine car in those months.

While my cost was a little more than double the common EV claim—which says EVs cost one-sixth as much to fuel as gas-powered cars—I probably could have gotten quite close to the promise of big EV cost savings if I had charged the Leaf only in the middle of the night; driven it more efficiently; and

Typical Driving Costs Compared



Based on 12,000 miles driven annually. Electricity & regular gasoline prices based on August 2012 averages for each state. Sources: eia.gov & aaa.com compared it to a 30 mpg gas-powered car instead a 40 mpg one (the national average for a new passenger car is currently about 23 mpg).

But thanks to solar and electric-drive technology, even with my lead foot and a charge-when-I-want-to attitude, I'm able to cut the cost of vehicle fuel by more than half. And to me, the reduction of carbon in the environment and the displacement of oil use—from a supply chain fraught with economic and political dangers—are absolutely priceless.

Access

Bradley Berman (brad@plugincars.com) writes about green transportation, contributing to *The New York Times,* KQED Public Media, PluginCars.com, and other publications. He is a research analyst for Pike Research—a clean technology market research firm—and serves as a consultant to eBay's Green Driving Center.

Tom Minczeski

Even if exact numbers are hard to pinpoint, the economics of driving an EV are compelling—less than half of what a 40 mpg gas car costs to fuel. An electric car's environmental benefits and fast, smooth acceleration are icing on the cake.

Getting the Green

For Your High-Performance Home

by Andy Kerr

Building an energy-efficient home is a winner for your pocketbook and the planet—so why is it getting short shrift from many banks and appraisers?

Building a highly efficient home will cost a little more, but it's worth it if for no other reason than you'll easily recoup the higher up-front payout through lower energy operating costs. Or maybe you want to take advantage of low interest rates by refinancing your existing home while doing some energy upgrades.

Most of us don't have the funds to build a high-performance home—or even do a few energy-efficient upgrades—without getting a loan. But convincing the bank that a high-performance home has greater value than a similar, but conventionally constructed home, is often a surprisingly difficult hurdle.

From PITI to PIETI

Roger Normand and his wife Lynn are building a state-of-the-art green home in Saco, Maine. Like many other green home-building pioneers before him, Roger has immersed himself in the ins and outs of building efficiency and green building. While their bank is supportive of their plans for a green home, the Normands' ability to obtain a construction loan is based on the appraised value of the prospective home.

Three appraisals (by two appraisers) were performed in the course of five months. Both appraisers were members of the Appraisal Institute (AI), and the second appraiser, according to Roger, had completed the AI's advanced education in green appraisals. Each considered both the "cost" and "sales" methods (see "The Art of Appraisals" sidebar) and provided a final valuation that reconciled the differences between their sales comparisons and cost evaluations.

However, the first appraiser's report gave no recognition to the home's energy-efficiency measures, though the standard Uniform Residential Appraisal Report (Freddie Mac form 70 or its equivalent, Fannie Mae form 1004) includes a line item in its value adjustments for "Energy Efficient Items."

The second appraiser's initial report listed some of the home's energy-saving features, which included passive solar design and a super-insulated building envelope, and valued the home's energy-saving attributes at $24,800.

The third appraisal accounted for Leadership in Energy and Environmental Design (LEED; program of the U.S. Green Building Council) and other green standards, assigning them $95,200. And it also estimated the net present value of ongoing energy savings, including 15 years of energy savings.

In Roger's experience, the appraisers just didn't "get" it—at least initially. But the appraisal was high enough that they were able to move forward with their building plans.

"If you want to build green, it's best to have deep pockets," says Roger. "It's still a very long journey ahead to find value in a green appraisal."

Roger recommends that the traditional PITI (principal, interest, taxes, insurance) mortgage lending ratio become PI*E*TI, "where the 'E' represents the home's energy costs.

"My goal in all of this is not to artificially inflate, but rather to realistically portray energy savings in green buildings," says Roger. "Not just for our house, but for all those who really want to build or remodel a greener, more energy-efficient home. We can quibble over the market value of things such as sustainable materials, recycled content, and other LEED items, although I believe these have some market value. I also believe that the energy aspect of green buildings must be objective and quantifiable to be considered."

Fortunately, for Roger (and the rest of us), the real estate industry is moving—albeit slowly—toward recognizing the monetary value of energy efficiency and other green-building features.

Financing Energy-Efficient Homes

Energy-efficient mortgages (EEMs), which allow a borrower to obtain a larger loan to cover the capital cost of energy-efficiency improvements, can be obtained, but are not routinely volunteered by lenders. The rationale supporting EEMs is that, due to monthly energy savings resulting from the improvements, the borrower can make a larger monthly mortgage payment.

The Database for State Incentives for Renewables and Efficiency (DSIRE) describes several energy-efficient mortgages, including ones offered through the Federal Housing Administration (FHA) and Department of Veterans Affairs (VA). Though "private," the government-controlled Federal Home Loan Mortgage Corporation (Freddie Mac) and Federal National Mortgage Association (Fannie Mae) also have EEM programs (see Access).

Getting Green Values

"It makes sense that sustainable buildings should have more value," says Alan Simmons in *An Introduction to Green Homes* (see Access). "They are built better, are better stewards of the environment, consume less energy, and save money on energy costs. They will probably have longer economic lives and provide healthier places for people to live, as well as social benefits, in the form of less soil and water pollution and fewer carbon emissions."

Yet, understanding, appreciating, and valuing energy-efficient homes are far from routine in the world of real estate. In many places, demand for green homes is still low, so there are not many qualified green appraisers. Of the AI's 23,000 members, a database query on green appraisers yields only 67 members in 26 states—less than 0.3%—who claim or promote their green appraisal experience. The most are in California, but not as many as population or lifestyles in the state would suggest. Only 41 AI members have completed the AI's Green/Sustainability Residential Professional Development program.

Homes are usually appraised by using the sales comparison approach. If there aren't many (or any) green homes in your area, your appraiser won't get good comparables ("comps"). Further compounding the problem is that appraisers often work from multiple listing service (MLS) data, which is collected and maintained in local (usually county) databases—and most of these still do not collect information on green features.

The Green Resource Council, a project of the National Association of Realtors, seeks to "green" the MLS by including green building information in their databases. Besides

Courtesy Roger Normand

The Normands' model of their LEED-certified, passive and active solar, super-insulated home. Three appraisals were required before the Normands were able to secure financing to build their green dream home.

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The Difficulty of Evaluation

Appraisers evaluating energy-efficient, green homes now have a couple of tools to use—the Appraisal Institute's (AI) "Residential Green and Energy Efficient Addendum" or Earth Advantage's (EA) "High Performance Home Evaluation Addendum," which helps document a home's green features (see Access). The AI form is basically a checklist of features, while the EA form allows a quantification of the value of green features.

While this is a step in the right direction, neither form provides a method to calculate ongoing savings due to the use of less energy, water, and other resources, which can be capitalized to estimate the market value increase of a home.

The easiest features to quantify are energy and water savings, since they can be calculated and then compared to energy and water costs of the same home without energy-efficiency features. More difficult to quantify are things like good indoor air quality or reduced heating loads from passive solar gain. The most difficult to quantify are the use of sustainably produced or recycled materials, since their benefits accrue mostly to society rather than the individual homeowner. While there is some market value increment for green home demand, such information is only revealed when a robust market exists, and this increment is recognized in the sales-comparison approach.

counting how many bedrooms and such, the MLS would also show if a house has a solar-electric system or carries a green certification. As this data set increases, appraisers will be able to better assess the value of green features.

For new construction, appraisers typically rely on the "cost" approach (see "The Art of Appraisals" sidebar). The company Marshall & Swift, which provides commercial and residential real estate industries with cost data, is now differentiating green building costs from traditional costs. Unfortunately, not all appraisers use the M&S data, as they must pay for it.

"Green building just got going five years ago and then the housing market crashed," says Simmons. "It is still going, but more slowly.

"It has generally been reported that the cost to build a green home usually only adds 1% to 5% to the cost of conventional construction," says Simmons. For folks interested in building a high-performance home, that's a cost worth paying, but most of us don't have the deep pockets to pay for it outright—we have to be able to finance it. A savings of $50 per month could translate into an additional $12,000 to $15,000 of buying power," says Simmons.

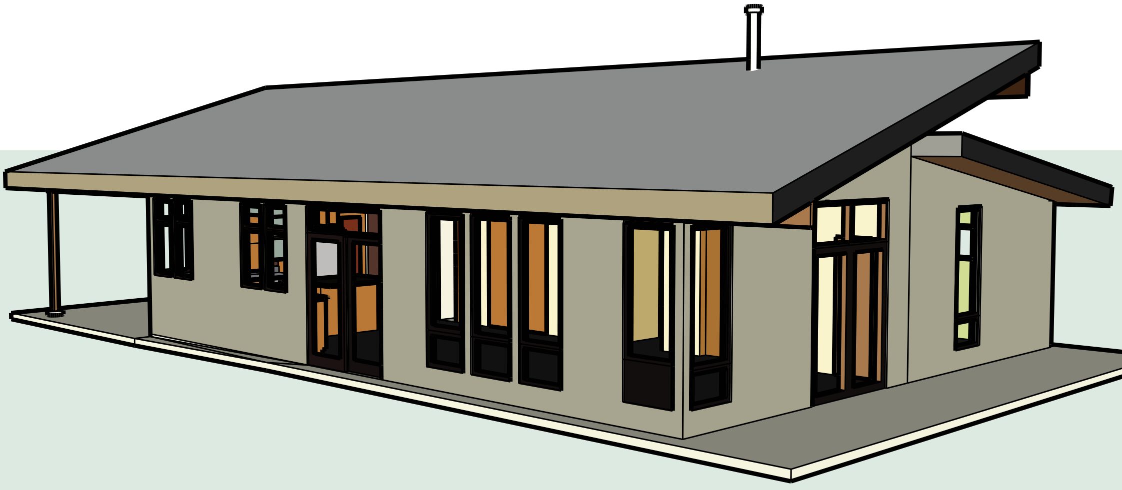
The Struggle—& Success

Until the market for green homes matures, what's an energy-minded home builder to do? Though some form of green building certifications have been around for 15 years (Energy Star, for example), green building is not yet mainstream. In other parts of the country, like Seattle and Denver, green residential construction is close to 25% of the market.

"Right now, homeowners pursuing their green dream home, especially in challenging real estate markets, will need to do their homework—and then some," says Claire Anderson, *Home Power's* managing editor.

Anderson and her husband, Shawn Schreiner, are no strangers to green design and energy efficiency. He installs PV systems for a living and she has a background in ecology and sustainable systems, including ecological home design.

In 2009, they started researching banks to seek a construction loan. However, the banks required a licensed general contractor to oversee construction. As a former job coordinator for a national builder and with previous home building experience, Schreiner couldn't justify spending an additional 15% to 20% on a general contractor when he could do most of the work himself or coordinate subcontractors. Although the couple had some savings to begin, they didn't have nearly enough to fund their entire project. After hitting a wall with the banks, they negotiated private loans, with the idea that they would seek conventional financing once the house had its certificate of occupancy.



An initial appraisal gave little value to the Anderson/Schreiner home's energy-efficiency features, although it was awarded a platinum rating by the Earth Advantage Institute.

An initial appraisal mistakenly classified these high-performance, argon-gas-filled fiberglass casement windows as conventional vinyl units and neglected to recognize the value of the home's passive solar contributions to offsetting its heating loads.

In May 2011, with the house complete, they were ready to roll their four loans into one lower-interest, conventional mortgage. Anderson had carefully researched rates and terms, and selected a local bank. The bank selected an appraiser who claimed to have experience in "green" appraisals. Even though Anderson took pains to prepare a five-page paper documenting the home's energy-efficient and green attributes (passive solar heating, highly insulated walls and roof, high-performance windows and doors, and the Earth Advantage Institute's platinum rating), the appraisal came in not only too low, but also inaccurate.

Rather than choosing another bank, Anderson thought that a mortgage broker might widen their financing horizons. She found a Texas-based firm that promoted EEMs, and was interested and capable. Meanwhile, she educated herself about the state of certified green appraisers in the area.

"The first few appraisers I spoke to were very 'light green,'" says Anderson. "Their definition of green was pretty much limited to finishes—like the recycled content of carpet—while I was speaking of a 'deeper green' home—things like passive solar gain and a significantly reduced energy footprint, which translates into real financial savings, year after year."

The second appraisal was done by the only green certified appraiser in the area and, according to Anderson, "was completely different. The appraiser had another person with her who she was training. As soon as she stepped out of the car, she immediately started elaborating to her trainee about the home's details—the overhangs that would help shade the windows in summer, the large number of south-facing windows for passive solar gain, the thermal mass in the floor, the R-values of the structural insulated panels. I felt confident that our home was finally being valued fairly," says Anderson.

"The appraiser took an extra week to research comps and charged an additional fee for extra time invested, but her attention to detail was worth it," says Anderson. The second appraisal came back weighted toward comps, but comps that were indeed comparable as they, too, had green and efficiency features. Although it had taken Anderson four months of effort, the second appraisal gave their home the value they needed to obtain their mortgage.

The Art of Appraisals

In the United States, there are three general approaches to appraising residences.

The **cost** approach considers the cost of building either a reproduction or replacement of the same home. Cost is a more reliable assessment for newer homes than older ones.

The **sales comparison** approach compares the features and attributes of a home with comparable (size, location, quality, age, etc.) ones. This is the most common method of appraisal for residences, and the most difficult for assessing a green home.

The **income capitalization** approach considers a property's income-generating potential and arrives at a value based on that potential. This approach is common for rental residences.

In the end, any appraisal is an "opinion of value." Opinion is closer to the art end than the science end of the spectrum. Yet an appraisal seeks to quantify in dollars, which is closer to the "science" of economics. A good appraiser gathers the most and best information possible and then issues an opinion—an opinion that can make or break your dream.

Most appraisers don't like to be accused of being subjective, so they tend to rely on "data" that they can reasonably evaluate to come up with a value for a house. The problem is that while metrics like square footage, sale value, and the number of bedrooms and bathrooms are commonly accepted, metrics such as air changes per hour; floor, wall, and ceiling R-values; and window U-values and the like are not—yet.

Government Help or Helping Yourself

In 2011, the Sensible Accounting to Value Energy (SAVE) Act (S. 1737) was introduced, which would require federal mortgage agencies to ensure that energy costs are included in the underwriting process. SAVE would also direct the covered agencies to "make the necessary credit policy decisions to adjust the maximum permitted debt amounts or debt-to-income ratios for eligibility to accommodate inclusion of expected energy costs." However, it was referred to the Senate Committee on Banking, Housing, and Urban Affairs, where it lays unaddressed.

While government can help, no one can help yourself like you can.

- **Know what you want.** Study up. If you know what you are talking about, you can tell if the "expert" knows their stuff.
- **Shop around.** If the bank or mortgage broker you've selected isn't connecting, find another. Brokers can widen your financing options, since they can tap into a variety of lenders.
- **Talk a lot.** Be very clear on what you want and make them be clear in telling you what they understand your wants to be.
- **Keep trying.** Persistence and diligence could win the day.

Access

Andy Kerr (andykerr.net) writes frequently on public policy aspects of renewable energy and energy efficiency. He splits his time between Ashland, Oregon, and Washington, DC.

Energy Star • tinyurl.com/HPESEEM • Energy-efficient mortgages

Appraisal Institute • Residential Green and Energy Efficient Addendum • appraisalinstitute.org

Earth Advantage • High Performance Home Valuation Addendum • bit.ly/EAI_Addendum

Database on State Incentives on Renewables and Efficiency (DSIRE) • bit.ly/GreenLoans • Energy-efficient mortgages

An Introduction to Green Homes by Alan Simmons (Appraisal Institute, 2010)

YOU JUST WANT YOUR SOLAR ELECTRIC SYSTEM TO WORK AS HARD AS YOU DO

PV System Commissioning
TESTS & TOOLS

by Bill Hoffer

The modules are mounted, the inverter placed, and the wiring is done—but before you (or your installer) put away the tools, commissioning procedures are necessary to verify system safety and initial performance.

Shawn Schreiner

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Although recommended in the North American Board of Certified Energy Practitioners (NABCEP) resource guide, a universal procedure for PV system commissioning has not been implemented in the United States. In Europe, many agencies are following the commissioning recommendations of the International Electrotechnical Commission (IEC). Extensive commissioning testing is commonplace for commercial-scale PV systems, and having a solid procedure for residential systems helps ensure the system is properly installed and performing optimally. This article focuses on the tests performed and tools used to commission the PV system at the Cloudview Ecofarm (see the "Commissioning Cloudview" sidebar in this article and "Increasing Production with Single-Axis Tracking" article in this issue).

The Tests

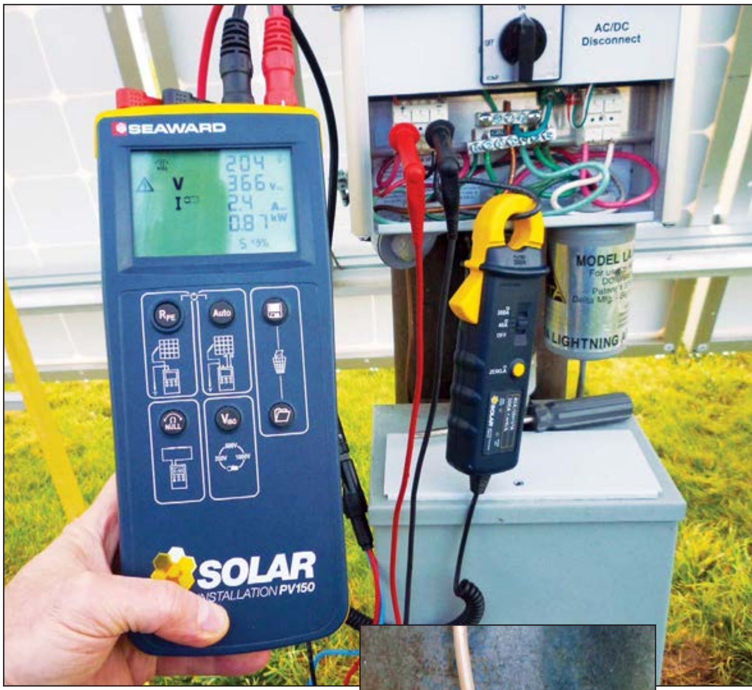
The following electrical tests are recommended by IEC 62446 (and by NABCEP) for commissioning:

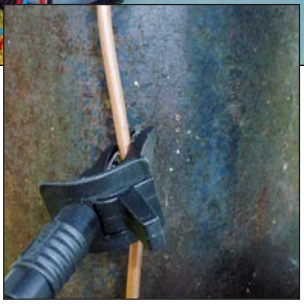
- **Polarity of each module string** to verify that wires are marked and connected properly—check before connecting to the inverter, since reverse polarity could harm it.
- **Open-circuit voltage (Voc)** to confirm that series strings are properly wired. All parallel strings' Voc should be within 5% of each other and within manufacturer's tolerances for the given irradiance and cell temperatures of the test conditions.
- **Short-circuit current (Isc)** to confirm that all strings' short-circuit currents are within 5% of each other.
- **Grounding continuity** to verify that adequate grounding has been established by measuring the array to earth ground resistance. A very high resistance means that there's a bad connection (for example, an improperly torqued ground screw) in the grounding system.
- **Insulation resistance testing (sometimes referred to as "megger testing")** confirms that there is no short-circuit connection between the positive and negative conductors and ground (see "Insulation Resistance" table for the pass/fail criteria and test voltages as recommended by IEC62446).
- **Performance verifications** ensure that the inverter is supplying the predicted output under operation based on the irradiance, ambient and cell temperatures, AC and DC voltage drop, and the inverter's efficiency.

Insulation Resistance Testing Criteria

System Voltage (Voc @ STC × 1.25) VDC	Test Voltage (VDC)	Min. Insulation Resistance (MOhm)
<120	250	0.5
120 – 500	500	1.0
>500	1,000	1.0

Shawn Schreiner





Above: Measuring the array's output during operation (DC voltage and current, and calculating power). Low irradiance (at top of screen) causes the very low kW measurement. Inset: A ground continuity test—One clamp is attached at the main ground wire (EGC) going to the ground rod at the pole-mounted array. The other clamp (not pictured) is attached to the module frame. Voltage-rated insulated gloves should always be worn when making electrical connections for specific commissioning procedures.

Below: The Seaward PV150 Solar Installation Test Kit (with 200R irradiance meter).

Bill Hoffer (3)

Bill Hoffer (4)

Left: A performance validation test measures irradiance, cell and ambient temperatures (not shown), DC input voltage and current, and AC output voltage and current. The Hukseflux Solar I-V automatically calculates DC and AC efficiencies based on these measurements.

Above: The Hukseflux Solar I-V and its components.

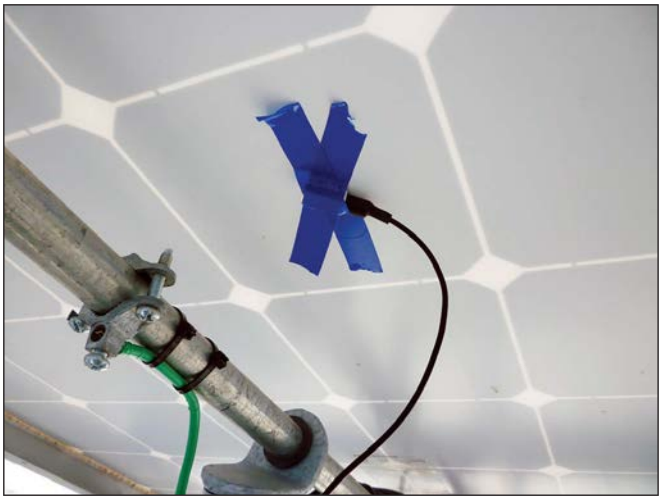
Commissioning Tools

Several manufacturers offer testing equipment for PV system commissioning, including the following products:

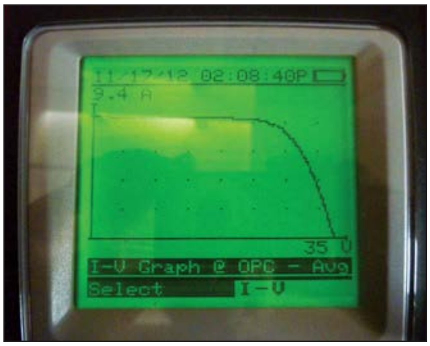
Seaward PV150 Solar Installation Test Kit, which includes the meter, leads, and AC/DC current clamp ($1,495). This device can perform all the minimum IEC 62446 commissioning tests (except performance verification) with the push of a button. It is designed to connect directly to MC4 output and can safely perform the short-circuit current measurement using an internal switch. The PV150 performs the insulation resistance testing of a module or string by safely shorting the array output (+ and -) and applying the appropriate test voltage between the shorted outputs and ground. (Note: Some methods of testing that involve measuring megohms of insulation resistance between a positive and ground or the negative and ground may damage the module or diodes and/or void module warranties.)

The PV150 can also measure irradiance, and ambient and cell temperatures simultaneously during all the test measurements used in performance verification calculations with its optional 200R irradiance meter ($475). (Note: The

A sensor placed on the module backing measures cell temperature.

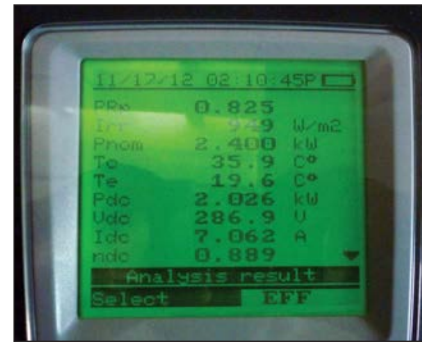


The Seaward Solar 200R measures the irradiance (w/m^2) on the array. This measurement, along with the cell temperature, is used in performance verification calculations.



This shows a typical, average IV curve for a module. Here, the string measurements were averaged to calculate the average module IV curve for comparison to manufacturer's data.

A typical power curve for an entire string—in this case, ten 240 VDC modules in series.



Bill Hoffer (3)

The performance analysis test results showing DC performance measurements for a 2,400-watt array.

FOR DIYers: COMMISSIONING A SINGLE SYSTEM

DIYers can perform many of these tests using a standard digital multimeter and a clamp-on current meter (like the industry standard, a Fluke 376, about $385, although less expensive meters are available). An infrared thermometer and a simple irradiance meter, like Daystar's DS-05A ($157), will allow more accurate adjustments for standard test conditions. Proper protective equipment such as high-voltage gloves and safety glasses should be worn when making electrical connections for live operational testing.

Assuming that you have proper ratings and fusing on your meters, the following tests are possible and safe to perform.

- **Polarity check** of individual and series string of modules
- **Open-circuit voltage** of individual or series strings of modules
- **Short-circuit current** of one module. Testing the Isc of one or more series strings of modules is *not* advised due to high arcing potential when touching and removing meter terminals. Even when testing an individual module, it is recommended that you do not touch meter probes in the MC4 connectors, as arcing can carbonize the terminals, causing excessive high resistance and overheating at the connectors after testing. To avoid damaging the connectors, use a sacrificial MC4 connector with a bare lead for testing.
- **Performance measurements** can be taken while the system is operating, using a meter to measure voltage and a clamp-on meter to measure AC and DC current. DC current can be safely measured using a clamp-on meter without disconnecting wires. This is a standard test that must be performed before turning the system on to ensure that there is no current in the wires, or after turning the system off, before disconnecting or removing them. Some power meters, like the Seaward Power Meter, can measure voltage and current at the same time. These devices will automatically calculate the power.

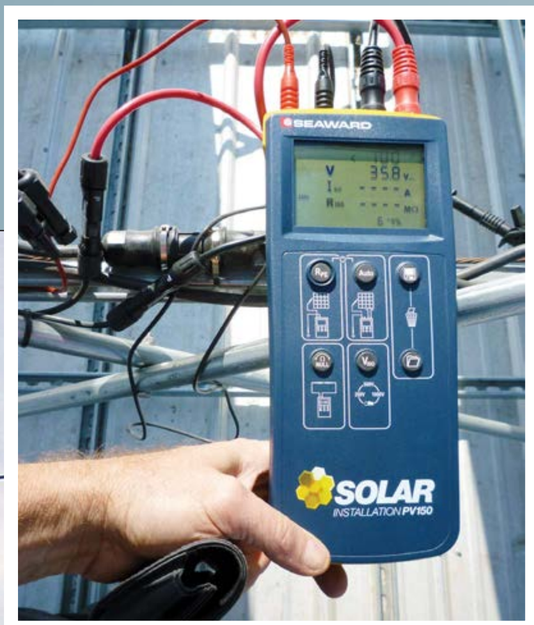
The following tests are *not recommended* without the proper equipment and training because they can be dangerous and/or provide inaccurate results.

- **Ground continuity**—this resistance measurement requires that a voltage and current be applied between the frame and the system ground. However, the resistance measurement on most meters is designed for measuring electrical components, such as resistors and fuses, and will not give an accurate repeatable resistance measurement of a frame or wire.
- **Insulation resistance tests** are performed at high voltages with either the Seaward or other available meggers. Standard digital multimeters are not appropriate devices to use for this measurement—besides being a significant hazard to the tester, damage to the modules or other sensitive electronics can occur.
- Because strings can have a high voltage (up to 600 VDC), a significant arc can occur when the leads are shorted. The Seaward meter is designed to make this connection internally to minimize and extinguish any arc.

In the field, there is simply no way to make an **IV curve** without an IV curve tracer. Fortunately, this is not necessary in most DIY systems—unless a major discrepancy is discovered during the simple tests above or to confirm an underperforming or failing module for warranty reasons. Many installers are now using this equipment, so if you think there's a problem you should be able to find someone with the tools to do it for you.

An inexpensive hand-held infrared thermometer can measure module **cell temperature** where the laser points, but a thermal camera can take numerous measurements at one time, providing greater precision. In both cases, proper training is needed to get accurate measurements, as the results are very much related to how you use the tool.

COMMISSIONING CLOUDVIEW



In the spring of 2012, EcoDepot Inc. installed a 4.8 kW PV array on single-axis trackers on the Cloudview Ecofarm's cold storage building. The system commissioning was performed by my company on the last day of the installation. Although the weather was less than ideal for the IV curve tracing tests, it was adequate for the IEC 62446 tests and performance evaluation.

As with any commissioning testing, each installation has different requirements, but a detailed test plan will help you complete the tasks efficiently. Here are the results of the Cloudview commissioning tests.

Polarity: All modules passed. The Seaward 150 automatically measures polarity upon attaching the module or string MC4 connectors to the meter's MC4 output cables. If the polarity is reversed, a "cross arrows" symbol will flash and no further tests can be completed. The system uses microinverters, so there were no high-voltage strings to test.

Voc: 35.63 VDC (average). All measurements taken were within the IEC standard of +/- 5% of each other. The PV150 calculates this value automatically. Although the measurements were a little lower than the manufacturer's cell-temperature-adjusted STC values, they were still well within the manufacturer's tolerance of +/- 3%.

Isc: 9.2 A (average). All measurements taken fell within the IEC 62446 guidelines of +/5%. Although they were slightly higher than the manufacturer's STC value of 8.7 amps, they still were well within the tolerance of +/-3% when irradiance was accounted for.

Grounding continuity: Because we used an unconventional ground connection between the pivot pole and tracker frame, this measurement was important to confirm that our technique would pass inspection. We measured ground continuity from the module frames to the tracker's main equipment grounding conductor (EGC). The average was 0.014 Ohms (continuity for a 10-foot piece of copper wire without connectors would be 0.004 Ohms). This result is reasonable, considering the continuity pathway—from the frame, through the WEEBs and the grounding connector on the pivot pole, and then through an additional Ilsco clamp connected to the main EGC conductor. There is no standard in IEC 62446 for this, but certainly high resistance would indicate a poor ground connection, requiring troubleshooting.

Commissioning tests performed on the Cloudview PV array and balance-of-system (BOS) equipment indicate a safe and well-performing system.

Bill Hoffer

Insulation resistance testing found no faults in the modules or in the wires, including the extensions from the modules to the microinverters, which were required for this particular installation (see "Increasing Production with Single-Axis Trackers" in this issue). The Seaward PV150 meter applies 250 VDC (the maximum voltage recommended for a less than 120-volt module circuit, see "Insulation Resistance" table) to the shorted output wires of each individual module at the point of connection at the microinverters, and automatically gives a pass/fail result based on the test voltage.

The resistance measurement was greater than 199 megohms. For a voltage of less than 120 VDC, IEC 62446 requires a minimum resistance of 0.5 megohms. All the modules passed.

IV curves were taken for each module to verify baseline performance. The shape of an IV curve can tell a lot more about a module's performance than its Voc and Isc measurements—it can indicate bad diodes, shading, or a damaged module. In this case, the testing results were submitted to the module manufacturer as data for degradation studies.

All modules had a normal-shaped IV curve and were within the manufacturer tolerances of +/- 3% once converted to STC. Curve tracers take a measurement at the specific field conditions and can make adjustments for irradiance and cell temperature automatically to compare to the manufacturer's STC values. The Solar IV will give an immediate "pass" or "fail" when its measurement is compared against the manufacturer's specifications. In addition, the IV curve tracer can calculate the maximum power point (Vmp, Imp, and Pmp) values of the array. Because IV curve tracing takes several seconds to perform, results can be impacted by changing weather conditions during the testing. During the Cloudview commissioning, intermittent sunshine caused edge-of-cloud irradiance changes and a 10 mph wind influenced cell temperatures.

A final performance measurement was taken for each microinverter branch circuit (two branch circuits of 10 in parallel) during normal operation to ensure that they were within +/-10% of the expected power output relative to the irradiance and cell temperature at the time of the measurement. (Note: There is not an established standard for this.) This was done using the Seaward 200R for irradiance and cell temperature, and a handheld digital multimeter and clamp-on meter. Calculations determined the expected output, while considering the irradiance, cell temperature, inverter efficiency, and wire losses (see the "Cloudview Commissioning Power Tests" table). In this situation, the branch circuits were tested, since we did not want to measure all 20 inverters and modules individually. These final measurements revealed that both strings were exceeding the calculated output, although this may have been due to edge-of-cloud effects.

Cloudview Commissioning Power Tests

String	Irradiance (W/m^2)	Cell Temp. (°C)	Air Temp. (°C)	Amps AC	Volts AC	Watts AC* (Calculated)	Watts AC** (Measured)	Difference
South	1,009	33	20	9.5	240	2,141	2,280	+6.5%
North	859	32	19	8.2	240	1,833	1,968	+7.4%

*Calculated AC watts = String STC watts × % irradiance relative to STC 1,000 W/m^2 × 2% voltage drop × % cell temperature loss × inverter efficiency; **New modules without curing & light degradation are expected to overperform

Bill Hoffer (4)

Left: The Hukseflux irradiance meter includes calibrated multi- and monocrystalline PV cells for accurate irradiance measurements.

Right: The Solar02 transmitter combines the temperature and irradiance readings into one unit that can transmit data back to the meter through radio frequency (RF) or record data that is synchronized with the main Solar IV meter when that unit is out of RF range.

200R has radio frequency communications with PV150 and the ability to download the data to a computer.) By using the separate clamp-on meter, you can verify the inverter efficiency.

There are other advanced tools that provide additional analyses and troubleshooting ability. If the system you're testing does not pass the IEC 61446 commissioning tests, these tools can help find the problem quickly. They are not required for standard IEC 62446- or NABCEP-recommended commissioning, but are briefly mentioned in both of those documents.

Infrared cameras give installers a quick way to identify the source of array performance problems. Additionally, the images can be helpful in supporting a warranty claim.

Hukseflux Solar I-V($5,625) combines the I-V400 curve tracer ($4,165) and parts of the Solar300 ($7,595). The Solar I-V can test each module or string's IV curve, and the output performance of a single-phase AC circuit from the inverter with one DC input into the inverter during operation, up to a maximum of 1,000 VDC and 10 A. Voltage-current curve tracing of installed modules and strings is useful to ensure they are matched and offers a good baseline for future performance validation and troubleshooting. This level of testing is not really necessary for most residential systems, but is becoming necessary for bank-financed utility-scale projects that are expected to give a minimum return on the investment. These tests were done on the Cloudview installation (see the "Commissioning Cloudview" sidebar).

Flir E40 infrared thermal imaging camera ($3,995) is helpful for detecting module defects, since it can show "hot spots" on modules, revealing problems like internal module wiring issues or failed diodes, which can be responsible for reducing the module's output. Thermal cameras are also useful for checking system connections, since loose or improperly torqued connections are hotter than other connections because of increased resistance. Like the IV curve tracer, these are not generally used in a typical residential installation except to troubleshoot problems that have been indicated by the other measurements.

Access

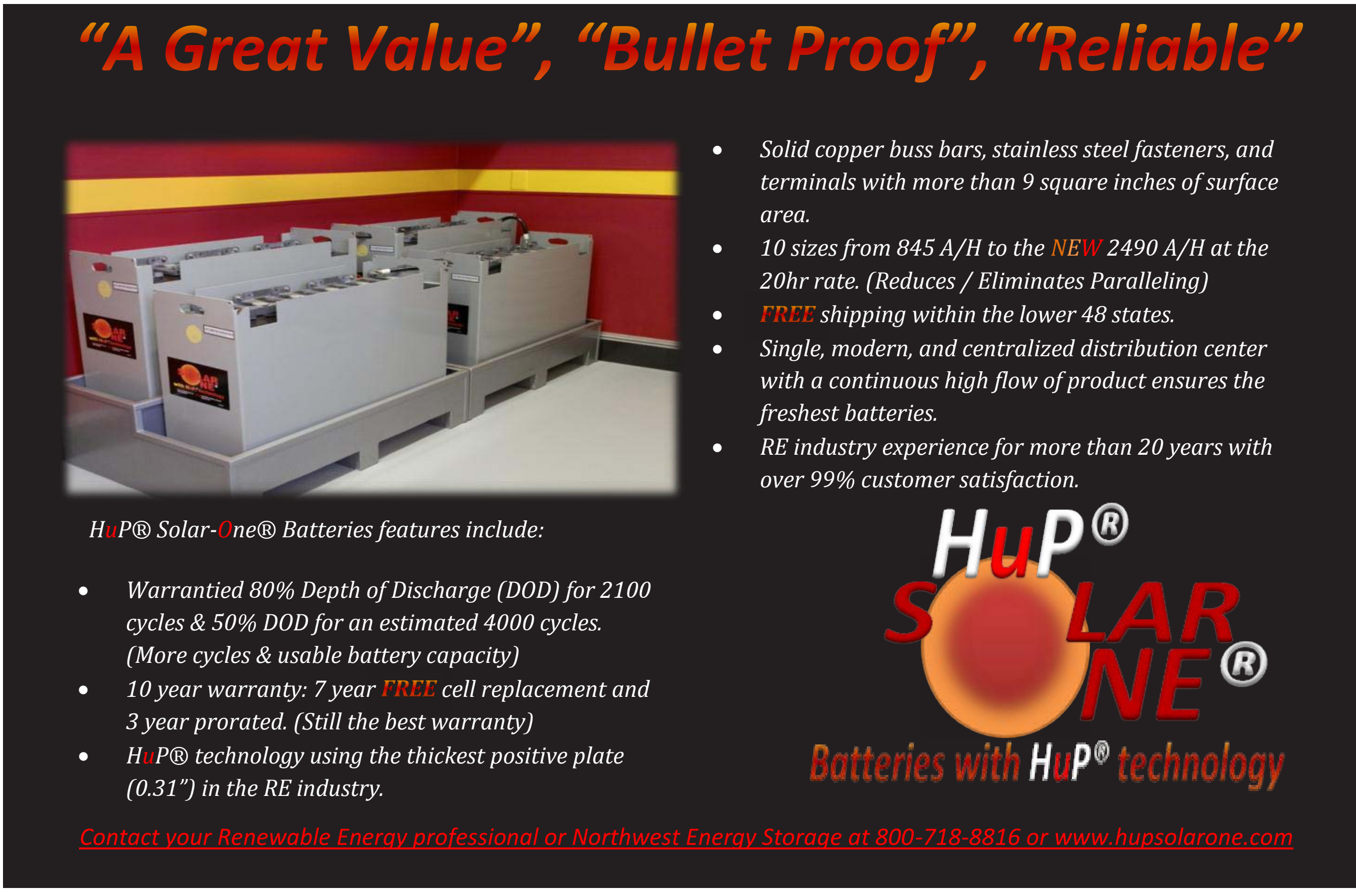
Bill Hoffer has worked in the solar industry for more than 20 years. He is an alumnus of Solar Energy International, where he now teaches. Bill also consults with manufacturers in product development and testing, and specializes in the third-party commissioning, performance validation, and troubleshooting for commercial- and utility-scale systems.

Testing Equipment:

Flir E-40 infrared thermal camera • Flir • flir.com

Hukseflux Solar IV curve tracer • Hukseflux USA • huksefluxusa.com

Seaward PV150 • Seaward Solar USA • seawardsolar.com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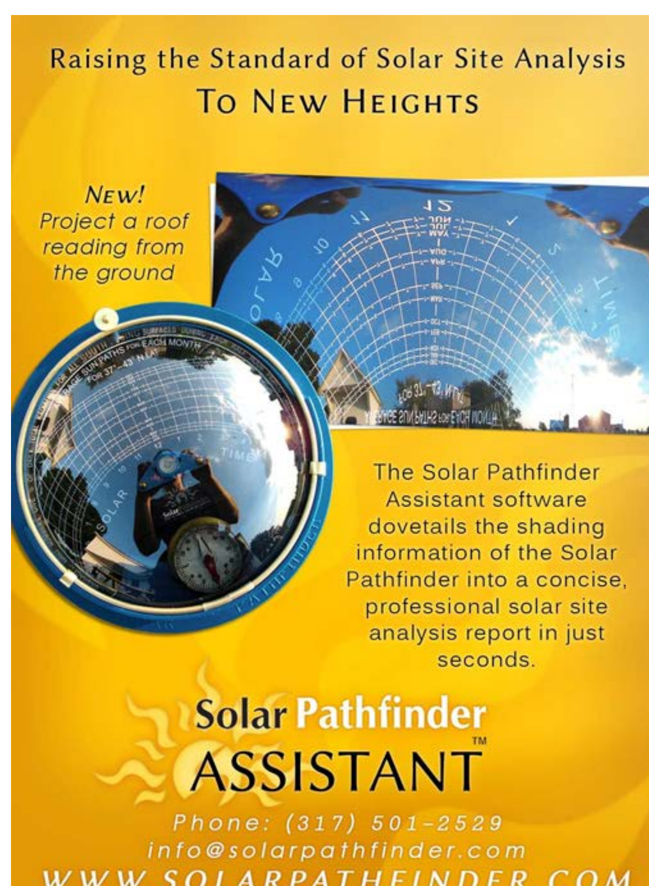
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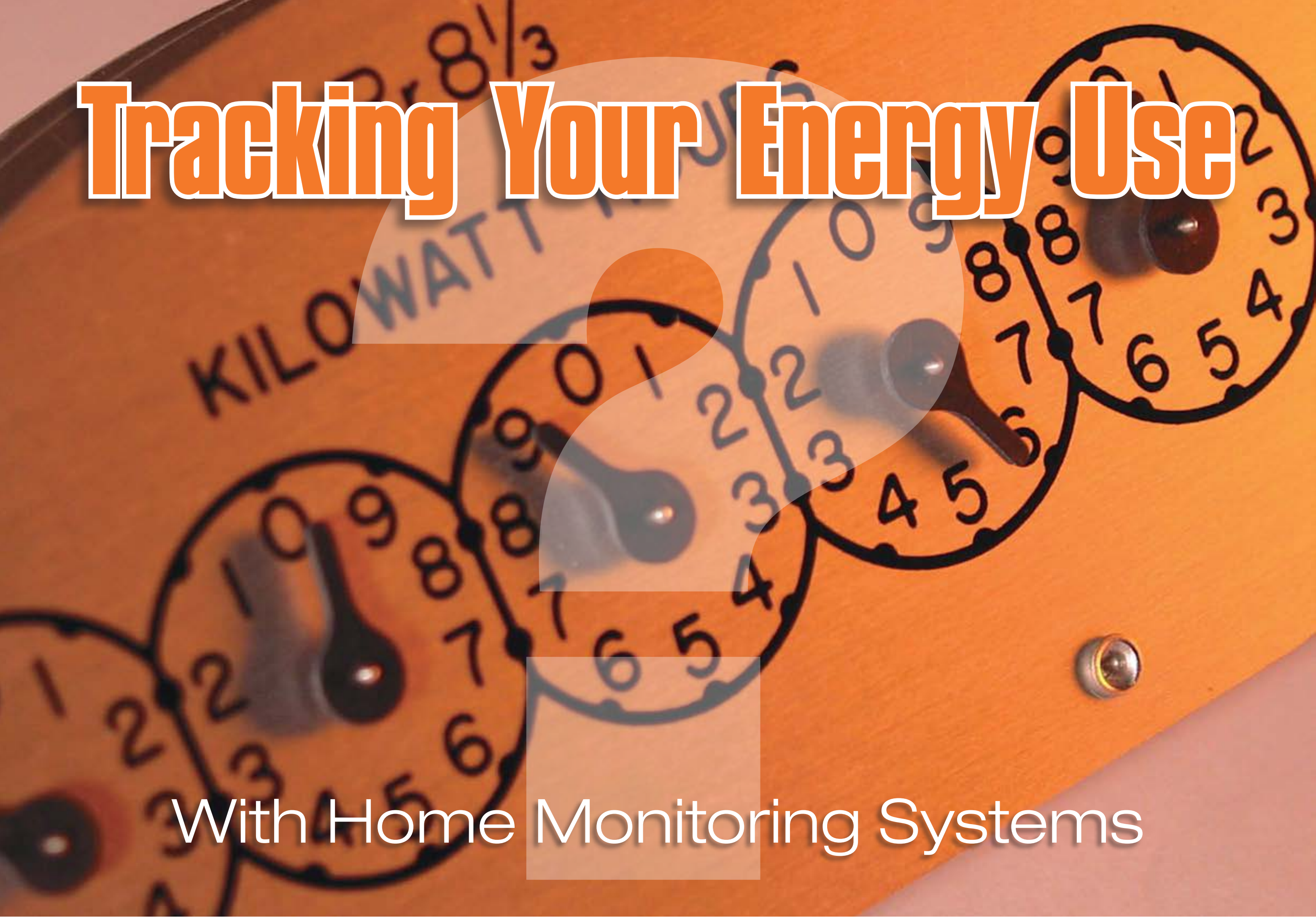
Tracking Your Energy Use

With Home Monitoring Systems



by Erika Weliczko

Measuring your home's energy consumption is the first step toward finding ways to decrease it. While almost every residence has an electric meter, it usually only shows total household energy (kWh) consumed, although some include instantaneous power being used (kW). And the meter is usually placed where it is convenient for the utility—not for you—to read. But conservation-minded homeowners and renters can choose from several products that measure and record electricity consumption to reveal the energy hogs. The information is shown on a convenient countertop display or remotely on a smartphone or a computer screen.

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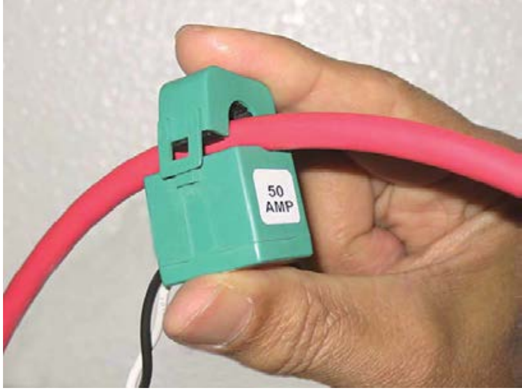
If you want to use energy data to help reduce usage or convince other household members to adopt energy-saving behaviors, an energy monitoring system is for you. Or maybe you want to see how large a backup generator you need for utility outages, or how large a solar-electric system you need for your home. Maybe you just want to identify the biggest electricity loads in your household. If you already have a PV or wind system, you might need to monitor the on-site generation.

Courtesy eGauge



Current transducers (CTs) measure electrical current using the magnetic field that's created by electrons flowing through the wires.

The Basics

A typical home energy monitoring system includes sensors, a data gateway, and a display to receive and view the information. Standard information includes energy consumption in kilowatt-hours (kWh) and power draw in kilowatts (kW). Often, monitors include the cost of the electricity consumed, and some allow programming with time-of-use rates.

Monitors require sensors at each point of measurement. Current transducers (CTs) and pulse sensors are most common. CTs are available in split-core or solid-core varieties. Split-core CTs make it easier to install in existing electrical installations, since you can open up the "donut," and then close it around the wire. Note that CTs are typically *not* interchangeable between different systems.

A magnetic field is created as the current in the wire flows. When that magnetic field moves through the coil of the CT, it generates voltage proportional to the current flow. This voltage is measured by the electronics and converted into an amperage reading. At the same time, the voltage in the circuit is measured directly, and simple multiplication results in kW. Include the elapsed time, and kWh are computed. The other sensor type—pulse—counts the electronic pulses made by the utility meter as it counts units. Many utility meters for electricity, gas, and water are pulse meters. Simple pulse sensors are not sophisticated enough to determine whether the energy flow is incoming from consumption or outgoing from a home source, like a PV system.

Some meters gather more data from the sensors than others, updating readings every second compared to every 30 seconds. The way in which the data is used in calculating kWh or instantaneous kW will also influence the meter's accuracy.

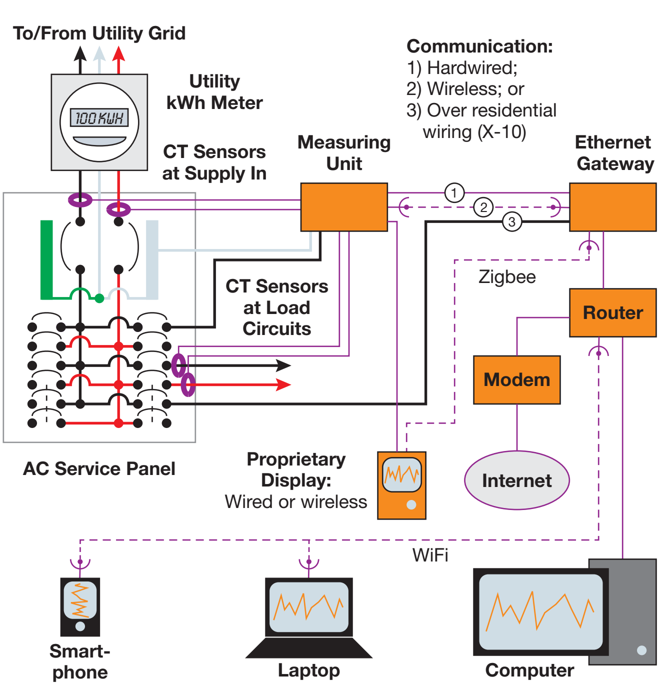
The sensors are hard-wired or communicate wirelessly through data loggers or transmitters that, in turn, send data to a local display. Some systems do not need or do not use a separate display. These transmitters are connected to the router so they can communicate within a local area network (LAN) and/or through third-party servers over the Internet. Several transmitters and gateways require a power supply and consume from 3 to 10 W. Most monitors allow information to be downloaded into a spreadsheet for further analysis.

Home Automation Systems & Monitoring

Home automation systems or building management systems go above and beyond just monitoring, since they can control many aspects of your home—turning on or shutting off heating and cooling systems, raising or lowering automated window blinds, even communication with surveillance devices. Control features require more hardware and compatible components, but also allow you to make energy consumption adjustments—often remotely—down to the appliance level.

Prices will range from a few hundred to a few thousand dollars depending on what you would like to control. Electrical manufacturers such as Lutron and Leviton offer products to control lights and individual plugged-in appliances. Product offerings by home automation manufacturers like Savant Systems, Control4, and Schneider provide control of many more household features. Besides lights and thermostats, some additional controllable features range from home audio and entertainment to securing your home by automatically locking the doors. One thing is sure—"smart home" products will continue to evolve as more devices and features become controllable.

Typical Configuration Options



With some practice with your home energy monitor, you'll be able to differentiate individual loads and assess their contribution to your home's total energy use.

Courtesy Blue Line Innovations

eMonitor

Powerhouse Dynamics' eMonitor uses CTs and a base unit installed in the electrical panel to collect data. The base unit communicates with the eMonitor Gateway, which in turn sends the data to off-site third-party servers over the home's broadband connection. Users can view real-time usage information from up to 42 circuits wherever there is an Internet connection.

The basic model, the eMonitor 4-14, comes with the equipment to monitor total building electricity consumption, as well as usage in 12 additional circuits. The eMonitor 4-24 and 4-44 can handle 22 and 42 total circuits with the addition of expansion pods, additional CTs, and additional monitoring services. In all units, two of the circuits are reserved for monitoring the main electrical service entering the building.

The base unit needs a 15 A dedicated circuit, though these products consume only 3 to 10 W to operate. In addition to the installation of the base unit, CTs, and the communication gateway, setup requires inputting circuit descriptions via a computer connection. Further configuration and registration allow the opportunity to confirm that communication is operating as intended and that all circuit labels were input correctly.

There is no local display. To view data and graphs, an Internet connection is required. The base unit will store data for several days in the event of loss of connectivity to the host server.

The eMonitor also offers remote control of compatible, Wi-Fi supported, third-party thermostats. If you forgot to turn the air-conditioning off before you left home, you can do this with a smartphone app—from anywhere. In the works is a plug-load-level control device that will allow remote-control of various appliances, such as a computer or window unit air conditioner.

The eMonitor offers some unique features. User-programmable alerts can help inform you about potentially worrisome conditions, such as a sump pump failure. These messages can be sent by email or text message to your smartphone. Apps for the iPhone and iPad allow viewing real-time operation and interface with the control features. The number of circuits that can be monitored makes the eMonitor appropriate for large homes and small businesses.

The eMonitor 4 is available through a dealer network or online retailers. A two-year monitoring service contract is required.

Choosing a Monitor

When choosing a whole-house electricity monitoring product, consider:

- Do you have the skills to install equipment in the main electrical panel? If not, you will need the help of an electrician.
- Is a dedicated display useful to you?
- Do you want access to information when you are away from home?
- Do you want to be able to control your household electricity use remotely?
- Do you intend to work with raw data, or do you need it in an easier-to-use format?

Courtesy Powerhouse Dynamics (4)

eGauge

Like the eMonitor, the eGauge has the ability to monitor multiple circuits. However, the eGauge monitor does not require a data monitoring contract. The information resides locally, rather than remotely on an outside web server.

The CTs are installed inside the electrical panel where the monitored circuits originate, so some electrical skills are needed to safely install it. The eGauge main unit, which also resides in the electrical panel or immediately adjacent to it, can accommodate input from up to 12 CTs. The main unit needs a 240 VAC, 15 A power supply which is supplied from within the panel being monitored. To view the data, the main unit is connected to your local network and computer, via Ethernet cable, or a HomePlug accessory or another variety of Wi-Fi adapter. While the eGauge data lives locally, it also can be viewed online. The eGauge doesn't offer a smartphone app, but its data screen can be viewed with any web browser.

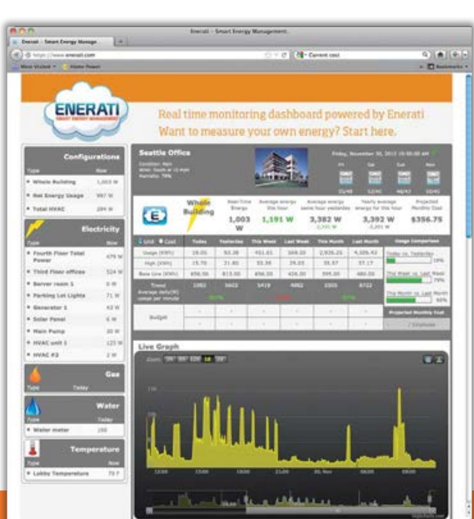
The eGauge does not include control features. The setup and monitoring interface are touted as intuitive and straightforward.

Courtesy eGauge (2)

EnviR

Current Cost's EnviR monitor basic model will monitor the consumption on one 240 VAC circuit—typically, the two incoming service wires. Setup of the standard kit includes installing a set of CTs and the battery-operated transmitter, which wirelessly transmits to the battery-operated display, if within 100 feet.

Current Cost offers accessories to monitor more circuits, view information online, and track usage of single appliances. For online viewing, you can opt for the Enerati Gateway kit, which requires a data subscription. Individual appliance monitors (IAMs) are plug-based sensors that monitor electricity usage of individual 120 VAC appliances, recording real-time power and energy use at 8- to 10-second intervals. Each display can accommodate up to 10 transmitters. Monitoring packages are also available for renewable energy systems that can track consumption, RE-system generation, and net usage. The EnviR can be purchased directly through the website or through resellers.



Courtesy Current Cost (3)

LGate

Locus Energy initially designed the LGate products to serve sites with PV systems. Now, it offers low-cost revenue-grade metering with the LGate 101. The LGate 50 monitors a building's electricity consumption in kWh, as well as power in kW. The LGate meters also come with a five-year monitoring contract (included in the purchase of the unit) that can be extended for another five years.

The LGate uses CTs installed in the electrical panel. The LGate itself is installed outside the panel, but nearby. It accepts up to two sets of CT inputs, which are generally used to measure total building energy consumption and PV production. The meter requires its own 120 VAC, 15 A breaker and corresponding wiring. The LGate 101 requires a 240 VAC, 15 A power supply. The LGate connects to the Locus Energy servers through your Internet connection brought directly to the meter. LEDs inside the meter box indicate its communication status.

The LGate meters do not come with a display. Data is viewed via the SolarOS platform through a browser. The information is downloadable. LGate products are available only through solar contractors.

Courtesy Locus Energy

OWL

The OWL devices are designed to monitor only one circuit, usually the incoming wires to the main electrical panel. The CTs require accessing the main electrical panel for installation. The CTs are connected to a sending device, placed just outside the panel, which wirelessly transmits data to the remote display, which can be located up to 90 feet away. The OWL devices show instantaneous power usage, energy consumption, and cost. Both the display and the sending unit are battery-operated. The products have a longer history in the UK and Europe, but these limited versions are now available in North America through the OWL partners and other online retailers. The OWL Intuition series (which may not yet be available in North America) allows users to view information via any Internet-connected computer or by using a smartphone via the OWL app. A PV version monitors on-site PV system generation along with utility consumption.

Courtesy OWL (3)

The PowerCost Monitor

Courtesy Blue Line Innovations (2)

Blue Line Innovations' PowerCost Monitor can be installed by homeowners—an electrician is not required—since the sensing unit attaches to the outside of the electric meter. The base model includes the sensor and display.

A pulse sensor on the meter communicates wirelessly, using your home Wi-Fi, to the display unit. For the basic BLI-28000, the information is only viewable on the display provided. To view your household's real-time electricity usage online or to store and analyze data over time, you'll need to choose from one of the third-party software offerings and need the PowerCost's Wi-Fi bridge or gateway. These Wi-Fi accessories require a 120 VAC power supply, while the sensor units and displays operate on batteries.

The sensor unit may not be compatible with your electric meter—check compatibility on the Blue Line website before purchasing. The base unit will keep a cumulative total, as well as show real-time, instantaneous demand. The user programs in the utility rates so that the display can report the cost of electricity consumed. Alone, the PowerCost does not offer any control features, but some models can be synced with the Iris automated control system, enabling you to incorporate usage information into a home automation platform.

The Energy Detective (TED)

Energy Inc.'s basic TED 5000, will monitor total household electricity consumption and show it on a small display. On the display, you can toggle through instantaneous power (kW), cost per hour, recent use, monthly use to-date, and you can compare to a monthly projection.

TED uses one or more measuring transmitting units (MTUs) for each set of CTs, and up to four circuits can be monitored. The MTU resides in the electrical panel being monitored and requires a 120 VAC power supply. The MTU transmits a signal over the household wiring to the gateway and/or the display. If you prefer to view graphical information on a computer screen, you can forgo the display. Setup requires downloading Energy Inc.'s proprietary Footprints software and configuring your gateway much like another device on your network. For online viewing and smartphones, several third-party applications exist.

TED can monitor on-site renewable energy generation as one of its data inputs. While not revenue-grade monitoring, it may be sufficient for keeping informal tabs on your electricity consumed and generated.

Installers report that it is not unusual to spend time troubleshooting the signal over the power line, since other electronic devices in the home can interfere with TED's signal. TED can be purchased from the website directly, or through distribution channels.

Courtesy Energy Inc. (3)

Wattvision

Courtesy Wattvision (3)

Wattvision is easy to install, but it only measures total electricity consumption—not other circuits or RE-system generation. With a pulse sensor installed at the electric meter, it does not require an electrician to install. You just select the correct sensor based on your existing utility meter technology, brand, and layout. The sensor is connected via 50 feet of wire to a Wi-Fi gateway, which requires a 120 VAC receptacle.

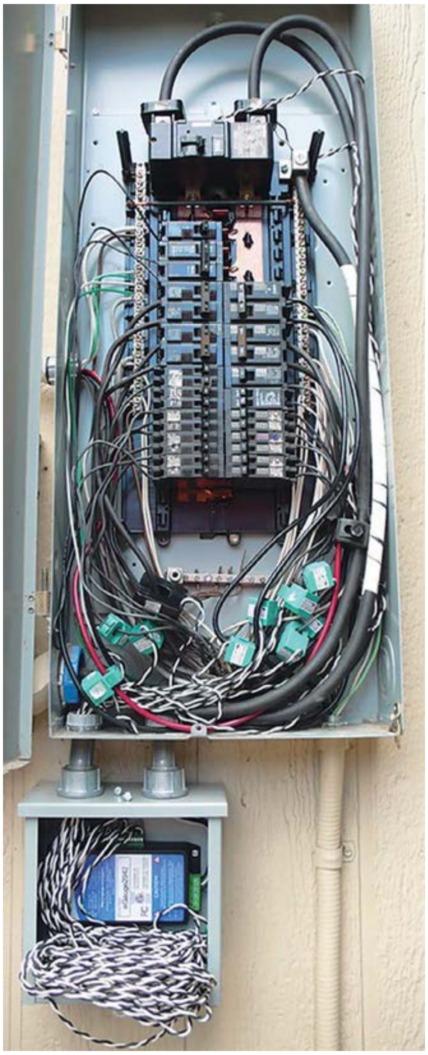
No display comes with the unit—the real-time data is viewed via computer or smartphone. Data can be downloaded to Excel or other data management software for further analysis.

One unique twist on Wattvision's approach to energy monitoring is the ability to "share and compare" your use with the electricity consumption of other Wattvision users. This has the opportunity to encourage engagement about energy consumption. The Wattvision unit is available on the company's website.

Home Energy Monitors Compared

Model	Manufacturer, website	Cost[1] (MSRP)	Sensor Style	Maximum Circuits[2]	Sensor Installation Location	Volt/Amp Options[3]
eGauge	**eGauge** egauge.net	$636	CT	12	Inside electrical panel	120/240 V, 200 A
eMonitor	**Powerhouse Dynamics** powerhousedynamics.com	500	CT	44	Inside electrical panel	120/240 V, 200 A
EnviR	**Current Cost** currentcost.net	129	CT	10	Inside electrical panel	120/240 V, 200 A
LGate	**Locus Energy** locusenergy.com	600	CT	2	Outside electrical panel	120/240 V, 200 A
OWL	**2 Save Energy** theowl.com	100	CT	1	Outside electrical panel	120/240 V, 200 A
PowerCost Monitor	**Blue Line Innovations** bluelineinnovations.com	109	Pulse	1	On utility kWh meter	120/240 V, 200 A
The Energy Detective	**Energy, Inc.** theenergydetective.com	200	CT	4	Inside electrical panel	120/240 V, 200 A
Wattvision	**Wattvision** wattvision.com	249	Pulse	1	On utility kWh meter	120/240 V, 200 A

1) All info for base model only; 2) May require accessories; 3) Other voltage options may exist.



Courtesy eGauge

If you're not comfortable with digging into your electrical panel to install a monitoring system, consider hiring a licensed electrician.

Monitoring the Monitors

A recent study by Advanced Energy of North Carolina tested the EnviR, PowerCost monitor, and TED. The side-by-side comparison illustrates differences in the monitors' installation, reliability, and reporting accuracy (see bit.ly/MonitorTest).

Happy Metering!

Although it falls outside of the scope of single-residence monitoring, one group of products in particular is worth mentioning—The E-Mon D-Mon (emon.com), which has been a workhorse of the electrical monitoring industry. The E-Mon products are targeted at commercial, industrial, multi-tenant facilities. Many electricians are familiar with these robust revenue-grade metering products, which start at $400.

But for monitoring a single source, the Blueline, OWL, or Wattvision products are good candidates. For monitoring a few circuits with some optional features, the EnviR and TED will probably do the trick. With more rigorous monitoring requirements, the eGauge, eMonitor, or LGate are the meters worth considering.

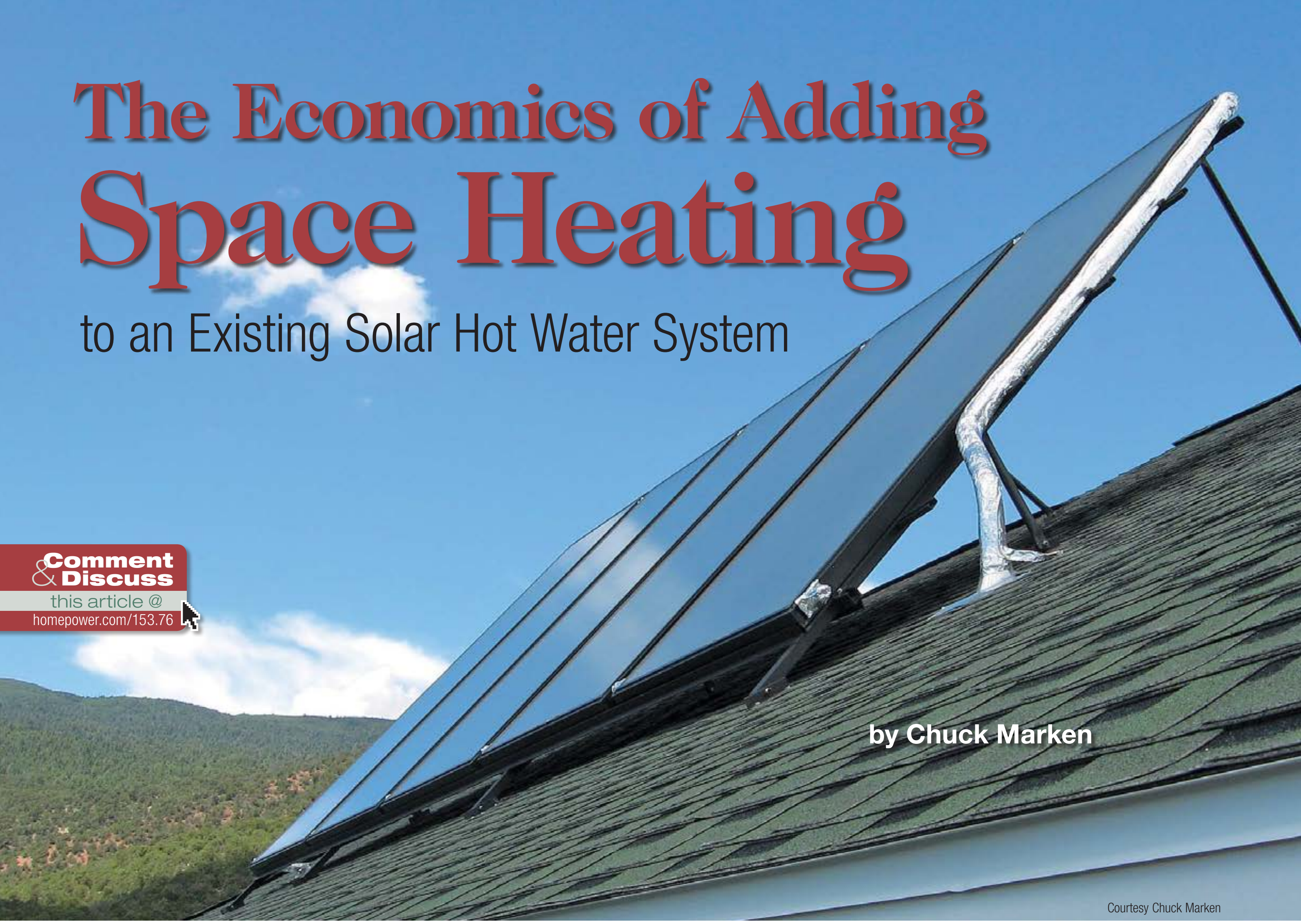
Access

Erika Weliczko (erika.weliczko@homepower.com) lives in Cleveland, Ohio, where she operates REpower Solutions. Erika is a licensed electrical contractor, and is a NABCEP Certified Solar PV and Small Wind Installer.

Revenue Grade	Local Display	Internet Connection Required	Smartphone Capability or App	RE-System Compatible	Additional Fee for Monitoring Service[2]	Interact with Thermostat, Controls, or Sensors	Data Storage	Dedicated Circuit Required	Warranty (years)
No	No	No	Browser	Yes	N/A	Yes; SMA sensors	Locally, 30 years	Yes; 240 V, 15 A	2
No	No	Yes	App	Yes	Yes: $173 for 2 yrs.	Yes; thermostats	Online	Yes; 120 V, 15 A	2
No	Yes	No	No	Yes	Optional	No	Locally, 30 days	No	1
No	No	Yes	Browser	Yes	5 yrs.; included with purchase	Yes; pulse sensors	Online	Yes; 120 V, 15 A	5
No	Yes	No	App	Yes	N/A	No	Locally, 2 months	No	1
No	Yes	No	No	No	N/A	No	Locally, cumulative, resettable	No	1
No	Optional	No	App	Yes	N/A	No	Locally, 10 years	Yes, 120 V, 15 A	1
No	No	Yes	App	No	No; 3 months available	No	Online, 3 months	No	1

The Economics of Adding Space Heating

to an Existing Solar Hot Water System



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by Chuck Marken

Courtesy Chuck Marken

When it comes to using active solar heating systems with a conventional home heating system, adding on to a solar domestic water heating system can be a viable solution—but the costs and benefits should be carefully considered.

Drainback and antifreeze solar water heating systems are easily adapted as an add-on home heating system—an additional one or two solar collectors serve the home's space-heating load. Balance-of-system components needed include a larger (or second) storage tank, pump, control, and heat exchanger. (Locations in which simpler direct forced-circulation SWH systems or passive water heaters usually have little or no need for space heating.)

To understand the economics of each system, the local winter solar resource and length of the winter heating season need to be examined. A common SWH system has an 80-gallon storage tank with two 4- by 8-foot collectors. Such a system might have an installed cost of $8,000.

Adding a third collector for space heating and replacing the tank with a 120-gallon tank brings the cost to $11,000. The first two–collector system cost $4,000 per collector, and the third collector adds $3,000. Let's assume that the heating season of the installation is six months, thus, the third collector is only used only half of the year.

However, because we're installing this system in a location with a lower winter solar resource (where half of the yearly average resource is available), the value of the third collector doesn't stack up to the first two. The math shows that the third collector gets only one-quarter of the useful production of the first two (0.5 for half the resource × 0.5 for half the year = 0.25). To have the same benefit-to-cost ratio of the original system, the add-on in this simple scenario would need to cost $1,000—not $3,000.

But the economics of the system change with location. Let's look at the add-on system scenarios in four different regions of the United States (see the "Add-On Heating System Economics" table). The Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors (bit.ly/SolarData) provides the solar resource and winter length information needed to evaluate active solar heating systems.

The heating season length is estimated using the heating degree days (HDD) per month in the solar radiation data. In the cities selected, the heating season varies from seven to nine months if we discount any month with fewer than 100 HDDs. (This is reasonable, since a month that measures fewer than 100 HDDs translates to about 3 HDD per day, for which even a small amount of passive solar gain will meet this need. If not, that's what sweaters are made for.)

The average solar resource is listed as "kWh per square meter" (aka peak sun-hours) per day for five different tilt angles. The data is given with a monthly and cumulative average. To compute the solar resource for the heating season only, the heating season months' resources are added and sum is divided by the number of months.

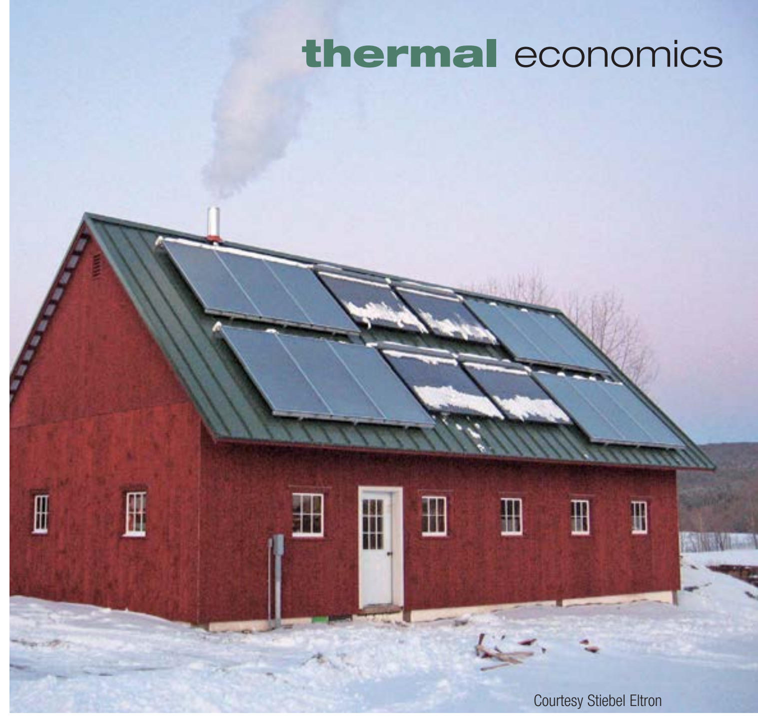
We used the "latitude plus 15° tilt" row for this evaluation, since, in most of the United States, a higher tilt angle gives better winter performance. However, in a few areas, such as the Pacific Northwest, heating season average peak sun-hours per month is slightly better at a tilt angle equal to the location's latitude. This is due to the extremely cloudy winters.

In all cases, during the coldest three months of the year the system benefits from having a greater tilt angle. The latitude plus 15° angle also provides a hedge against the possibility of summer overheating. Note that the "Add-On Heating System Economics" table contains the data gleaned from the U.S. Department of Energy's *Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors* (aka the "Redbook") and has a multiplier to represent the relative benefit-to-cost ratio of additional collectors required for space heating only.

The multiplier applies to the value of solar home heating collectors when compared to collectors used exclusively for domestic solar water heating—a 12-month job. To calculate the multiplier, first divide the heating season solar resource by the annual resource. Then, multiply that value by the length of the heating season divided by 12 months. For Seattle, the math would be 2.8 ÷ 3.5 = 0.8; 0.8 × (8 ÷ 12) = 0.53. The multipliers are somewhat misleading in that the average heating season sun-hours are higher than the sun-hours of the midwinter months. This is particularly true in the case of Seattle, which has only 1.6 average daily sun-hours when November, December, and January are factored in together. Essentially, there is almost no solar resource to harvest and the multiplier would fall to 0.31 for those months, close to the 0.25 of the first simple scenario outlined at the beginning of the article. Contrast this with Alamosa, Colorado, where these three months average 5.9 sun-hours, and the multiplier is 0.73.

What's an HDD?

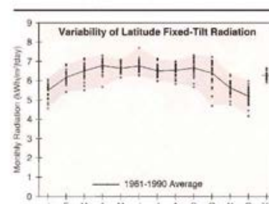
A heating degree day (HDD) is calculated by adding the high and low temperatures of each day and dividing by two. If this average daily temperature is below 65°F, a heating degree day is recorded for each degree below 65°F. An example would be a day with a high of 77°F and a low of 50°F—this day would be recorded as having 1.5 HDDs. Any day with an average temperature above 65°F has zero HDDs. HDDs are an excellent resource for evaluating the climate and estimating heating costs in any location. Note that HDDs in the "Redbook" are given in degrees Celsius.



Courtesy Stiebel Eltron

This solar heating system uses both flat-plate and evacuated-tube collectors to supply radiant heat for the barn, as well as a house and office. The system's size, seasonal resource, and application all play an important part in its thermal and economic viability.

Although the U.S. Department of Energy's "Redbook" is out of print, users can download flat-plate and concentrating collector solar radiation data for select cities at rredc.nrel.gov/solar/pubs/redbook.



Alamosa, CO

WBAN NO. 23061

LATITUDE: 37.45° N
LONGITUDE: 105.87° W
ELEVATION: 2297 meters
MEAN PRESSURE: 772 millibars

STATION TYPE: Primary

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	3.0	4.0	5.2	6.4	7.1	7.7	7.2	6.5	5.6	4.5	3.3	2.7	5.3
	Min/Max	2.6/3.2	3.6/4.4	4.5/5.6	5.4/6.8	6.6/7.6	7.1/8.8	6.6/7.9	5.8/6.9	4.9/6.2	3.6/4.9	3.0/3.6	2.4/3.0	5.0/5.6
Latitude -15	Average	4.7	5.5	6.2	6.9	7.1	7.4	7.0	6.8	6.5	5.9	4.9	4.4	6.1
	Min/Max	3.9/5.1	4.9/6.1	5.3/6.8	5.8/7.4	6.6/7.6	6.8/8.4	6.5/7.7	6.1/7.3	5.6/7.2	4.4/6.6	4.2/5.5	3.6/4.9	5.8/6.5
Latitude	Average	5.5	6.2	6.5	6.8	6.6	6.8	6.5	6.5	6.7	6.4	5.6	5.2	6.3
	Min/Max	4.6/6.1	5.4/6.8	5.5/7.2	5.7/7.3	6.2/7.1	6.3/7.7	6.0/7.1	5.8/7.0	5.7/7.3	4.7/7.2	4.8/6.3	4.2/6.0	5.9/6.6
Latitude +15	Average	6.0	6.5	6.4	6.3	5.8	5.7	5.6	5.9	6.4	6.5	6.0	5.7	6.1
	Min/Max	4.9/6.6	5.6/7.3	5.4/7.1	5.3/6.8	5.4/6.2	5.3/6.5	5.2/6.2	5.3/6.3	5.4/7.0	4.7/7.4	5.0/6.8	4.5/6.7	5.7/6.5
90	Average	5.7	5.6	4.7	3.7	2.9	2.5	2.6	3.2	4.3	5.2	5.5	5.5	4.3
	Min/Max	4.6/6.2	4.8/6.7	4.0/5.2	3.2/4.1	2.7/3.0	2.4/2.7	2.4/2.8	2.9/3.4	3.7/4.7	3.7/5.9	4.4/6.1	4.2/6.7	3.9/4.5

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	4.9	6.2	7.6	9.2	10.0	10.8	9.8	9.0	8.3	7.0	5.2	4.5	7.7
	Min/Max	3.9/5.4	5.3/7.1	6.1/8.6	7.4/10.2	8.8/10.9	9.7/12.3	8.9/11.3	7.8/10.0	6.5/9.2	5.0/8.0	4.3/5.9	3.5/5.2	7.1/8.3
Latitude -15	Average	6.1	7.4	8.4	9.6	10.1	10.7	9.8	9.4	9.0	8.0	6.4	5.7	8.4
	Min/Max	4.8/6.8	6.3/8.4	6.7/9.5	7.7/10.7	8.9/11.1	9.6/12.2	8.9/11.4	8.1/10.3	7.1/10.0	5.6/9.3	5.2/7.2	4.4/6.6	7.7/9.0
Latitude	Average	6.8	7.9	8.7	9.6	9.8	10.3	9.5	9.2	9.1	8.4	7.0	6.3	8.5
	Min/Max	5.3/7.6	6.7/9.0	6.9/9.8	7.6/10.7	8.7/10.8	9.2/11.7	8.6/11.0	7.9/10.2	7.1/10.2	5.8/9.7	5.6/7.8	4.8/7.4	7.8/9.2
Latitude +15	Average	7.2	8.1	8.6	9.2	9.3	9.6	8.9	8.8	9.0	8.5	7.3	6.7	8.4
	Min/Max	5.6/8.0	6.8/9.2	6.8/9.7	7.4/10.3	8.2/10.2	8.6/10.9	8.0/10.3	7.6/9.7	7.0/9.9	5.8/9.8	5.9/8.2	5.1/7.9	7.6/9.1

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	7.2	8.1	8.7	9.7	10.2	11.0	10.0	9.4	9.2	8.5	7.3	6.8	8.8
	Min/Max	5.7/8.1	6.8/9.2	6.9/9.8	7.7/10.8	9.1/11.2	9.9/12.5	9.1/11.6	8.1/10.4	7.2/10.2	5.9/9.8	5.9/8.3	5.2/8.1	8.0/9.5

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	4.8	5.0	4.7	5.0	5.4	6.2	5.5	5.0	5.1	5.2	4.8	4.6	5.1
	Min/Max	3.5/5.7	3.8/6.0	3.3/5.7	3.3/5.9	4.3/6.3	5.1/7.4	4.7/6.9	4.0/5.9	3.5/6.3	2.8/6.4	3.5/5.8	3.2/5.6	4.4/5.7
1-Axis, N-S Horiz Axis	Average	3.7	4.8	5.7	6.9	7.4	8.4	7.4	6.7	6.5	5.5	4.0	3.4	5.9
	Min/Max	2.6/4.6	3.6/5.9	3.8/6.9	4.6/8.3	5.8/8.8	6.9/9.9	6.2/9.4	5.4/8.1	4.2/8.0	3.0/7.0	2.8/4.9	2.3/4.2	5.0/6.6
1-Axis, N-S Tilt=Latitude	Average	5.3	6.2	6.5	7.2	7.2	7.9	7.0	6.8	7.2	6.8	5.6	5.0	6.5
	Min/Max	3.8/6.4	4.7/7.6	4.4/7.9	4.8/8.6	5.7/8.5	6.4/9.3	5.9/8.9	5.5/8.1	4.7/8.8	3.7/8.5	4.0/6.8	3.4/6.1	5.5/7.4
2-Axis	Average	5.7	6.3	6.5	7.3	7.6	8.6	7.5	7.0	7.2	6.8	5.9	5.4	6.8
	Min/Max	4.1/6.9	4.8/7.8	4.4/8.0	4.9/8.7	6.0/9.0	7.0/10.1	6.3/9.6	5.6/8.4	4.7/8.8	3.7/8.6	4.2/7.1	3.7/6.6	5.7/7.7

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-9.6	-5.3	0.2	5.1	10.2	15.2	18.3	16.9	12.7	6.4	-1.2	-8.1	5.1
Daily Minimum Temp	-19.9	-15.1	-9.0	-4.7	0.4	5.0	8.8	7.4	2.6	-4.1	-10.9	-18.1	-4.8
Daily Maximum Temp	0.7	4.4	9.3	14.8	20.0	25.4	27.8	26.2	22.6	16.9	8.6	1.9	14.9
Record Minimum Temp	-45.6	-37.2	-28.9	-21.1	-11.7	-4.4	1.1	-1.7	-9.4	-23.3	-34.4	-41.1	-45.6
Record Maximum Temp	16.7	18.9	22.8	26.7	29.4	33.9	35.6	32.2	30.6	27.2	21.7	16.1	35.6
HDD, Base 18.3°C	866	663	563	398	252	97	23	54	170	371	585	818	4861
CDD, Base 18.3°C	0	0	0	0	0	3	22	9	0	0	0	0	34
Relative Humidity (%)	71	67	57	48	47	46	56	60	56	55	64	70	58
Wind Speed (m/s)	3.4	3.4	4.7	5.1	4.8	4.5	3.6	3.4	2.7	3.4	4.0	2.6	3.8

45

Courtesy DOE

Average Daily Solar Insolation & Heating Degree Days

Alamosa, CO

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Insolation (kWh/m^2/day)*	6.0	6.5	6.4	6.3	5.8	5.7	5.6	5.9	6.4	6.5	6.0	5.7	6.1
Heating degree days	866	663	563	398	252	97	23	54	170	371	585	818	4,861

Madison, WI

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Insolation (kWh/m^2/day)*	3.6	4.4	4.6	4.6	4.8	4.9	5.0	5.0	4.6	4.0	2.9	2.8	4.3
Heating degree days	844	691	563	327	163	38	7	21	93	277	493	746	4,263

Richmond, VA

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Insolation (kWh/m^2/day)*	3.9	4.4	4.9	5.0	4.9	4.9	4.8	5.0	4.9	4.8	4.1	3.6	4.6
Heating degree days	504	409	293	134	34	0	0	0	13	129	257	429	2,202

Seattle, WA

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Insolation (kWh/m^2/day)*	1.7	2.5	3.5	4.1	4.5	4.5	4.9	4.9	4.5	3.2	1.8	1.4	3.5
Heating degree days	429	334	334	263	171	80	32	36	87	210	328	422	2,727

= Heating season months (>100 HDDs)

Source: Redbook (rredc.nrel.gov). *Insolation for flat-plate collectors facing south at latitude + 15° fixed tilt

Add-On Heating System Economics

City	Region	Avg. Insolation (kWh/m^2/day)	Heating Season (Months)	Avg. kWh/m^2/day Heating Season	Multiplier
Alamosa, CO	High Desert Southwest	6.1	9	6.2	0.76
Madison, WI	Northern Midwest	4.3	8	4.0	0.62
Richmond, VA	Mid-Atlantic	4.6	7	4.4	0.56
Seattle, WA	Pacific Northwest	3.5	8	2.8	0.53

The cost of the extra installed collectors, the value of the fuel displaced, and available incentives will also affect the relative value of a solar space-heating system. Having a summer application for the extra collectors—such as heating a pool or hot tub—makes the extra collectors as valuable as the domestic solar water heating system if the cost is the same per collector.

Other Options

Even larger space-heating systems with massive storage are influenced by the diminished heating season resource and limited months of use, but many of these systems have lower costs per collector due to their economy of scale. Solar space-heating systems (and solar domestic water heating) are usually designed with a day-to-day cycle of energy gathering, storage, and distribution. A design that calls for more heat storage than the collectors can supply in a day relies on banking the energy in thermal mass. This semi-seasonal storage strategy could increase the benefit-to-cost ratio of solar heating systems.

Simple, lower-cost air collectors can have a reduced cost per collector. The collectors are less expensive per square foot and installations are simple compared to liquid collector heating systems. These simple systems can be wall-mounted vertically. In areas with snowfall, wall-mounted air collectors further benefit from the reflected winter sunlight.

PV systems can also be used for heating. Just a few years ago, there was no question that solar thermal collectors were more economical than a PV system for heating domestic water or a home. The ratio of benefit-to-cost value of the two technologies was about 10:1 or more in favor of

Heating System Compatibility

All heating systems are compatible with solar retrofits, but some offer less-costly alterations. Radiant floor systems with the tubing embedded in concrete are normally the best match for solar system integration. The lower temperature required by the radiant floor results in higher collector efficiency, since less heat is lost from the collectors to the surrounding cold atmosphere, and the thermal mass in the concrete provides some storage for night usage. Other common heating systems, like hydronic baseboard and forced-air furnace systems, can also be retrofitted with solar heating systems—but additional storage (at an additional cost) will usually be required. The storage temperature will need to be higher to match the normal output temperatures of these systems, resulting in reduced collector efficiency.

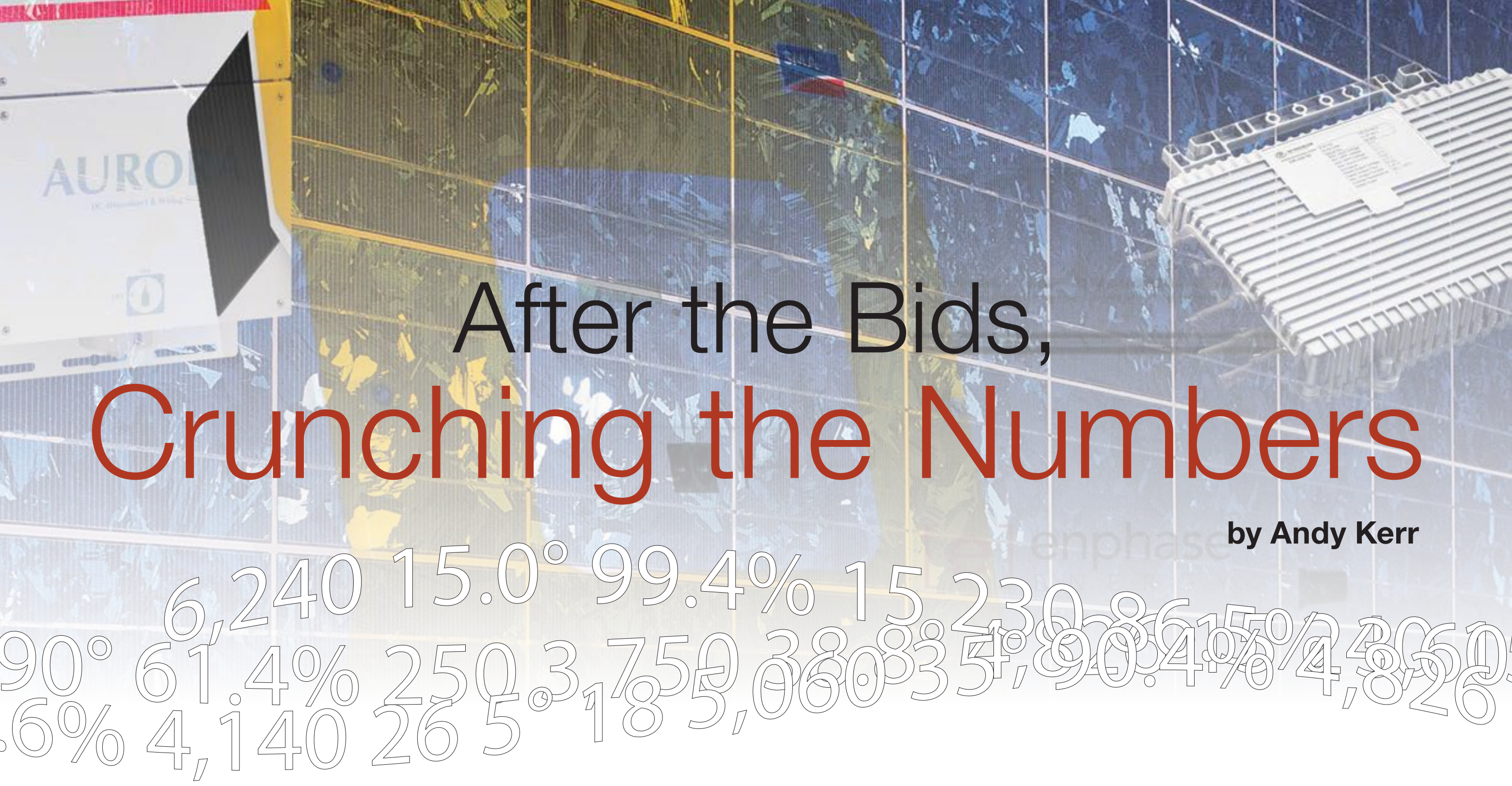
Courtesy Chuck Marken

Simple and inexpensive solar hot air collectors can often augment space heating systems more economically than hot water collectors.

SWH collectors over PV modules. This has changed in the last decade—PV prices have come down dramatically, and the cost of SWH installations has increased due to a more than eightfold copper cost increase. A grid-tied PV system, which produces energy year-round that can be "banked" by the utility, is a better value than an active solar space heating system in locations with significantly reduced winter solar resources.

Access

Chuck Marken (chuck.marken@homepower.com) is a *Home Power* contributing editor and solar energy trainer/instructor. Chuck's 30-plus-year career as a solar installer included installing, repairing, or altering more than 5,000 solar energy systems, which included domestic water, pool, and space heating systems, and on- and off-grid PV systems. Chuck has taught classes and workshops for Solar Energy International, Sandia National Labs, and numerous other educational and nonprofit organizations in the United States.



After the Bids, Crunching the Numbers

by Andy Kerr

The bids are in, but then what? Andy Kerr examines how you can fairly compare different PV system bids to optimize your investment.

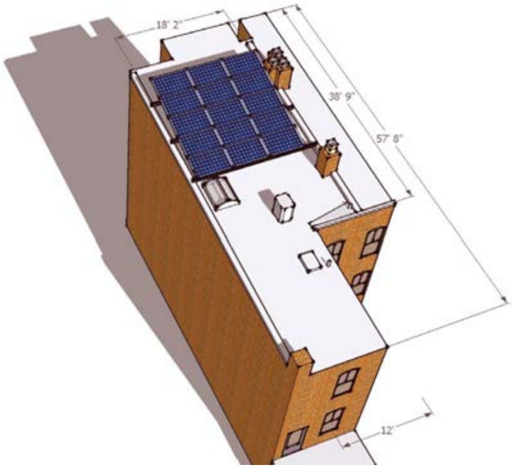
You should no more buy a PV system for your house based only on the lowest installed cost than you should buy a water heater or refrigerator in such a manner. For energy-consuming appliances, it's critical to consider ongoing operating costs. But for energy-producing equipment—like a PV system—once you are satisfied with the qualifications of your potential installers, considering operating efficiency of the presented systems is crucial.

As a way to provide comparative information on the cost-effectiveness of batteryless, grid-tied PV systems, DC Solar United Neighborhoods (DC SUN), a coalition of solar cooperatives, solicited bids from four installers for a rooftop system in the Capitol Hill neighborhood of Washington, DC. The results shown are specific to one homeowner and rooftop scenario, but DC residents can use the customizable spreadsheet (at homepower.com/webextras) to assess the finances of installing your own PV system. (The worksheet can also be modified for the circumstances in any location.)

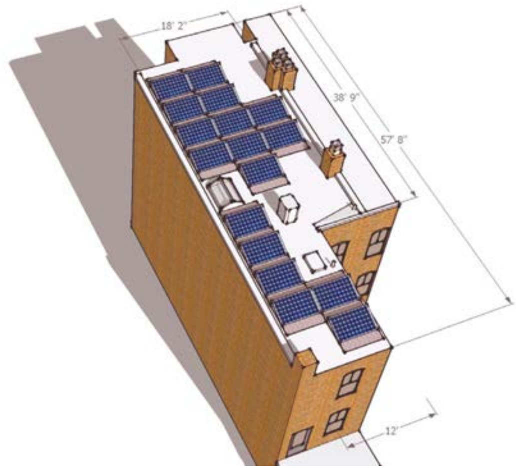
In this comparison, the constant is the slope and size of the roof, which in this case is the flat roof of a row house, found commonly in many DC neighborhoods. The variables are the installers and their bids, some of whom offered more than one equipment and/or financing option. The proposal analyses included:

There's no prescriptive path for solar-electric systems, since each site is different. Several configurations were proposed for this row house's rooftop (see illustrations, opposite page).

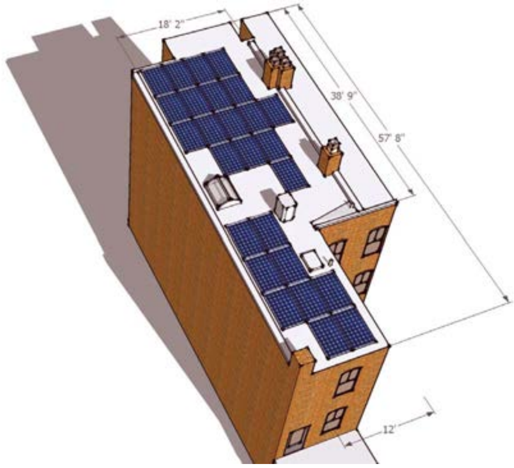
Vendor D Options



Purchased I-Beam Array
Tilt = 14.5°; 15, 240 W modules with microinverters for 3.6 kW total; Est. production = 4,477 kWh per year



Purchased Tilted, Ballasted Array
Tilt = 15°; 17, 240 W modules with microinverters for 4.08 kW total; Est. production = 5,086 kWh per year



Purchased Flat-Ballast Array
Tilt = flat; 26, 240 W modules with microinverters for 6.24 kW total; Est. production = 6,983 kWh per year

Module Tilt & Impacts on Production

Washington, DC, is known for its row houses—two- or three-story structures that are narrow and deep. Roof space is sparse, and fitting enough PV modules on a rooftop to zero out a household's annual electricity usage can be challenging.

If modules are mounted at a tilt optimized for annual production—which is usually somewhat close to the degree of latitude—the rows of modules on flat roofs have to be widely spaced to avoid shading each other.

Reducing the tilt somewhat decreases output, but allows more modules in a given space. In this case, deviating from what is generally considered the optimal tilt can provide more net production since more modules can be placed on the roof—as long as interrow shading is avoided (see "Methods: Interrow Shading" in *HP151*).

Vendor D offered three options (see illustrations at left): tilting the PV modules on I-beams that would lay across the "party" walls to avoid any weight on the roof; a tilted, ballasted array; and an array that was mounted flat on the roof, resulting in an estimated 4,477, 5,086, and 6,983 kWh per year production, respectively. Each option was progressively more expensive initially, but progressively more profitable in terms of net present value and internal rate of return. If you can afford to make the larger investment, the payoff will also be larger.

Production vs. Array Tilt for Washington, DC

Tilt	% of Max. Production	Notes
90°	61.4%	Vertical
45°	98.8%	12:12 pitch roof is 45°
40°	99.4%	10:12 pitch roof is 39.8°
38.8°	99.6%	Latitude of Washington, DC
35°	100.0%	Accounts for climate & annual changes in the sun's position
25°	99.4%	6:12 roof pitch is 26.6°
20°	98.1%	4:12 roof pitch is 18.4°
15°	96.2%	3:12 roof pitch is 14.0°
10°	93.6%	2:12 roof pitch is 9.7°
5°	90.4%	1:12 roof pitch is 4.8°
0°	86.5%	Horizontal

Source: PVWatts

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Example Results (With District of Columbia Grant)

Initial Costs	How To Generally Interpret
Acquisition method: configuration	—
Gross system cost	—
Net cost (after subsidies) for purchase, or initial cost for lease	Generally, lower is better, but SP, IRR & NPV are better metrics
Annual lease payment	NPV & IRR are better metrics to consider
Annual increase in lease payment	NPV & IRR are better metrics to consider
Cost per watt	Lower is better; cost per kWh is better, as it includes system efficiency
Cost per kWh per year	Lower is better

Production Results

Nameplate Rating (DC Watts)	Size of array
Portion of consumption offset	Close to 100% is better unless anticipated loads are higher (electric car) or lower (improved efficiency)

Financial Results

Simple payback (SP), years	Year cash flow turns positive
Internal rate of return (IRR)	Higher is better
Net present value (NPV)	Higher is better

Residential Property Value Increase

Estimated increased property value ($6.00 per nameplate watt)	Higher is better
Estimated increased property value ($7.60 per nameplate watt)	Higher is better
Estimated price premium (low; 21x foregone electricity cost)	Higher is better
Estimated price premium (high; 26X foregone electricity cost)	Higher is better

- **Financial return.** Simple payback (SPB), net present value (NPV) and internal rate of return (IRR) were all calculated. NPV and IRR are sophisticated financial metrics that consider the time value of money and are therefore more useful.

- **Production.** Estimated annual production is a function of local seasonal climatic conditions, PV array size, and DC-to-AC derate values (wiring losses, module soiling, inverter efficiency, etc).

- **Energy Cost.** Both dollars per nameplate watt and dollars per kilowatt-hour per year were calculated. The latter is more useful, as it factors in overall PV system efficiency.

Methodology

So as not to prejudice the evaluation by having an adequately informed consumer, no direction was given to the vendors as to the goal of the PV system, be it to just offset annual household electricity consumption or to maximize energy production given the available space. Nor was a preference expressed for buying or leasing a system. While the competing vendors saw the same roof, each proposed different configurations. Though most all PV bid packages came with their own presentations of the financial benefits the homeowner would receive, each made different enough assumptions as to make any across-the-board comparisons useless without further analysis.

To compare the competitors, the bids were analyzed using PVWatts (see Access). The same key variables were extracted from the bids: number of PV modules and module rating to determine DC nameplate rating; inverter type (string or microinverters) to determine inverter efficiency; and module tilt to determine array efficiency. Except for the case of microinverter efficiency, all the PVWatts default derates were used. The PVWatts results were used in the financial calculations.

Interpreting the Results

As you review the "Results" table, keep in mind:

- With net metering, sizing your system to get as close as possible to producing 100% of your annual electricity consumption is the most cost-effective plan. Both your PV system's production and your energy consumption vary each year, so "close" is the best you can do. (And as appliances are replaced or added, consumption will change.)

- The negative net present value (NPV) for most options is a result of the owner's savings investment rate, which

Vendor A	Vendor B				Vendor C	Vendor D			Averages	
Purchase	Purchase	Lease: 0% down plan	Lease: initial payment plan	Lease: prepay plan	Purchase	Purchase: I-beam	Purchase: tilt ballast	Purchase: flat ballast	Purchase options	Lease options
$19,382	$23,196	N/A	N/A	N/A	$22,995	$24,975	$25,500	$34,320	$25,061	N/A
$4,672	$8,110	$0	$3,639	$7,278	$4,677	$7,747	$7,005	$9,004	$6,876	$3,639
N/A	N/A	$816	$516	$0	N/A	N/A	N/A	N/A	N/A	$444
N/A	N/A	3.9%	0.0%	0.0%	N/A	N/A	N/A	N/A	N/A	1.3%
$1.25	$1.96	N/A	N/A	N/A	$0.92	$2.15	$1.72	$1.45	$1.57	N/A
$1.06	$1.66	N/A	N/A	N/A	$0.80	$1.73	$1.38	$1.29	$1.27	N/A
3,750	4,140	4,140	4,140	4,140	5,060	3,600	4,080	6,240	4,478	N/A
92%	99%	99%	99%	99%	117%	102%	115%	159%	111%	N/A
7	10	Never	12	10	6	10	8	8	8	11
16.23%	9.46%	#DIV/0!	29.20%	10.83%	20.35%	10.35%	13.46%	14.39%	14.04%	10.02%
$7,431	$5,024	-$2,130	$2,579	$5,823	$10,571	$5,701	$8,199	$11,842	$8,128	$2,091
$22,500	$24,840	N/A	N/A	N/A	$30,360	$31,600	$24,480	$37,440	$26,870	N/A
$28,500	$31,464	N/A	N/A	N/A	$38,456	$27,360	$31,008	$47,424	$34,035	N/A
$13,296	$14,297	N/A	N/A	N/A	$16,802	$14,663	$16,653	$22,901	$16,435	N/A
$16,462	$17,701	N/A	N/A	N/A	$20,802	$1,815	$20,618	$28,354	$20,349	N/A

we assumed to be 4%. In all cases, NPV is more than $0, so one would be that much "richer" today for having made the investment. In the case of 0%-down leasing, one would be that much "poorer" for making such an investment. If you don't have the cash or can't get a loan, then get a $0-down lease, as you will lose less money on such an investment than paying the "noninvestment" of your monthly electric bill.

- The highest NPV and/or IRR—or shortest simple payback (SP)—should not be the only factors you consider when choosing a vendor. Also make sure to consider the quality of equipment and warranties offered, and the installer's experience and follow-up service capabilities. These factors must be qualitatively evaluated and they are not easily quantified for a NPV or IRR analysis.

- In the IRR for Vendor B, "DIV/0!" is a Microsoft Excel error code for division by zero. Excel's IRR function requires at least one negative number (more cash out than in) during one investment year. The 0% down leasing option is cash-flow positive from the start (compare SP and NPV instead).

- Because it accounts for overall system efficiency, the metric of $/kWh/year is more useful than $/nameplate watt.

The example row house roof, with the Capitol Power Plant in the background—the largest source of pollution in the nation's capital.

Courtesy Corey Ramsden (2)

Unfortunately, when the air-conditioning compressor was placed, no thought was given to the placement of future PV modules.

Courtesy Corey Ramsden (2)

Configuration Options

Company	No. of Modules	Module Rating (W)	Array Size (W)	Tilt	PVWatts Est. Production (kWh/Yr.)*	Inverter Type
A	15	250	3,750	14.0°	4,413	Aurora string inverter
B	18	230	4,140	14.0°	4,872	Not specified
C	22	230	5,060	10.0°	5,819	SMA string inverter
D1	15	240	3,600	14.5°	4,477	Enphase microinverters
D2	17	240	4,080	15.0°	5,086	Enphase microinverters
D3	26	240	6,240	Flat	6,983	Enphase microinverters

*Based on PVWatts data for Sterling, VA, and using the default derate values (DC-to-AC derate of 0.77). In systems using microinverters (which improve system availability, and negate the module mismatch and DC wiring derates), a DC-to-AC derate of 0.81 was applied.

Leasing

From purely a financial standpoint, our results show that a prepaid lease of a PV system might be the most financially advantageous. However, leases are a relatively new option and have not been well-tested in the marketplace. Make sure you understand all the ins and outs of a lease—such as liability, performance guarantees, and access for maintenance—before you sign. There is also some risk that the leasing company might go out of business (which doesn't necessarily mean you end up with a free system). Leasing may be a preferred option if you cannot immediately absorb incentives in the form of tax credits (they may be carried over to future years).

The leasing company will contract another party to install the system, and will receive all of the incentives. Depending upon which state you live in, a solar leasing company may either "lease" you the PV equipment on your roof, in which you receive the benefits of its production, or sign a power purchase agreement (PPA) with you, where you contract to pay for the electricity at a set rate, usually below, or at least at the current utility retail rate. In either case, you don't own the system or have to maintain it. At the end of the lease term, you sometimes are able to buy the system at a "salvage value" cost or it will be removed by the hardware owner.

There are two other major financial benefits to leasing or purchase beyond IRR and NPV:

- Electricity prices are locked in. You no longer are affected by utility rate increases. In fact, if rates rise, your actual NPV and IRR will improve.
- In most locations, a PV system increases the home's resale value (probably more if you own, rather than lease, the system), possibly enough to offset most or all of your initial capital outlay for the system.

Access

Andy Kerr (andykerr@andykerr.net) spends part of his year living in the Capitol Hill neighborhood of Washington, DC, where he advocates for nature and writes about energy efficiency and renewable energy.

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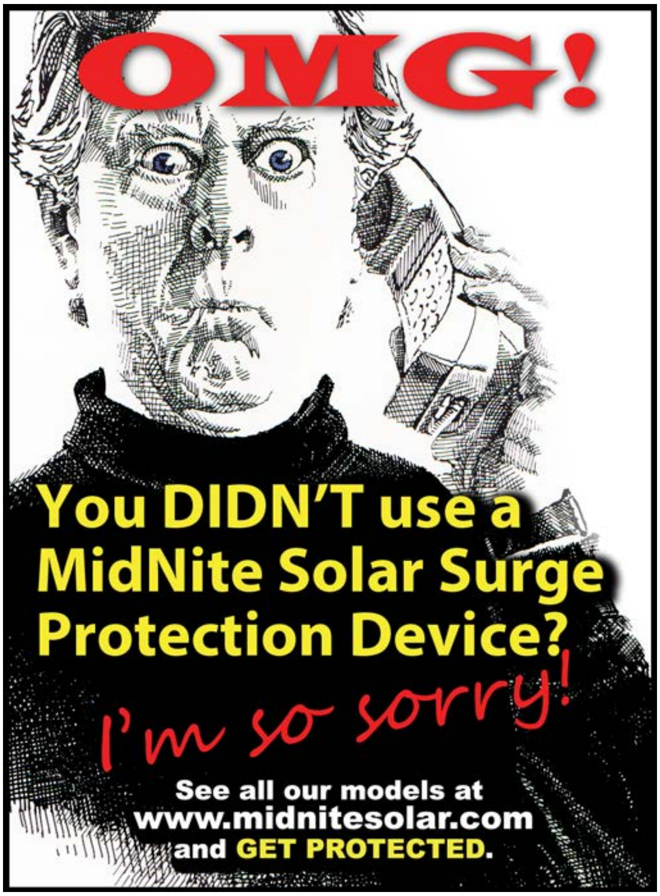
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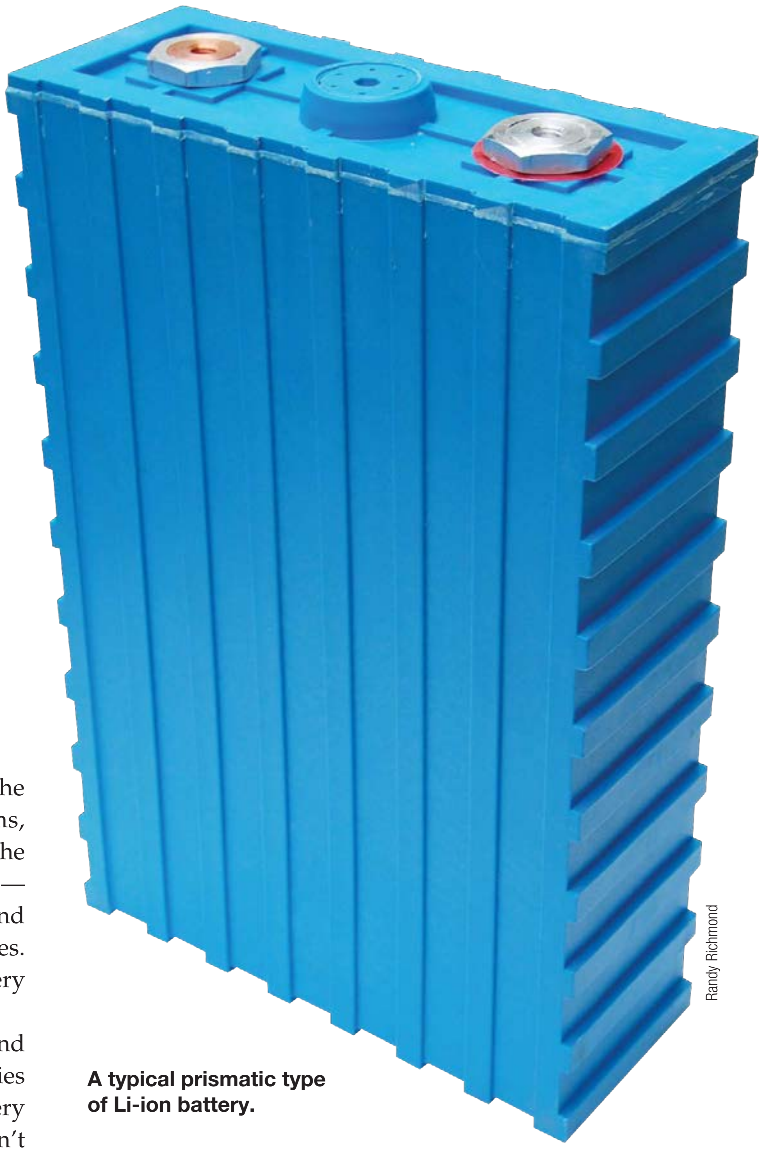
Lithium-Ion Batteries for Off-Grid Systems

Is lithium-ion technology a good match for off-grid RE systems?

by Randy Richmond



A typical prismatic type of Li-ion battery.

For decades, lead-acid battery technology has been the mainstay of battery-based renewable energy systems, providing reliable storage and ample energy capacity. The most common battery used—flooded lead-acid (FLA)—requires regular watering to maintain electrolyte levels and venting to avoid the buildup of hydrogen and sulfuric gases. Additionally, FLAs are large and heavy, making battery replacement a challenging task for some systems.

With all of the recent action in the electric vehicle and personal electronics industries, lithium-ion (Li-ion) batteries have gained much attention. Here, we examine Li-ion battery pros and cons, and discover why most system owners won't be swapping out their FLA batteries anytime soon.

What's Behind Li-Ion?

"Lithium-ion" refers to a variety of lithium-based battery chemistries. Each chemistry has its strong and weak points, which means certain types of chemistries are better-suited for particular applications. There continues to be new lithium-based chemistries being developed (such as lithium-air), but it is too early to tell which will become commercially viable. See the "Lithium Battery Technologies" table for details on a few of the more common types of Li-ion chemistries.

Lithium Battery Technologies

Chemical Name	Material	Abbreviation	Applications
Lithium cobalt oxide	$LiCoO_2$	LCO	Cell phones, laptops, cameras
Lithium manganese oxide	$LiMn_2O_4$	LMO	Power tools, EVs, medical, hobbyist
Lithium iron phosphate	$LiFePO_4$	LFP	Power tools, EVs, medical, hobbyist
Lithium nickel manganese cobalt oxide	$LiNiMnCo0_2$	NMC	Power tools, EVs, medical, hobbyist
Lithium nickel cobalt aluminum oxide	$LiNiCoAlO_2$	NCA	EVs, grid storage
Lithium titanate	$Li_4Ti_5O_{12}$	LTO	EVs, grid storage

Source: batteryuniversity.com

Cylindrical Li-ion batteries are often ganged into voltages appropriate for cordless tools.

Courtesy Wikipedia

You'll find these pouch types of Li-ion batteries in radio-controlled hobbyist cars and other places where weight is a concern.

Li-ion batteries typically come in one of three formats: pouch, cylindrical, and prismatic (rectangular-cubic). Pouch types tend to be used in small portable devices, such as smart phones and tablet PCs, or in devices where low weight is important, such as hobbyist remote control vehicles. Cylindrical forms lend themselves to powering medium-sized portable devices, such as power tools. Prismatic are generally the largest, and are typically used in electric vehicles. Prismatic types are also favored in applications that were previously powered by lead-acid batteries, such as backup or off-grid telecommunication systems. Prismatic types usually have hard corrugated sides, which creates air gaps between adjacent cells—an aid to cooling.

Suitable for Renewables?

If Li-ion has an application for residential RE storage, the best candidate is the large-format prismatic lithium iron phosphate ($LiFePO_4$; LFP) battery. But how do they compare with lead-acid technologies?

Weight. Comparing weight versus available energy storage, an LFP is about one-third the weight of a lead-acid (LA) battery. This is a great advantage for mobile applications, such as boats/RVs, but for stationary RE applications, weight is usually a consideration only during battery change-out.

Space. At about half the volume of an LA battery with equivalent energy storage, LFPs take up far less space. This may be an advantage for mobile applications, but for stationary RE applications, size or volume is typically not a deciding factor.

Low-Temperature Capacity. The storage capacity of LAs drops by 50% at -4°F, compared to 8% with LFP. Keeping lead-acid batteries warm so that they maintain reasonable capacity in cold climates can be challenging, giving LFPs an advantage. However, LFP batteries generally should be charged at a slower rate when cold—usually no more than a C/10 at ambient temperatures below 32°F. (For example, if you have a 200 Ah battery, a C/10 charge rate will be 20 A.)

Discharge Voltage & Impedance. LA batteries' discharge voltage tapers significantly as state-of-charge decreases, whereas LFP batteries' voltage remains fairly steady until they are close to being fully discharged. LFPs have about one-quarter the internal resistance (impedance) of LA batteries, which reduces battery energy lost to heat. These both combine to improve system efficiency and prevent DC voltage sags that can affect voltage-sensitive equipment.

Charge & Discharge Current. LFPs can be safely charged and discharged at a higher current than LA batteries. But the relatively low current in RE applications (compared to EV applications) makes this aspect not very useful.

Self-Discharge. At room temperature, idle (stored or disconnected) LA batteries lose 5% to 15% of their electrical capacity per month, compared to 1% to 3% for LFPs. In RE applications where energy is used only occasionally (such as pleasure boats, RVs, or vacation cabins), or during periods of low RE source, this can be a useful attribute.

Maintenance. Wet LA batteries, if not watered when needed, will have a greatly shortened life. LFPs require no additional liquid to maintain their electrolyte levels. Sealed LA batteries, which have a much lower up-front cost than LFP batteries,

Lithium Timeline

Although Li-ion research started in the late 1970s, commercialization of Li-ion batteries didn't begin until the 1990s (it took about a dozen years to figure out how to manufacture usable, stable Li-ion batteries).

1991
Sony commercializes the first Li-ion battery, used in cell phones and laptop computers.

1996
Lithium polymer batteries become commercialized.

1999
Lithium-phosphate batteries become commercialized.

2006
Lessons learned from laptop computer fires: battery chemistry and manufacturing quality control are important.

2007
Large-format lithium iron phosphate batteries become widely available (for EV conversion).

Battery Technology Comparison

Specifications	Lead-Acid	NiCd	NiMH	Li-Ion: Cobalt	Li-Ion: Manganese	Li-Ion: Phosphate
Specific energy density (Wh/kg)	30 – 50	45 – 80	60 – 120	150 – 190	100 – 135	90 – 120
Internal resistance (mΩ/V)	<8.3	17 – 33	33 – 50	21 – 42	6.6 – 20	7.6 – 15.0
Cycle life (80% discharge)	200 – 300	1,000	300 – 500	500 – 1,000	500 – 1,000	1,000 – 2,000
Fast-charge time (hrs.)	8 – 16	1 typical	2 – 4	2 – 4	1 or less	1 or less
Overcharge tolerance	High	Moderate	Low	Low	Low	Low
Self-discharge/month (room temp.)	5 – 15%	20%	30%	<5%	<5%	<5%
Cell voltage	2.0	1.2	1.2	3.6	3.8	3.3
Charge cutoff voltage (V/cell)	2.40 (2.25 float)	Full charge indicated by voltage signature	Full charge indicated by voltage signature	4.2	4.2	3.6
Discharge cutoff volts (V/cell, 1C*)	1.75	1	1	2.5 – 3.0	2.5 – 3.0	2.8
Peak load current**	5C	20C	5C	> 3C	> 30C	> 30C
Peak load current* (best result)	0.2C	1C	0.5C	<1C	< 10C	< 10C
Charge temperature	-20 – 50°C	0 – 45°C	0 – 45°C	0 – 45°C	0 – 45°C	0 – 45°C
Discharge temperature	-20 – 50°C	-20 – 65°C	-20 – 65°C	-20 – 60°C	-20 – 60°C	-20 – 60°C
Maintenance requirement	3 – 6 months (equalization)	30 – 60 days (discharge)	60 – 90 days (discharge)	None	None	None
Safety requirements	Thermally stable	Thermally stable, fuses common		Protection circuit mandatory		
Time durability				>10 years	>10 years	>10 years
In use since	1881	1950	1990	1991	1996	1999
Toxicity	High	High	Low	Low	Low	Low

Source: batteryuniversity.com. The table values are generic, specific batteries may differ.

*"C" refers to battery capacity, and this unit is used when specifying charge or discharge rates. For example: 0.5C for a 100 Ah battery = 50 A.

**Peak load current = maximum possible momentary discharge current, which could permanently damage a battery.

compare better than FLA but their lifetime cost per kWh is greater than either LFP or wet LA batteries.

Lifetime. While longevity can vary widely depending on factors such as daily depth of discharge and LA battery type (marine, golf cart, AGM, industrial, etc.), regularly used and properly maintained common deep-cycle LA batteries have an average lifespan of about five years; LFP batteries have an estimated longevity of 10 years—half the frequency of LA battery replacement. In both cases, natural aging of the battery chemicals can impair batteries before their cycle life is used if they are cycled infrequently. When used up, both types of batteries can and should be recycled by returning them to a dealer, although due to the long history of LAs, there are presently more recyclers for LAs than LFPs.

Cost. Although LA batteries are cheaper up-front than LFPs, their lifetime price per kWh can be higher. This assumes that you can use most of the lifetime capacity (usable capacity multiplied by cycle life) prior to the battery failing due to age. With a 3,000-cycle or 10-year life (whichever comes first), one would need to cycle LFP batteries nearly daily to optimize the payback. (Note: End-of-battery life is generally considered to be when the battery can maintain only 70% to 80% of its original capacity.)

Lithium Safety

Any energy storage technology can be dangerous if the energy gets in or out too quickly. For example, if charged too quickly, LA batteries can heat up and be damaged and even explode. Similarly, an LA battery that's discharged too quickly (such as a short circuit), can spark and ignite lingering hydrogen gas. Lithium technologies, relying on a chemical reaction to store energy, are no exception. Two incidents were widely publicized—impurities combined with oxide-based lithium batteries fostered thermal runaway, causing laptop computers to overheat and catch fire; and the 2011 Chevy Volt fire, in which the coolant from the battery system dripped onto the ruptured batteries in a junkyard Volt and caused a fire. (General Motors has redesigned the battery system to reduce the likelihood of another incident.)

Of all of the Li-ion chemistries, lithium iron phosphate ($LiFePO_4$ or LFP) offers the most stable chemistry and is considered very safe. For this reason, LFP is used for most large-capacity Li-ion batteries, and is the most common type used in EVs and telecom power systems.

Lithium Iron Phosphate Two-Part Reaction

$LiFePO_4 \longleftrightarrow FePO_4 + Li^+ + e^-$ $\qquad$ $Li^+ + e^- + C \longleftrightarrow LiC_6$

Positive Electrode (Cathode): Lithium iron phosphate on aluminum terminal

Electrolyte: $LiPF_6$ in ethylene carbonate (EC)/ dimethylcarbonate (DMC)

Negative Electrode (Anode): Graphite on copper terminal

Left to Right = Charging **Right to Left = Discharging**

The Need for Management

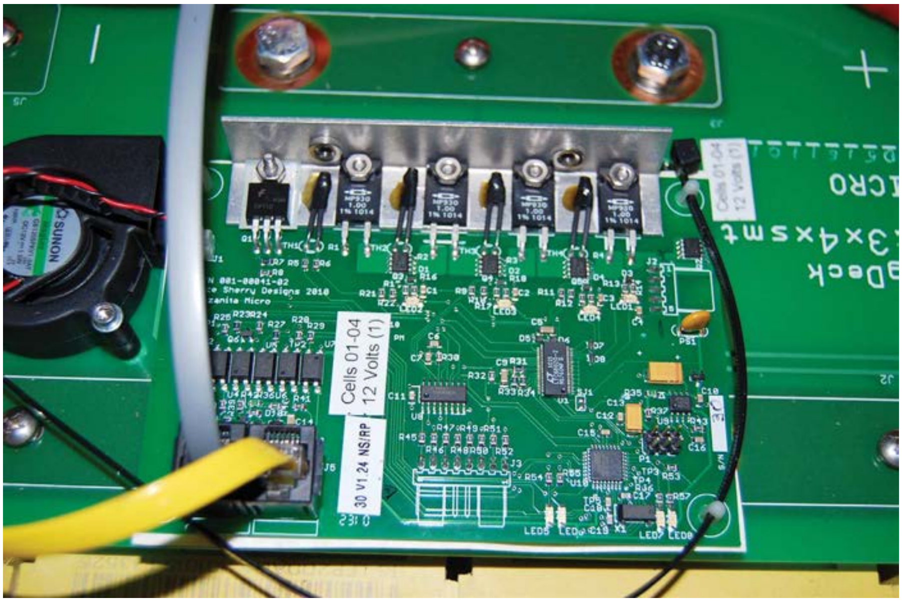
The biggest disadvantage of any Li-ion battery is needing a battery management system (BMS). The job of a BMS is to monitor the voltage and temperature of each individual cell and protect from excessive charging and discharging. While any battery system, whether it be LA or LFP, can be improved with a BMS, a BMS is not typically required of LA cells. As long as all the batteries in a pack are of the same model and age (ideally from the same manufactured batch) and have been treated equally, the individual cells tend to behave the same while being charged. However, LFP battery cells, even in the same manufactured batch, can have variations in capacity. When charging, cells with lower capacity can become full much sooner than cells with higher capacity, which can lead to dangerously elevated voltages on the full cells as the others continue charging.

While LA cells tolerate brief periods of overvoltage (in fact, periodically elevating charge voltage to perform an equalization charge is recommended), even a fraction of an hour at elevated voltage can damage an LFP cell. A BMS protects individual cells from overvoltage by shunting current around the full cells when they reach their recommended "full" voltage. This allows the remaining cells to continue charging. A good BMS can detect when a cell is beginning to overheat (another sign of pending danger to cells) and shut off charging to the pack to protect all cells.

A BMS can also help during discharge by signaling for load disconnection when individual cells drop below their minimum voltage. Cells discharged too deeply can be permanently damaged or, at minimum, have their capacity or cycle life permanently reduced.

Li-Ion in RE Systems

There are no known Li-ion BMS power conversion products (inverters with chargers, and charge controllers) for the residential RE industry (although Clean Power Auto does have a solution for RVs and boats). The missing feature in standard power conversion is BMS cell monitoring and the available RE equipment can't modify charging characteristics to handle when some cells have reached full capacity and other cells have not. Reading the voltage of the entire pack of cells is not helpful, since there's no means of knowing whether or not some cells have already reached their capacity. Available charge controllers can't adjust



Randy Richmond

This BMS cell-balancer board is mounted to a set of four LFP cells. It is typical of a BMS for EVs.

LFP Precautions

Expect the precautions for using LFP battery cells to be refined as more experience is gained. In considering whether or not to use LFP instead of LA batteries, take the following precautions:

- Never overcharge LFP batteries—even a fraction of an hour of overcharging can permanently damage the cells. A battery management system (BMS) is essential to preventing overcharging.
- Never short LFP batteries! LFP batteries can put out even more instantaneous current than LA. When working around any batteries, always use insulated tools.
- Don't place LFP batteries upside-down (any other orientation is OK). If upside down, electrolyte can leak out of their safety vents if the batteries become overheated.
- When creating a series pack, use cells from the same manufacturer, and the same model and age, so they are as closely matched as possible. This is the same for LA batteries. You won't be able to get LFP cells perfectly matched, and that is another reason why a BMS is needed.
- To increase capacity, it is preferable to use a single string of larger cells rather than paralleling smaller cells. The weaker of the paralleled cells will reduce the overall efficiency of the pack. For this same reason, LA batteries also have better performance when not in parallel. If paralleling is unavoidable, then only well-matched cells (make, model, age, capacity, impedance) should be paralleled.
- Reduce the charging current for LFPs to a C/10 or less when the cell temperature is below 32°F. Otherwise, permanent damage to the cell may result. Check with the manufacturer for specific temperature and current limits.
- Long-term trickle or float charging is not LFPs' optimum use. LFPs have the best price/lifetime energy payback when cycled often. If floating is unavoidable, then caution must be used to select a safe yet effective float voltage.
- Store LFP battery cells at a 40% to 60% SOC to optimize their shelf life. Storing them at 0% SOC is likely to permanently damage them, and storing them at 100% SOC may reduce their cycle life.
- With only 12 years of history, the battery industry is still learning the optimum way to treat LFP batteries (e.g., some say charging to 80% rather than 100% will greatly increase cycle life).

Randy Richmond

An overcharged LFP cell can rupture, leaking caustic electrolyte.

current on the fly to match the BMS's ability to shunt current as cells start to reach 100% SOC.

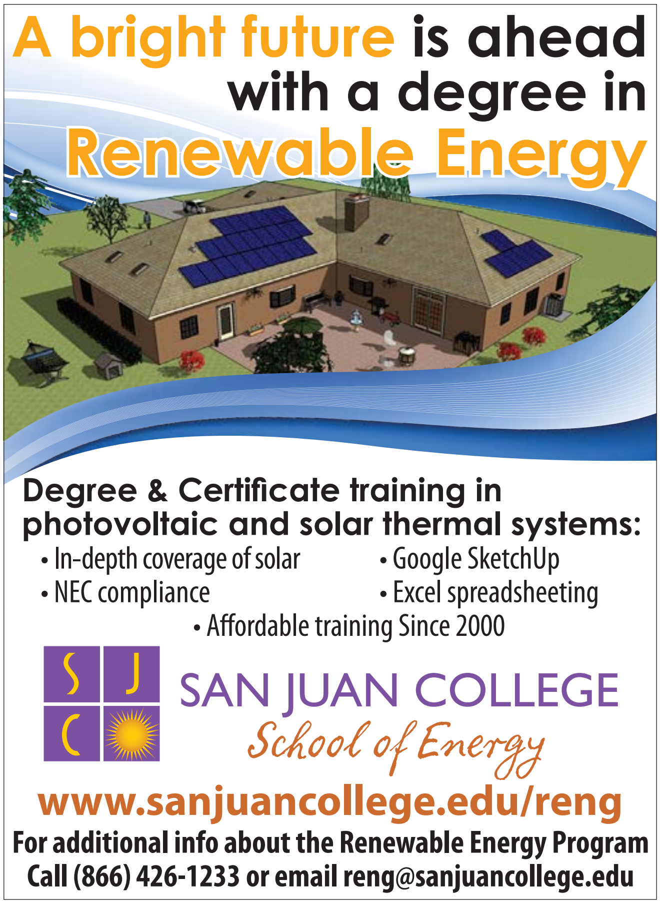
If power conversion equipment with provisions for BMS become available, then LFP batteries can be useful in RE systems if:

- The depth of cycle is often more than 30% of capacity. Otherwise, LA batteries are a more cost-effective option.
- The space available for batteries is at a premium. LFPs can save about 50% of the space compared to LA for the same usable capacity. (These factors can be very important for RV and boat applications.)
- The application requires low maintenance (such as hard-to-reach sites, or a user who won't or can't do the work). With twice the longevity of LAs, this also means halving the battery replacement frequency.
- The application calls for frequent cycling of the batteries—with LFPs having several times the cycle life of LAs and at a deeper depth of discharge. Off-grid applications generally fit this profile.

LFPs can definitely help solve some residential RE storage problems. But perhaps a better question is, "Is the residential RE industry ready for LFPs?" At present, the lack of BMS integration in residential RE power conversion equipment is the biggest hurdle. Once LFP-compatible products become available, then LFP batteries will find a home in many RE applications, especially off-grid and mobile.

Access

After earning his electrical engineering degree, Randy Richmond (randy@RightHandEng.com) worked for the telecom industry. In 1999, he founded his own company, RightHand Engineering LLC, which makes products for monitoring RE systems. Since then, Randy has earned his professional engineer license and also offers design, test, educational, and consulting services for Li-ion-based power systems.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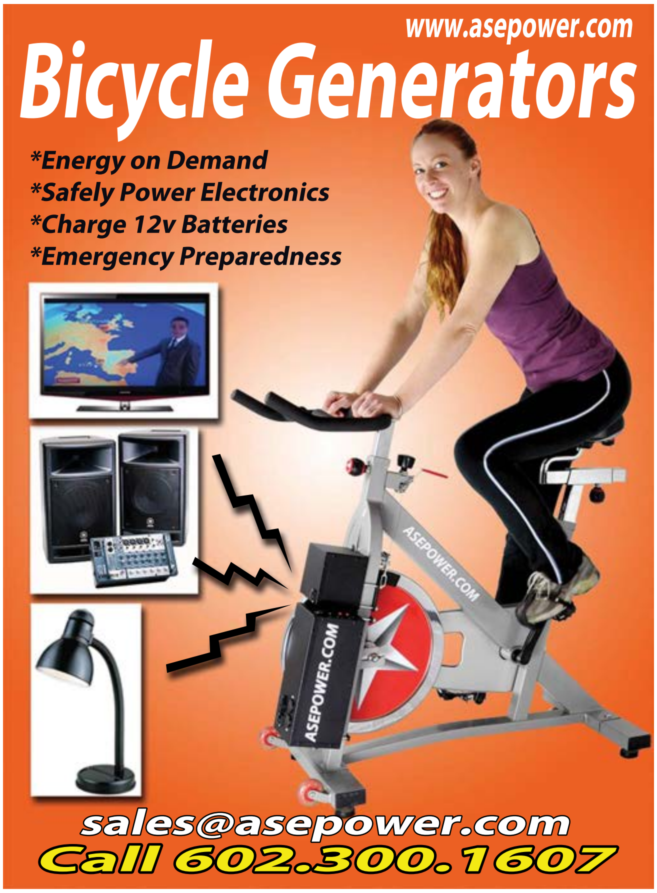
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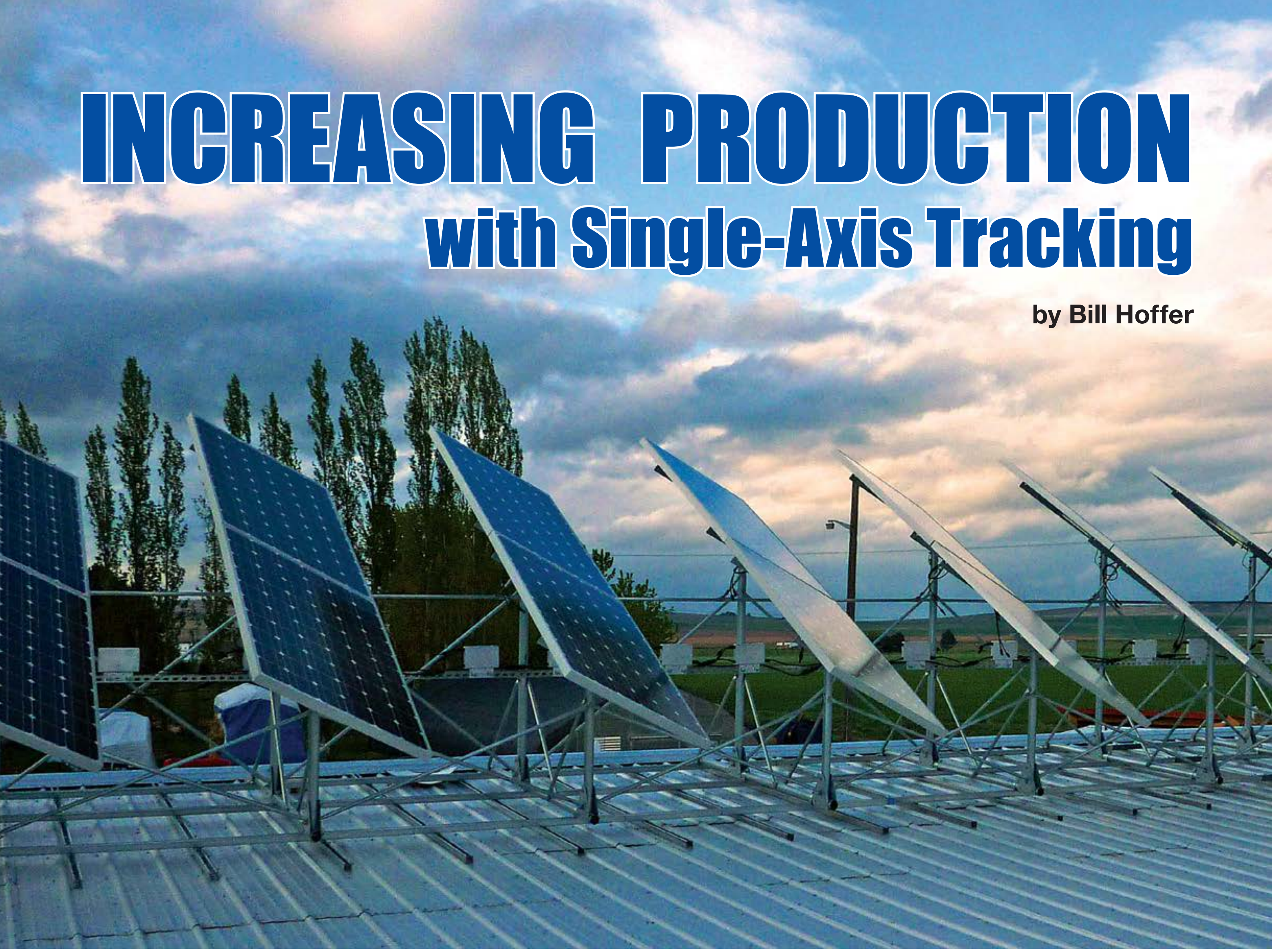


INCREASING PRODUCTION with Single-Axis Tracking

by Bill Hoffer

A single actuator arm adjusts 20 PV modules on 10 single-axis trackers.

Cloudview EcoFarms strives to farm in an ecologically sound manner, providing food to members of a community-supported agriculture (CSA) network. Installing a PV system using locally made modules and inverters matches their "buy local" philosophy, and using the clean solar energy to offset electricity usage on the farm's new cold storage unit—which enables them to store their produce—just made good financial sense.

Washington state's incentive program, slated to be in place until 2020, pays a system owner based on the PV system's annual production. Currently, the base rate is $0.15 per kWh, up to a $5,000 maximum payment per year. Systems using Washington-made inverters get compensated at $0.18 per kWh. And systems using Washington-made PV modules earn an additional $0.36 per kWh, for a total of $0.54 per kWh. The system's output is measured by a production-grade meter. Participants are paid for all of their PV systems' production, even if the majority of it is used to power on-site loads. The utility still net-meters and credits any excess production, though it zeroes out at the beginning of a new 12-month period. After 2020, the state incentive ends and the only payback is the offset energy consumption.

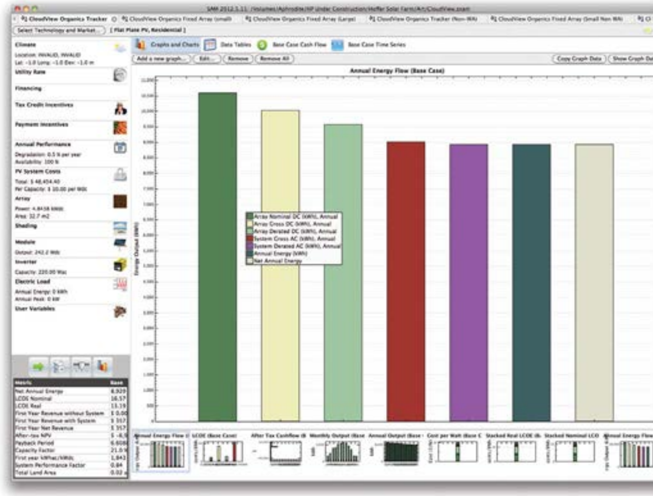
Design Options

Cloudview's system was designed to maximize the annual incentive payment. Its single-axis tracker pivots east to west to follow the sun's path, helping the modules capture as much energy throughout the day as possible, especially during the sunny summer months. (In this region, winter production is typically low due to cloud cover.) Even with a larger up-front cost (compared to a conventional, fixed PV array), this system has only a seven-year simple payback.

The National Renewable Energy Laboratory's System Advisor Model (SAM), free system analysis software, was used for modeling the array output and its financial payback. The first goal was to maximize the annual incentive payment. Three options were examined:

- 20 modules with a single-axis tracker
- 20 modules on a fixed array (to compare production to the tracked system)
- 26 modules on a fixed array, the number of modules calculated to maximize the annual incentive payment of $5,000.

All photos courtesy Bill Hoffer



Free System Advisor Model (SAM) software from the National Renewable Energy Laboratory can model system performance variables and calculate financial payback.

The SAM analysis was made using the following assumptions:

- A 30-year array life, which includes an appropriate derate for module cell degradation.
- An inflation rate of 2.5%—the average rate of inflation in the United States over the past 10 years.
- An 8% real discount rate, which is used to discount constant year benefits and costs and is based on the average short-term business loan rate, was used. In essence, it's the present cost of money that is tied up in the project.
- The 30% federal tax credit was applied in the first year.
- Operation and maintenance costs were not included.
- Tracker costs were based on actual installation costs; fixed array costs were estimated.
- Avoided power costs were calculated using the current utility rate for the farm, which is $0.04 per kWh.
- A 0.5% degradation per year in module output was assumed.

SAM deducts the 30% tax credit in the first year and also deducts the incentive payment and the avoided cost of utility energy that the PV system offsets. After seven and a half years, the only deduction is the avoided cost of energy times the inflation rate, assumed to be 2.5%.

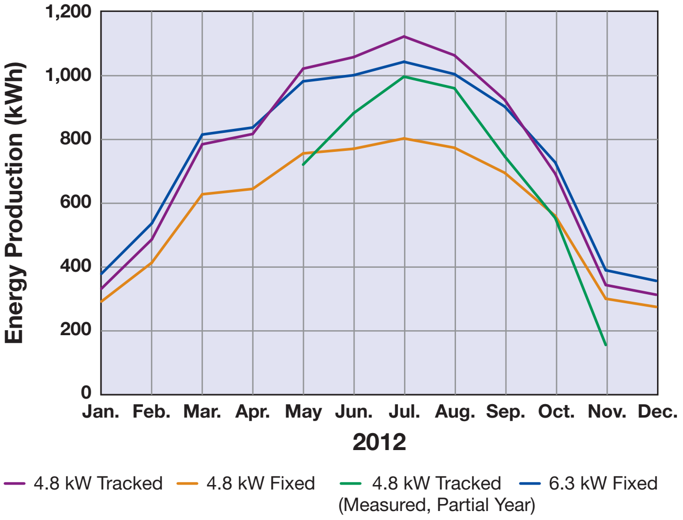
While the 26-module fixed system yielded the largest annual output, the tracked system had the greatest summer yield of all three options and wasn't far behind in estimated annual production (8,947 kWh vs. 8,929 kWh). Even though the tracker's cost adds $1 per W, it yielded the best payoff of the compared systems—it will provide about double the income of the 20-module fixed array and 23% more than the larger 26-module fixed array.

SAM Modeling Output Summary

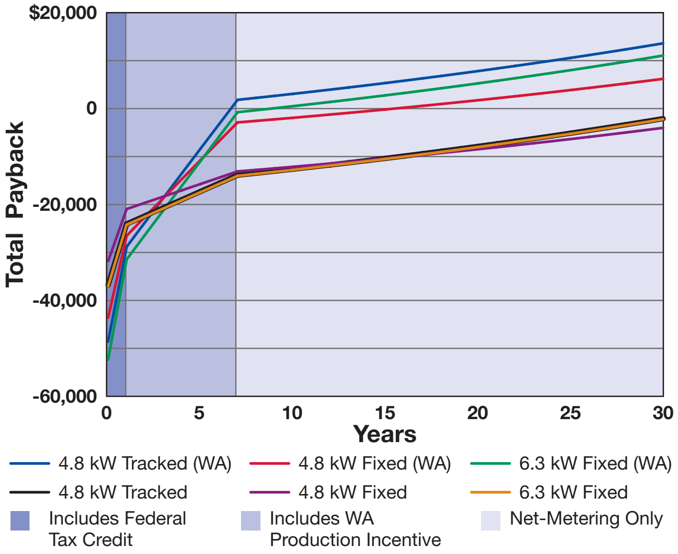
Array Configuration	240-Watt Modules (Qty.)	Power (kW)	Initial System Cost	Cost per Watt	Annual Output (kWh/Yr.)	Yearly WA Incentive Payment	Annual Energy Cost Offset	Simple Payback (Yrs.)	30-Yr. Cumulative Income After Payback
Single-axis tracker, WA-made	20	4.8	$48,455	$10.09	8,929	$4,821	$357	6.60	$13,584
Smaller fixed array, WA-made	20	4.8	43,756	9.12	6,886	3,718	275	15.62	6,163
Larger fixed array, WA-made	26	6.24	52,593	8.43	8,947	4,831	358	8.94	11,025
Single-axis tracker*	20	4.8	36,632	7.63	8,929	1,339	357	>30 years	-2,155
Smaller fixed array*	20	4.8	31,933	6.65	6,886	1,033	275	>30 years	-4,079
Larger fixed array*	26	6.24	37,815	6.06	8,947	1,342	358	>30 years	-2,278

*Bid with non-Washington-made components

Projected Monthly Energy Production



Projected 30-Year Cumulative Income



The installed cost of Washington-made components is a premium—and in the case of the tracker, this changed the outcome considerably. Using less-expensive, out-of-state modules and inverters results in the tracked system and larger array's costs being about even, in which case there would be no advantage to using the tracker since there will be more maintenance issues over the system's life.

Because of the premium cost of Washington-made modules and microinverters, the larger fixed array had a greater up-front cost—about $4,000 more than the tracked system. In comparison, the cost difference by specifying non-Washington-made modules was much less (see "SAM Modeling Output Summary" table on the previous page). The larger array would have required more space on the roof and the tracked system fit perfectly in one row in the width of the roof. (Ground mounting was not feasible—the cold storage building sits in the middle of a maintenance yard in which heavy equipment is frequently being moved around.)

Compared to a fixed array, the tracked system will likely have maintenance costs, although these were not factored into the analysis. Those could negate the slight financial advantage that the tracker has compared to the fixed array.

The back of the tracking array, showing the mounting base, pivots, and the long actuator arm.

Special System Details

Mounting the tracker on a roof required additional attention to attachments, due to higher wind loads of an array that was tilted from the roof plane. It also required engineering to ensure that the additional wind loads and the added weight of the tracker could be carried by the existing structure.

The tracker base is Unistrut placed on 48-inch centers, providing several connection points through the corrugated steel roof into the 2-by-12 trusses, which are on 24-inch centers and oriented north/south. They also provided the additional height needed to mount two rows of Unistrut cross rails above the corrugated roofing profile. Six or more 5/16-inch, 5-inch-long structural construction screws were used in each 8-foot Unistrut base. All penetrations were sealed with GeoGreen 4500 roof sealant. To resist wind forces on the back and sides of the array, 2 feet of Unistrut extend beyond the tracker base toward the top of the roof and an extra Unistrut was placed on 24-inch centers at each end.

DH Solar's single-axis 10-bay tracker has upright sections every 8 feet with one pivot rod in each bay, which holds two modules each. The lightweight system has a lot of bracing that required additional assembly time compared to a fixed rail system. An arm extends the length of the tracker and moves the pivot rod for each bay using one electric screw actuator.

Two modules were attached per pivot rod with standard 1/4-inch stainless steel bolts. It was critical that the module wiring was long enough and had enough slack to handle the

Tech Specs

Overview

System type: Batteryless, grid-tied solar-electric

Location: Royal City, Washington

Solar resource: 6.5 average daily peak sun-hours

Record low temperature: -28°F

Average high temperature: 92°F

Average annual production: 8,929 AC kWh

Photovoltaic System Components

Modules: 20 Itek Energy 240 W STC, 30.0 Vmp, 8.2 Imp, 38.0 Voc, 8.7 Isc

Array: 20 modules, 4,800 W STC total, 30.0 Vmp, 8.2 Imp, 38.0 Voc, 8.7 Isc

Array installation: DH Solar single-axis tracker mounts installed on south-facing roof, 35° tilt

Inverters: 20 APS YC200-NA microinverters, 220 W rated output, 55 VDC maximum input, 22–45 VDC MPPT operating range, 240 VAC output

System performance metering: Online microinverter monitoring with ECU and APS Monitor

System Costs

Initial Cost: $48,455

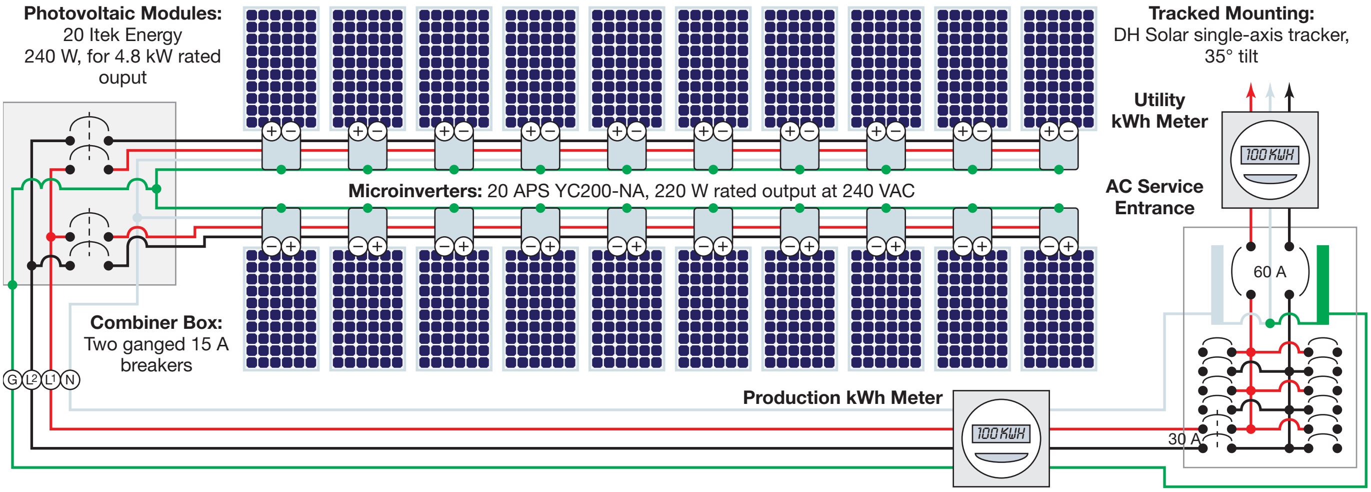
Less Incentives, Rebates, Tax Credits: (see “SAM Modeling Output” table)

The routing of PV output wires and ground connections at the top of the pivot rods allows full movement without binding or pinching the wires.

changing position of the modules as they are moved to track the sun. The pivot rod was then bonded to the equipment-grounding conductor using a ground pipe connector.

The microinverters were mounted on a horizontal cross-piece of Unistrut that also serves as wire management for AC and DC wiring and the equipment-ground wire. This required extending the wires from the modules with custom MC4 extensions. The modules help shade the inverters, allowing them to operate more efficiently. Each inverter is connected to the equipment-grounding conductor through the manufacturer-supplied grounding point. The microinverters greatly simplified the DC wiring, which would have been rather complex if we had to series-wire between the tracking pivot arms.

Cloudview Single-Axis Tracked Batteryless Grid-Tied PV System



Microinverter branch circuits and tracker disconnect.

The two branch circuits from the microinverters were combined on the tracker rack using a standard outdoor air-conditioning disconnect that had two 15 A, 240 VAC breakers combined into one 30 A disconnect output circuit. This allows the system to be disconnected on the roof for commissioning tests and maintenance, and allows troubleshooting of each branch circuit. This circuit then passes through the production meter and is interconnected on the load side of a 240 V subpanel with a 30 A breaker in the building. A separate circuit powers the tracker actuator and control electronics.

System Performance

DH Solar is new to the PV industry but has had a long-standing business making satellite trackers. The system was lightweight, but very strong because of additional cross-bracing. The tracker has to be manually programmed for seasonal variations. With 32 programmable positions per day, it is not as accurate as a tracker using astronomical data for a specific latitude and season.

The system has been operating for only five months, so it is too soon to see how well it is performing compared to the SAM predictions. The first month had only three weeks of production and we had an unseasonably cold and wet summer. The last month was also poor, since smoke from nearby forest fires significantly impacted PV production.

Access

Bill Hoffer has worked in the solar industry in the Pacific Northwest for more than 16 years. He is a NABCEP Certified Solar PV Installer and a professional mechanical engineer in Washington state. He lives in a straw bale home he designed and built himself, and is an avid gardener and skier.

PV System Equipment:

APS • solaraps.com • Microinverters

DH Solar • dhsolar.net • Single-axis tracker

Itek Energy • itekenergy.com • Modules

PV Grounding & Bonding; Part 2

by Ryan Mayfield

With PV systems and other electrical systems, grounding and bonding is one of the most discussed and contested topics. "Code Corner" in *HP152* covered general requirements for equipment grounding and some of the applicable rules in *National Electrical Code (NEC)* articles 250 and 690. This second part dives deeper into the equipment grounding rules and gives an overview of the other half of the discussion—the grounding electrode system.

Equipment-Grounding Conductors

A PV system's metallic, noncurrent-carrying components must be bonded together and then bonded to earth through the use of an equipment-grounding conductor (EGC). Article 250 establishes multiple ways in which this bond can be established. For PV systems, the most common method is to use a conductor to bond the materials together, especially from the PV array.

Sizing this conductor is determined by referring to Section 690.45 in the *Code*. The general rule, 690.45(A), states that the "EGC in PV source and output circuits shall be sized in accordance with Table 250.122." Knowing the exact circuit designations and locations is important for properly applying the rules. If necessary, revisit the definitions section of Article 690 to familiarize yourself with the definitions of PV source and output circuits.

Table 250.122 indicates that the EGC size is determined by the rating of the overcurrent protection device (OCPD) that's protecting the equipment. For PV source circuits, this will typically be the OCPD located in the combiner box. For PV output circuits, this will typically be the OCPD located at the inverter, recombiner, or fused DC disconnect, depending on the installation methods used (see "Methods" in this issue for EGC sizing examples).

If there are no OCPDs in the PV source circuits, as allowed by the exception in 690.9, the circuit's rated short-circuit current shall be the assumed overcurrent protection rating for the table. In no case can the EGC be sized smaller than a 14 AWG conductor, the corresponding conductor size for a 15 A OCPD. The 2011 690.9 exception for OCPDs applies to source-circuit conductors. If an external combiner box (i.e., not integrated into the inverter) is used, then OCPDs need to be provided for the PV output circuits—this is accomplished via a fused disconnect shown in the diagram.

Section 690.45(A) does not require that the EGC be upsized if the current-carrying conductors are increased in size to account for voltage drop. Section 250.122(B)'s general rule requires that the EGC size be increased in proportion to the circular area of the current-carrying conductors. In PV installations, the rules set in 690 take precedence over the general rules in 250, and increasing the diameter of the EGCs is not required. The second subsection of 690.45 sets the requirements for the uncommon systems that do not use

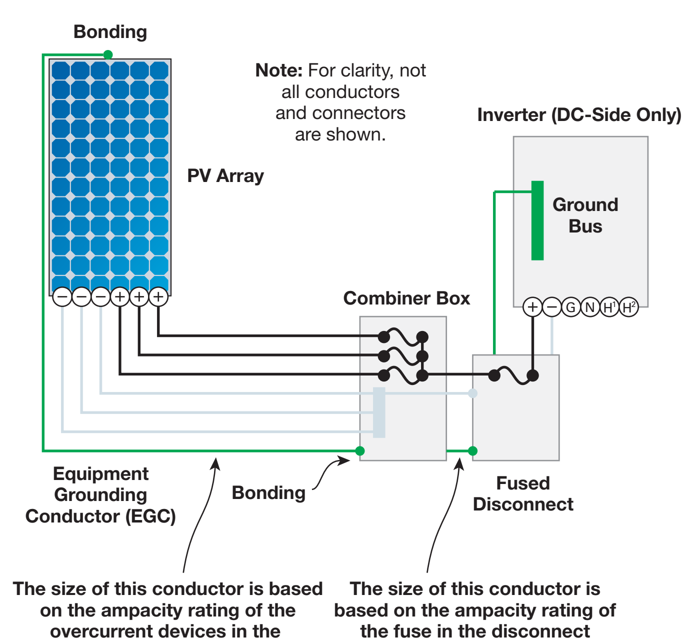
NEC Table 250.122

Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Overcurrent Rating (Amps)*	Size (AWG) Copper	Size (AWG) Aluminum or Copper-Clad Aluminum
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1

*Setting of automatic overcurrent device in circuit ahead of equipment, conduit, etc., not exceeding (amperes)

Grounding Conductors




Ryan Mayfield

Per *NEC* 690.46, #6 AWG will commonly be required as EGCs for module frames.

ground-fault protection, which include increasing the EGC's size to meet safety requirements of 690.45(B).

The final EGC sizing requirement is in 690.46. It references 250.120, which requires protecting EGCs smaller than a 6 AWG conductor in places where the conductor may be "subject to physical damage." This may include the back of an array, even on rooftops, according to some authorities having jurisdiction (AHJs). Some jurisdictions have also applied a general ruling that any EGC associated with PV systems must either be a minimum 6 AWG or protected in a raceway, regardless of the location. Discuss this with your AHJ early in the design process, since changing an EGC after the array has been installed can be a difficult task.

Grounding Electrode System

For PV systems that use grounded current-carrying conductors, i.e., systems using transformer-based inverters, Section 690.47 is the primary reference for the grounding electrode system. In grounded systems, a connection must be made between the DC circuit grounding point and earth, as required in 690.41 and 690.42. This required connection consists of the grounding electrode (GE) and the grounding electrode conductors (GECs). It is worth noting, regardless of the inverter's use of a transformer, that the EGC requirements discussed always apply. It is also very important to read the installation instructions included with all inverters to make sure all of the grounding instructions specific to that inverter are being followed.

Over the past few *Code* cycles, the changes to 690.47 have been dramatic. In the 2011 *Code*, the changes made to 690.47 seemed well-received by the PV community, primarily due to the deletion of the most difficult and controversial requirement, 690.47(D), which called for additional electrodes for array grounding. The 2011 *NEC*'s 690.47 has three subsections, with the third being the most widely used. The first two are for systems that exclusively produce and use DC or AC. The third subsection, 690.47(C), applies to systems that have both DC and AC electrical requirements—the majority of PV systems installed today. That third subsection is divided into three additional subsections for different installation scenarios.

All three of 690.47(C)'s subsections require that the DC grounding system be connected to the AC system's grounding electrode. For grid-direct PV systems, this is generally the existing grounding electrode—a ground rod, water pipe, concrete-encased electrode, etc. A new DC grounding system connection to earth can be accomplished by:

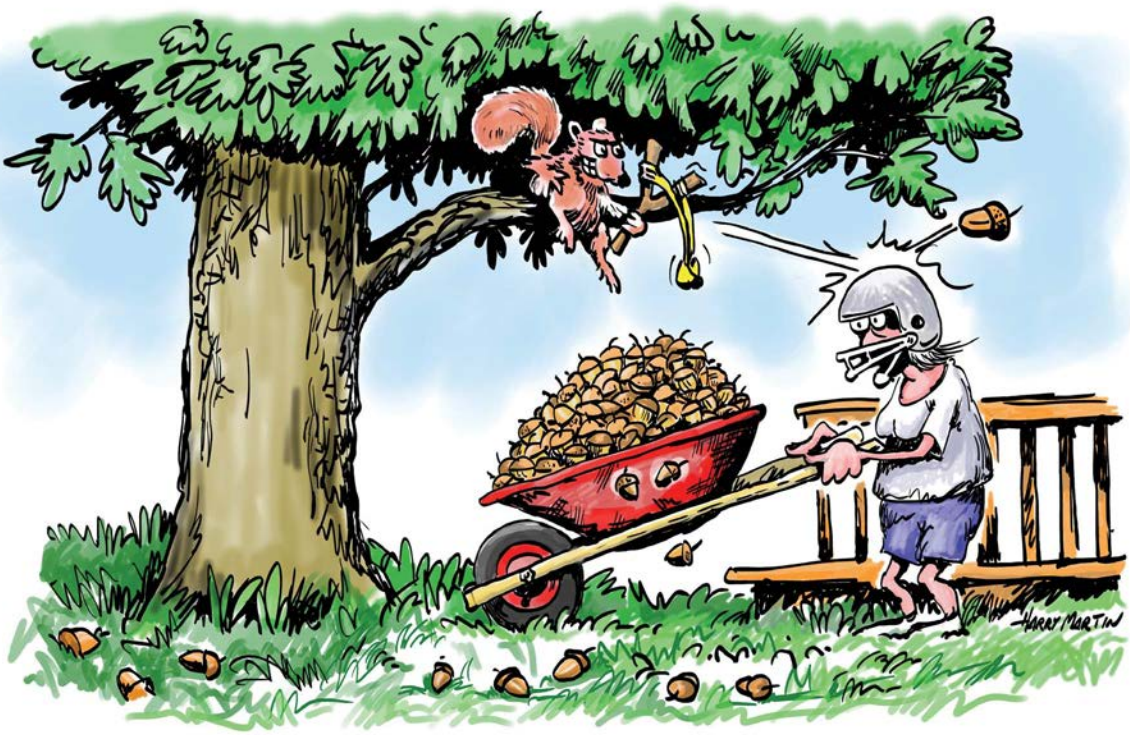
- Establishing a new DC GE and bonding the new electrode to the existing AC GE.
- Connecting a new DC GEC from the inverter to the existing AC GE.
- Using a combined DC GEC and AC EGC (in one wire) from the inverter to the grounding bus bar in the associated AC equipment.

Each of these provisions has its own unique set of rules to follow. Grounding and bonding is always a complicated case. Future "Code Corners" will explore these 690.47 requirements in more detail to help decipher the grounding electrode system requirements.

Access

Ryan Mayfield (ryan@renewableassociates.com) is the principal at a Corvallis, Oregon, design, consulting, and educational firm with a focus on PV systems. He is currently working on international projects that prove that grounding and bonding issues know no borders.

In a Nutshell



An oak tree partially overhangs our deck. I am at an eye level with its branches, so I always notice if it is going to be a good acorn year. This fall, I could not let this obvious food source go to waste. I started reading about, and then eating, acorns.

by Kathleen Jarschke-Schultze

E'ekoons

The local Karuk Indians, along with many other Native American tribes, harvested "e'ekoons"—acorns—which were a major part of their diet. In the Karuk language, there are 19 different words describing acorns—for every stage of processing and every type of acorn.

When I first became interested in harvesting and eating acorns, I purchased Suellen Ocean's *Acorns and Eat 'Em*. But I lent the book some years ago and never got it back—sigh—so I was pleased to find the entire book downloadable for free (see Access). This book has a wonderful identification section that had me out and picking leaves and acorns from my nearby oaks. Turns out, I have a preponderance of mountain white oak (*Quercus garryana*), a single California black oak (*Quercus Californica* or *Q. kelloggii*), and I know where some tan-bark oaks (*Quercus densiflora*) grow.

Suellen, an experienced acorn eater, describes a very easy process to leach the bitter tannins from the nuts, making them ready for use as food. Some varieties of acorns have more tannins; some, much less. The acorns with less bitterness were, of course, highly prized by Native Americans.

Acorn Abundance

This year as I watched the acorns grow from small green spots to an abundant crop, I knew I wanted to gather them. One reason was to process and eat them. The other reason was to hone my acorn-gathering skills so that next fall, when we are fattening our pastured pork, we can feed them acorns.

Acorns fed to hogs in the final fattening phase are called "mast," and feeding mast to hogs is an ancient tradition. In the Middle Ages, European wooded areas were carefully surveyed to ascertain the number of hogs they would feed or fatten. Greenwoods were frequently designated as "one-hog" groves, "ten-hog" woodlands, or "hundred-hog" woods. Fattening hogs on acorns is called "pannage."

What is thought by many to be the finest ham in the world is called jamón Ibérico de bellota (*bellota* means acorn). The wild black pigs of Iberia, Spain, feast on acorns in the last months of their lives and gain more than 50% of their butcher weight during this time. Nearly 60% of these hogs' marbled fat contains healthy monotriglycerides, which lower your LDL (bad) cholesterol and raise your HDL (good) cholesterol. Does this mean bacon could be good for me?

Mast Repast

This year, I am harvesting just what I can process and use myself. I found that the best method for collecting is to wait until the acorns are golden, but still on the tree. They are so ripe that when you touch them they fall into your palm. My husband Bob-O and I spread a ground cloth under the tree branches. Then, using a long pole, we hit the branches smartly—a lot like the "amond knocking" harvest we used to do at my Aunt Anna's orchard. This reminds me of an old joke: Do you know why people who grow almonds call them "amonds?" Because they knock the "L" out of them at harvest time.

The acorns readily fall onto the tarp, which can be emptied into a wheelbarrow. Go through your acorns and discard any with tiny black holes, which indicate an acorn weevil has already drilled a hole through the acorn and laid eggs inside—and ruined that nut for eating. Left with the other acorns, a ruined nut will spoil them, too, when the larva hatch.

Acorns have a very tough shell, and removing it is tedious. Forget about multitasking—just listen to a recorded book or music while you toil. So far, the best way I've found to get the nut meat separated from the shell is to cut the shell in half lengthwise with a sharp paring knife, then pick the meat out. This yields large pieces of acorn to process in whatever way I choose.

Immediately dropping the hulled nuts into a bowl of water results in leaching, which you can see from the water taking on a brown tinge. The meat is combined with a little water (at a 3:1 ratio) in a blender until it becomes a coarse acorn meal. I use a quart pitcher to store the acorn-and-water mixture in the fridge and change the water every day for a week. At this point, the acorns are ready to use in any number of recipes (Suellen's book has 35) or freeze in convenient-sized amounts for use later. The acorn nut can also be hulled, bagged, and frozen for later leaching.

Sprouted acorns are even easier to shell by cracking the shell at the pointed end. Suellen prefers hers this way and will soak buckets of acorns to get them to sprout. According to Suellen, an acorn with a two-inch-long sprout is fine, as long as the acorn nut meat hasn't turned green. The acorns I opened were sprouting just enough to crack the shell for me.

Acorns have a low sugar content and a sweet, nutty aftertaste. Substitute acorn meal for approximately one-fourth of the flour in bread and stew recipes. Since acorns contain natural sweetness, reduce any other sweeteners in the recipe by one-fourth. Acorn grits can be used in place of nuts in cookies, brownies, and bread. Acorns are a reliable source of carbohydrates, protein, six vitamins, eight minerals, and 18 amino acids, and they are lower in fat than most other nuts.

Browsing the Web, I found acorn recipes like acorn soba noodles, orecchiette with a mushroom ragu, cookies, pancakes, soups, cakes, and, of course, acorn bread. My friend Myna still raves about the acorn enchiladas I brought to a potluck dinner. Acorns as food can be a real conversation stimulator.

I certainly was able to easily gather enough acorns for my own use, and, this year, I could have gathered many more for feeding pigs. Whether or not next year will be such a great acorn year is an unknown. But I am going to pay attention to see if a heavy acorn crop indicates a long, cold winter.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is fermenting apple cider vinegar at her off-grid home in northernmost California.

Acorns and Eat 'Em • bit.ly/AcornsEatEm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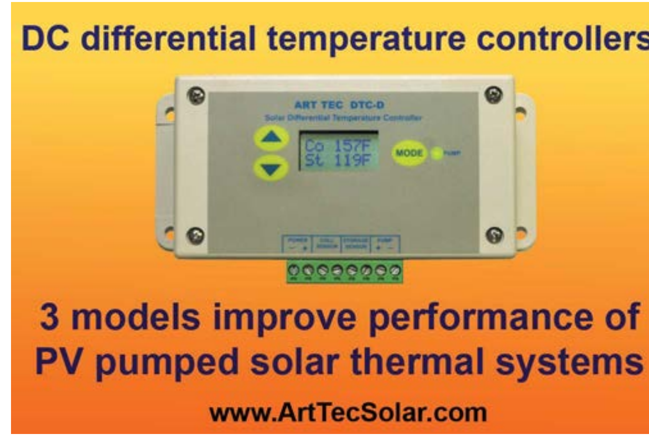
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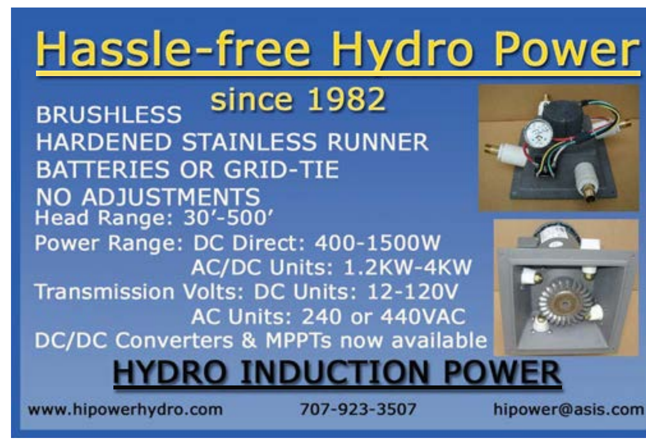
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Feed-In Tariffs

Designed to encourage investment in renewable technologies, a feed-in tariff (FIT) requires utilities to buy renewable electricity from customer-generators at fixed prices, typically at retail rates (or higher).

Unlike upfront incentives (rebates, buy-downs, and grants) that reduce the initial equipment and installation costs, a FIT pays out over a long-term contract (typically 10 to 20 years). Over time, the payments are usually sufficient to recoup system development costs and provide a reasonable return.

In Germany, FITs helped boost renewables to now comprise 25% of the country's energy mix (up from 6.3% in 2000). Compared to other countries, the United States has been slower to implement FIT policies, favoring renewable portfolio standard (RPS) policies driven largely by non-performance-based incentives (like rebates and tax credits). Only a few areas—such as in California, Florida, Hawaii, Indiana, New York, Vermont, Washington, and Oregon—have FIT programs through various utilities thus far.

A key distinction between net-metering and FITs is that most net-metering programs do not pay out cash—retail rate credit is given for any amount produced in excess of what is used on-site. The credit is rolled over from one billing cycle to the next and typically expires after a certain duration (a one-year cycle is common). Because the best that net-metered systems can do is to reduce (or zero out) the site's electricity bill, there also is no financial incentive to produce more electricity than the site uses.

Conversely, FITs provide profit motivations to maximize a system's generation, which ultimately diminishes demand for conventionally produced electricity. Unlike net metering, a FIT encourages development on sites where there are no loads (vacant lots) or on sites where the generation may exceed what the site requires (for example, warehouses, farm buildings, and parking facilities). A typical FIT pays at a fixed rate (retail or higher, in most cases) based on the total number of kilowatt-hours (kWh) of renewable electricity produced.

FIT programs, like any incentive program, are not without their weaknesses. Incentive programs are vulnerable to changing political and economic conditions. Spain's FIT, for example, was remarkably successful in driving the development of new solar projects, but in response to the global economic downturn in 2008, the government lowered the FIT payments. Investors were shaken and projects were abandoned, and the resulting glut of PV modules helped to drive down global prices by nearly 40% in 2009.

In the United States, the size of projects qualifying for FITs varies by jurisdiction, and most FIT programs establish a queue on a first-come, first-served basis, with caps on how much electricity any site can sell back to the utility. To see FIT program details (along with all other RE incentives), visit the Database of State Incentives for Renewables & Efficiency (dsireusa.org).

—Kelly Davidson

Germany's FIT program has resulted in one of the most significant deployments of solar electricity in the world.

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