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Home Energy Storage

The Next Wave

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Energy storage is splashed across a lot of headlines these days. Most notably, in April, Tesla Energy announced its maintenance-free lithium-ion battery "storage solution" for homes. This announcement caused much public excitement, as it seemed as if a startling technical advancement had been made: "Hurray! We can finally store energy from solar modules!" However, along with curiosity and excitement, reaction from *Home Power* readers and the RE industry ranged from suspicious to confused. Electrochemical energy storage has been around for hundreds of years, but perhaps something about this Tesla battery could be special.

So, is this a revolutionary development in energy storage? What about the technical questions, such as how do you work with the 350 to 450 VDC Tesla battery output, when existing battery-based inverters needed to convert DC to household AC are built for 12, 24, and 48 V battery banks? How does the Tesla battery compare to existing options, such as a maintenance-free AGM lead-acid battery? These and many more questions have been asked by our staff, our colleagues, and our readership.

What we know is that the lithium-ion battery technology Tesla is using isn't new, but the packaging is slick and the pricing is potentially competitive. However, because the batteries are not being shipped yet, many of our technical questions remain, along with the simple question—is the Tesla battery too good to be true? We are just as curious as our readers, and we won't know the answer to that question until the press releases become real purchases. Other battery manufacturers have also begun to offer new energy storage options, and power electronics manufacturers are racing to release the missing electrical components. Additionally, with electric cars now increasingly occupying driveways around the nation, we are looking forward to seeing how those battery packs under the hood can also be used to supply homes with electricity during an outage.

With the continued impressive growth in the solar industry (see "PV Modules: Updates & Trends" in this issue) coupled with new energy storage options and a seemingly heightened global awareness (from the Pope to the Surgeon General) focused on climate change, it feels somewhat like we are experiencing an energy renaissance. *Home Power* has been navigating the RE industry and sharing our findings for almost three decades, and we are gearing up and excited for what is coming as we crest this next big RE wave.

—Justine Sanchez, for the *Home Power* crew

Think About It...

"Surfing's one of the few sports that you look ahead to see what's behind."

—Laird Hamilton, professional surfer

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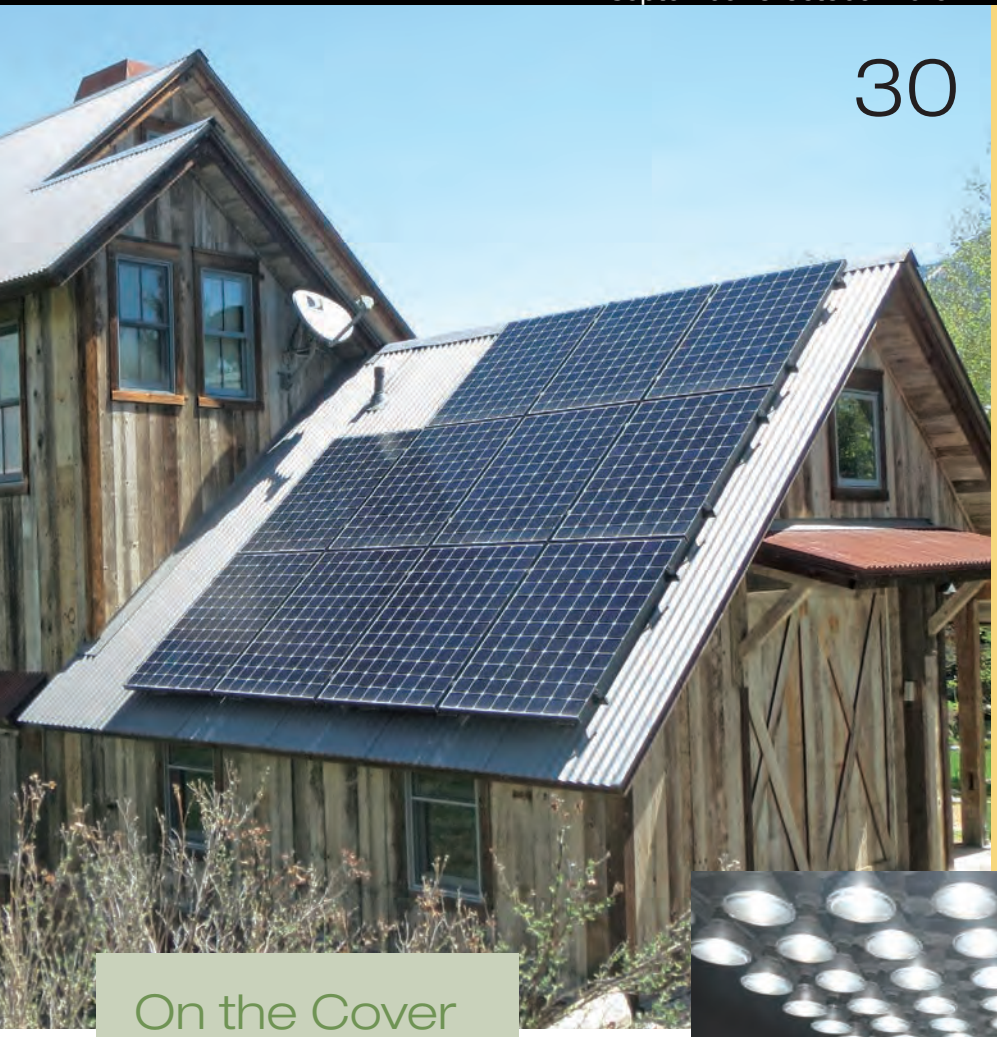

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On the Cover

Juanita and Jack Clay with their PV-powered, active and passive solar home in Vermont.

Photo by Khanti Munro

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Photos: Lena Wilensky; courtesy PV Evolution Labs (a DNV GL company); ©istockphoto.com/ (L to R): Bryngelzon, David Parsons, Minerva Studio, SlobodanMiljevic

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Photos: Khanti Munro; courtesy Envision Solar International; Bentek

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The Magnum-Dimensions MMP Panel System and the PT-100 Charge Controller from Sensata Technologies are perfectly matched to help you get the most out of your PV array while optimally charging your batteries. Off-grid living has never been so convenient.

PT-100 Charge Controller

The PT-100 is a MPPT Charge Controller designed to maximize energy harvest from your PV array and improve battery life. Optimally charging batteries, providing electronic protection, and extinguishing series arcs with an integrated PV arc-fault circuit interrupter, the power you'll see is smooth.
The PT-100 supports a PV array of up to 6600 watts with continuous charging current of 100 ADC and a high input voltage of up to 240 VDC (Voc).

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MMP Panel System

The Magnum-Dimensions MMP is an inclusive, easy-to-install panel designed to work with one Magnum-Dimensions MS-PAE, MS, RD or other inverter/charger. The MMP has a small footprint, is prewired for fast installation, and saves on labor costs with its easy access design.

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contributors

this issue's experts

Christopher Freitas is an engineer and project manager for international RE projects around the world. He was a cofounder of OutBack Power Systems and director of engineering at Trace Engineering, both located in Arlington, Washington.

Khanti Munro is the director of development and technical design at Same Sun of Vermont. He is a NABCEP-certified PV installation professional and a PV instructor for Solar Energy International. Munro holds a degree in Renewable Energy Applications from Green Mountain College, and was formerly a technical trainer for SunEdison.

Desmond Wheatley is the president and CEO of Envision Solar International Inc. He teaches a LEED-accredited class on sustainability in parking and is a recognized industry leader in renewables and electric vehicle charging infrastructure. He has a widely viewed TED talk and is frequently invited to speak at and chair industry events.

Thirty years ago, **Kathleen Jarschke-Schultze** answered a letter from a man named Bob-O who lived in the Salmon Mountains of California. She fell in love, and has been living off-grid with him ever since. *HP1* started a correspondence that led Kathleen and Bob-O to *Home Power* magazine in its formative years, and their histories have been intertwined ever since.

Justine Sanchez is *Home Power*'s principal technical editor. She's held NABCEP PV installer certification and is certified by IREC as a Master Trainer in Photovoltaics. An instructor with Solar Energy International since 1998, Justine leads PV Design courses. She previously worked with the National Renewable Energy Laboratory (NREL) in the Solar Radiation Resource Assessment Division. After leaving NREL, Justine installed PV systems with EV Solar Products in Chino Valley, Arizona.

Lena Wilensky was inspired to take leave from her high school teaching career to explore the world of renewable energy. She built her experience from Solar Energy International as well, taking classes and helping construct their PV Lab Yard, and now teaches PV Design and Installation classes around the country and online. She worked as an electrician in Crested Butte for several solar installers, and is thrilled to now own her own business.

Chuck Marken is a *Home Power* contributing editor, licensed electrician, plumber/gas fitter, and HVAC contractor who has been installing, repairing, and servicing SWH and pool systems since 1979. He has taught SWH classes and workshops throughout the United States for Sandia National Laboratories, Solar Energy International, and for many other schools and nonprofit organizations.

Allan Sindelar installed his first off-grid PV system in 1988. He retired from Positive Energy Solar of Santa Fe, New Mexico, in 2014, and now designs, services, and consults on off-grid and water pumping systems. He is a licensed electrician with dual NABCEP certifications.

Alex Wilson is the founder of BuildingGreen, the Brattleboro, Vermont-based publisher of *Environmental Building News*, *GreenSpec*, and LEEDuser.com. He is also president of the Resilient Design Institute.

Ryan Mayfield is the principal at Renewable Energy Associates, a design, consulting, and educational firm in Corvallis, Oregon, with a focus on PV systems. He also teaches an online course in conjunction with *SolarPro* magazine and HeatSpring.

Michael Welch, a Home Power senior editor, is a renewable energy devotee who celebrated his 25th year of involvement with the magazine in 2015. He lives in an off-grid home in a redwood forest in Humboldt County, California, and works out of the solar-powered offices of Redwood Alliance in nearby Arcata. Since 1978, Michael has been a safe-energy, antinuclear activist, working on the permanent shutdown and decommissioning of the Humboldt Bay nuclear power plant.

Home Power senior editor **Ian Woofenden** has lived off-grid in Washington's San Juan Islands for more than 30 years, and enjoys messing with solar, wind, wood, and people power technologies. In addition to his work with the magazine, he spreads RE knowledge via workshops in Costa Rica, lecturing, teaching, and consulting with homeowners.

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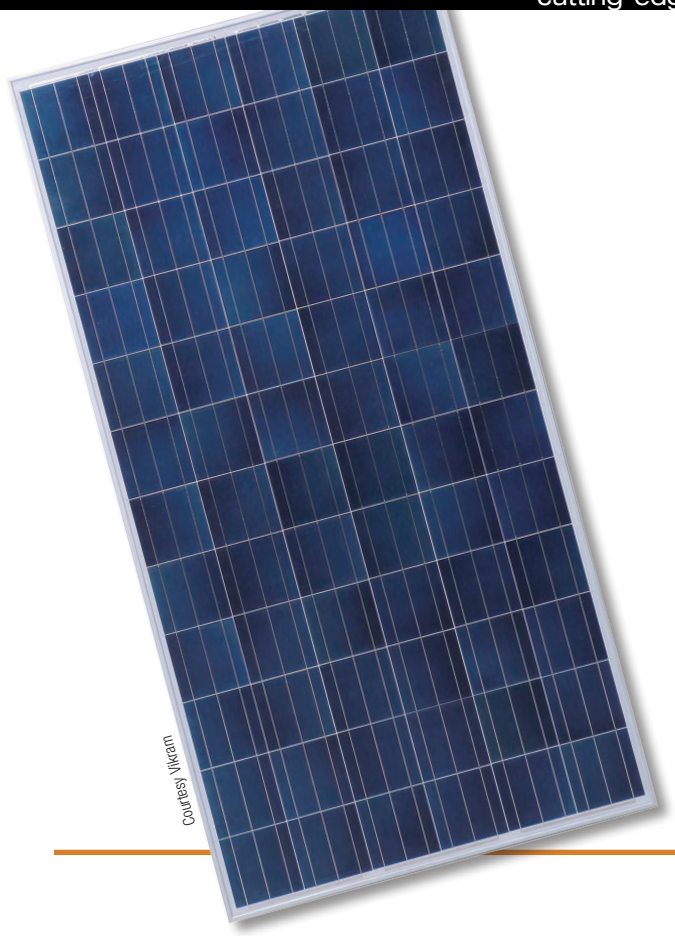
Courtesy Bentek (2)

Bentek

Residential Rapid Shutdown System

Bentek (bentek.com) offers its rapid shutdown system (RSS) for remote disconnection of PV systems per 2014 *NEC* Article 690.12. The RSS is comprised of the rapid shutdown controller (RSC), installed at building service entry; and the rapid shutdown module (RSM), installed at the array. The controller has an emergency PV shut-off button, indicator lights showing array connection status, and a cover latch used to lock out the system (i.e., "lock-out/tag-out"). The RSM is available in two- or three-series string options and has preinstalled input/output wire connectors for plug-and-play installation. The RSS works for both transformer-based and transformerless string inverters.

—Justine Sanchez


Courtesy Vikram

Vikram

Grand Ultima PV Module

Vikram Solar (vikramsolar.com) offers its Grand Ultima Silver Series polycrystalline modules, with six models ranging from 290 to 315 watts. Manufactured in India, they have 72 cells for a maximum power voltage (Vmp) range of 36.88 to 38.33 V, while maximum power current (Imp) ranges from 7.87 to 8.22 A. Module efficiency is listed at 14.95% for the 290 W, and 16.23% for the 315 W model. They have a 10-year product and a 25-year performance warranty (guaranteed 90% of rated power output for 12 years and 80% for 25 years).

—Justine Sanchez

Emissions-Free Charging for EVs

Comment & Discuss
this article @
homepower.com/169.14

In January 2015, California's Governor Brown announced an ambitious set of climate goals, including reducing cars' petroleum use by up to 50% by 2030. Achieving these goals will require broad electrification of the transportation sector. That's where Envision Solar International's EV ARC (Autonomous Renewable Charger) comes in.

Invented and manufactured in the United States, the EV ARC fits inside a 9-by-18-foot parking space. Depending on the daily sun-hours it receives, the 2.5 to 4.8 kW PV array can generate up to 37.5 kilowatt-hours per day—enough to power up to 110 miles of EV driving. The system's solar electrical generation is enhanced by tracking the sun, generating 18% to 25% more electricity than a fixed array. The energy is stored via 24 or 30 kWh of lithium-ion batteries, allowing EVs to charge during nighttime as well as during the day.

Mounted on its own ballasted pad, the EV ARC requires no trenching, foundations, or installation work, allowing it to be deployed in minutes and moved to a new location with ease via its customized trailer. The array can fully recharge one or more typical EVs per day or offer top-off charges.

"California has about 40% of the United States' EVs," says Desmond Wheatley, CEO of Envision Solar. According to a report from Navigant Research, California, New York, Washington, and Florida will lead the United States in annual sales of plug-in EVs through 2022.

EV ARCs have been installed for the City of Boulder, Colorado; and the City of Shasta Lake, California, and San Francisco. They are also being sold to state governments, such as California and U.S. Virgin Islands, and several commercial clients. They have been deployed both in public and private parking lots, shopping malls, and remote rest areas. So far, says Wheatley, the response has been overwhelmingly positive—people just love driving on sunshine.

—Desmond Wheatley

Courtesy Envision Solar International

Overview

Project name: EV ARC stand-alone EV charger

System type: Battery-based off-grid

Installer: Envision Solar

System capacity: 2.5 or 4.8 kW STC

Average annual production: Depends on daily sun-hours at given location

Equipment Specifications

PV modules: 9- or 12-module array

Batteries: 24 or 30 kWh lithium-ion

Array installation: Top-of-pole mount, EnvisionTrak single-axis, tracking

EV charging: Level 2 EV charger or two Level 1 chargers

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After the First kWh

I love your magazine—I've been reading since 2008. In 2013, we had a 5 kW PV system installed: 20 Renesol 250 W modules with SolarEdge DC optimizers and a SolarEdge 6 kW inverter. We're now contemplating adding four more modules to make it a 6 kW system. It's a small job, so I can't interest any company (including the original installer). I'm looking into doing it myself and then having a licensed electrician complete the hookup. Do you foresee any problems with maximizing the 6 kW inverter with 6 kW of modules?

Our meter says 8,522 kWh now, but somehow my wife got this picture. Sort of like the first dollar hanging in mom and pop restaurants, I framed it!

Brian Lengel • Austin, Texas

You are not alone—it is common for folks to want to increase their array capacity after a few years. This is a good reason to plan for a larger system from the get-go. Regarding inverter capacity, since you only have 5 kW installed on your 6 kW inverter, there is no problem with adding another 1 kW. In your warm climate, you could potentially add even more array capacity. This is because your modules are rated for 250 watts at standard test conditions (STC: 25°C cell temperature and 1,000 W/m^2 irradiance); generally, you will see less power from each module since cells will be much warmer and irradiance will usually be lower. (If you look at your inverter's specification sheet, the maximum DC input power is 8,100 W.) However, you will need to check with SolarEdge to see how many series power optimizers can be in each string.

Also, your original optimizers may no longer be available, so you will need find out about compatibility issues with adding newer optimizers, including interconnect (such as MC4, Tyco, Amphenol, etc.) compatibility.

Be sure to take appropriate safety precautions (even with the inverter shut down), since PV modules produce power whenever exposed to sunlight. And depending on where your modules are mounted, you may also need safety equipment to deal with heights.

Justine Sanchez •
Home Power *technical editor*

IBEW Training Center

I am the assistant training director for the International Brotherhood of Electrical Workers (IBEW) 134 in Chicago. We've had a proactive approach to renewable energy training for both apprentice and journey levels since 1995, and expanded our RE training over the years with an ambitious approach. The solar industry needs qualified electricians who can assess, fabricate, install, maintain, and troubleshoot any and all renewable energy technologies. We provide this type of training at our electrical apprenticeship school.

Courtesy Harry Ohde

The PV installation facility at the IBEW training center in Chicago.

National Electrical Contractors Association (NECA) members and IBEW 134 built a state-of-the-art training facility—the EJATT Renewable Energy Training Field. This is a hands-on training institution, and includes classroom lectures and assignments. The RETF components are:

- a 45 kW fixed-tilt, ground-mount PV system that simulates a utility installation. Electricians will fabricate and weld the mechanical structure to support both the 216 PV modules and cable tray wiring system.
- an 18 kW solar carport with four EV charging stations and provisions for future charging technologies.
- a 10 kW roof-mounted system with monitoring.
- a 100 kW bidirectional inverter that charges a 45 kWh lithium-ion battery system and 45 kWh lead-acid battery.
- a 5 kW Bergey wind turbine.
- a 4 kW system on a standing-seam metal roof.
- a 4 kW system on a composite-shingle roof.
- a 3 kW system with a dual-axis tracker and Enphase microinverters.

Harry Ohde, Assistant Director,
IBEW-NECA Technical Institute •
Alsip, Illinois

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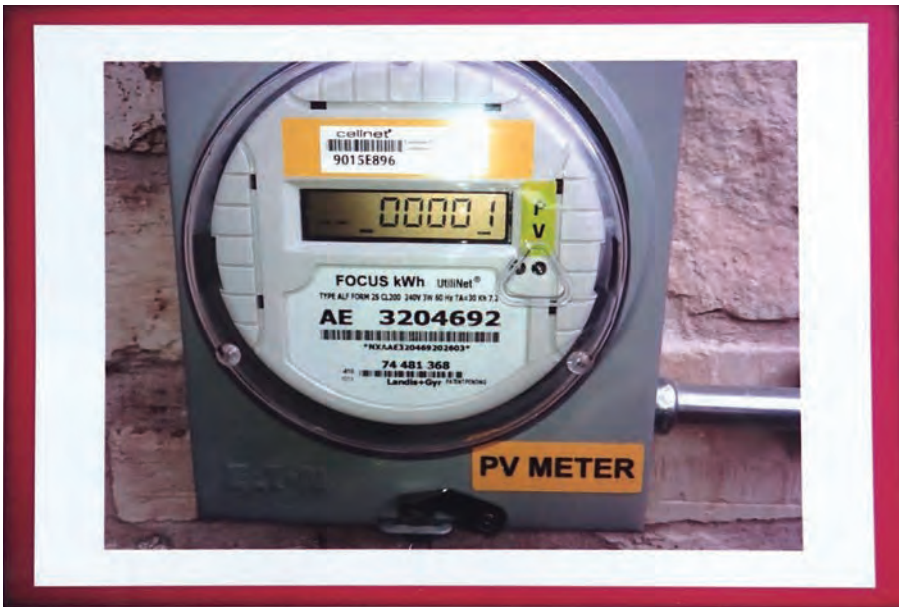
More than 8,500 kilowatt-hours ago—the Lengels' meter shows its first PV-generated kWh.



Courtesy Brian Lengel

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Resilience

Claire Anderson's editorial on "Building Resilience" in *HP166* was a welcome recognition of this aspect of self-sufficiency that goes beyond sustainability. System design must consider all of the what-ifs and alternatives. I live off-grid with an PV system sized to meet all of my energy needs for my home and shop (with generator backup), and a separate PV system provides energy for my well pump, which can alternatively be operated through the inverter.

When designing a grid-tied system, consideration for what happens when the grid goes down should be a major factor. There are ways to be more resilient while relying on one energy source. Consider a battery backup system, either on its own or as part of your grid-tied solar-electric system, to cover critical loads during outages. A PV-direct water pumping system that moves water from your well to a large storage tank that gravity-feeds water to your home is an ideal solution even if you have grid power—you will always have water.

There are many ways to provide resilience in system design. Use of renewable energy sources is usually the first consideration, but a more cost-effective design approach may be to use the same PV modules in a way that can help you when the grid goes down. You may have some inefficiency affecting system output, but you are not out of luck during an outage, and you will feel better by your wise selection of resilient equipment.

Lloyd Smith • Onyx, California

Florida Politics

I read your article entitled "Off the Grid, On the Grid, or Somewhere in Between" in *HP168*. You may be interested to know what the Ocala (Florida) Electric Utility is doing to ensure their monopoly and make sure that no one stands to benefit from installing solar-electric modules on their roofs. There is no payback with its new policy. Here is part of a letter to the editor of the *Ocala Star Banner*:

"In April, 2015, the Ocala (Florida) Electric Utilities (OEU) instituted a new policy that replaced the old net-metering system with a new system that has two meters. One meter is used to record the amount of solar energy a home generates in a given day, less what the homeowner has used. A second meter records any power that the home uses at night or when the sun is not shining. So far, so good. The problem arises when the new policy requires that I, the homeowner, sell my daily unused solar energy to OEU for less than 2.9 cents per kilowatt-hour. I, in turn, have to pay between 12 and 13 cents per kilowatt-hour for energy I use from the grid, including taxes. How can they change the rules *after the fact?* We invested in solar energy in December 2014 under one policy and now they have changed the rules so their monopoly can continue.

To give you an idea on how unfair this is, we were out of town for the month of May; during this time, our PV system generated more energy than we used, and our bill was $56.04. Of that amount, $19.02 was for taxes. OEU did give us $11.35 for energy we generated over what we used. The electricity we generated gives us no "tax break" whatsoever. OEU does not want people putting solar on their homes. There is no longer any payback or the investment solar owners made in the PV system. Who in their right mind is going to put solar on their roof when they simply become a power station for OEU?"

Glenn Hallick • Ocala, Florida

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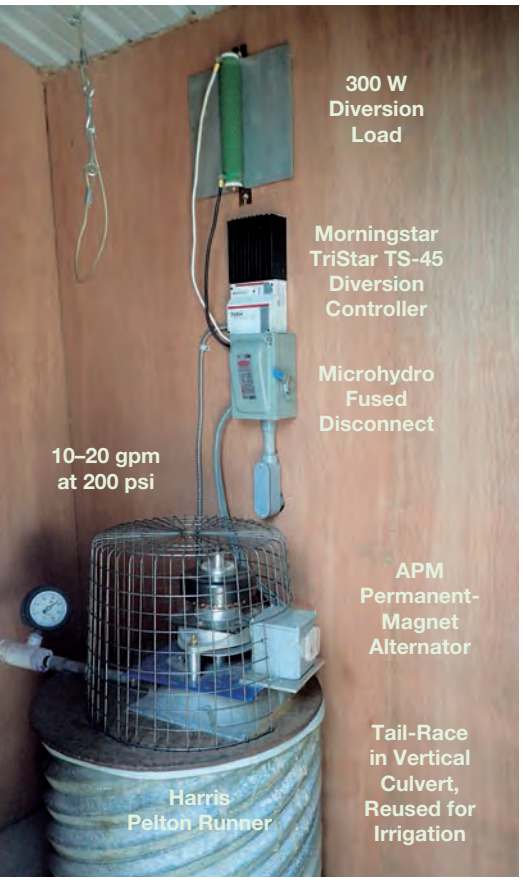
Hydro System Upgrades

Thank you for forwarding the comments from Michael Lawley that were published in *Home Power's* July/August 2015 issue. We provide responses to Mr. Lawley's concerns related to our hydro-electric system below. Mr. Lawley is hardly unique in his concern for safety—we are all doing the best we can.

Concerns: The turbine's magnetic rotor is not covered and is a rotational hazard. Lacquer copper wire is not classified as insulation for touch safety. Exposed copper stator wire is clearly visible and could be touched when operating.

The turbine is in a locked building and does not present a realistic rotational hazard nor is the stator wire exposed to any but the owner/installer. Note that this system is so weak that the rotor can be stopped by hand without any risk of injury. We understand that others might consider this article a general guide, and more powerful systems might present a realistic risk. Therefore, in the interests of extra safety, we have revised the installation to include a removable cover for the rotor, which addresses both of these concerns.

Courtesy Penny & David Eckert



Concern: The resistive diversion element is bolted to a plywood wall without any heat shield. This is a fire hazard and not allowed under U.S. standards/codes.

This is an excellent point. We installed a heat shield, with an air space between the heat shield and the wall, after the article was finalized, but before it was published.

Concern: According to the wiring diagram, the metal turbine body has no earth connection and, under a fault condition, could become a shock hazard. As the turbine is mounted on a plywood cover, it appears to have no earth connection.

The turbine is mounted on a steel cover and has an earth connection through the vertical steel culvert. Based on Christopher Freitas' article in *HP160*, we agree that an additional ground is needed to protect the electronic components. Therefore, in the interests of making the need for a ground clearer, a ground wire was added, connecting all the components of the Pelton system to a grounding rod outside the microhydro system's building. Note that the grid-tied main system, several hundred feet away, is independently grounded.

Concern: The photo on page 63 shows a red positive wire to the TriStar TS-45 and a green (assumed to be the negative, as there is no other wire) to the TS-45. Green wire cannot be used for negative connections.

With the greater focus on combined DC and AC circuitry, we understand that there has been a move away from using green as negative in DC systems. Therefore, in the interest of conformity, we replaced the red and green wire with 2 AWG Romex.

Concern: The TS-45 is not wired in per the manufacturer's advice. If the fused disconnect was opened while the turbine was running (or the fuse was to blow), the TS-45 would be damaged by overvoltage.

We were attempting to use the TS-45 to keep the turbine from overspinning when disconnected. I gather now that this is an inappropriate use and have revised the wiring to connect it directly to the batteries, using it as a diversion load only. We note that Mr. Lawley's advertised system uses a crowbar three-phase shorting unit to control overspeeding with disconnect, which sounds like a very good idea, but we don't know how to obtain such a unit for our system. For now, we have to remember to shut off the water before shutting off the electrical system.

Concern: To comply with the intent of the *National Electrical Code*, hydroelectric systems using a diversion controller should be equipped with a second independent means of charge control to prevent overcharging the battery in the event of a component failure.

The *National Electrical Code* has language that states requirements for diversion controllers used in PV and small wind power systems. It does not specifically address their use in microhydro systems. However, we note that best practices for a standard installation would include a second independent means of regulating the battery charging, even in a grid-tied system like ours, for backup if the grid is not available.

Penny & David Eckert • Orleans, California

Thanks for the detailed response, Penny and David. More importantly, the immediate action you took to address your hydro-electric system's safety and Code *compliance issues is impressive! We've updated the online version of your article in* HP167 *to reflect the upgrades you made to the system.* Home Power's *main goals are to increase the use of renewable energy systems, as well as improve their performance and safety. This is a great hands-on example of how, collectively, our community can do just that.*

Joe Schwartz •
Home Power *executive editor*

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Off-Grid Surplus Energy Use

I'm wondering if I can use surplus electricity generated by the off-grid PV system that serves my cabin, particularly in the winter. Is there a safe way to convert this excess energy to heat so that when we arrive, the cabin is not so cold? Could a single module and microinverter be dedicated to this task?

In January, the 1% design temperature is -30°C. After time away, the temperature inside the cabin is often -20°C. We have a wood heater in the bedroom that brings up the temperature to comfortable levels within two hours with the door closed, but the rest of the cabin does not get up to temperature until the next morning. We stoke a main-room fireplace over the course of the night, but there is a lot of mass to bring up to room temperature.

Gary Gardiner • North Bay, Ontario

Modern hardware makes diverting excess energy easier, and many charge controllers include diversion controls to drive a relay coil. The relay controls the supply of excess electrical energy to the diversion load, which makes possible what you want to do.

However, I would not recommend this for you. A cabin typically has a relatively small system—enough for lights, communications, refrigeration, water pumping, and entertainment. Usually, none of these loads demand a large PV array. Heating needs, whether for space or water heating, or cooking, are normally met with other energy sources, usually wood or fossil fuels.

A small PV system simply won't supply enough energy to provide space heating. For example, a typical electric space heater uses 1,200 to 1,500 watts. Running at its high setting of 1,500 W for five hours consumes 7,500 watt-hours. Factoring in inverter, battery, and wiring inefficiencies, that figure rises to more than 10,000 DC Wh needed. Assuming 3 daily peak sun-hours in midwinter, you'd need a PV array of greater than 3,300 rated W—just for the heater. This will likely be substantially more array than you need to run the entire home when you're there.

Gary makes his way to his off-grid cabin, supplies in tow.

web extras

For more on diversion controllers, see "Managing Battery Charging Using Diversion Loads" by Jeff Tobe • **homepower.com/166.52**

Courtesy OutBack Power

OutBack Power's FLEXmax series has the ability to control a diversion load via its aux output.

Ian Woofenden

An air-resistance heater diversion load (inside a protective cage).

You also would be running this heater when the cabin has remained unoccupied for several days or weeks, and its interior is likely to be as low as the outside temperature. All of the cabin's frigid interior mass must be warmed, and running an electric heater won't make much difference.

A single PV module and microinverter is not a solution. Most put out 200 to 250 W—not enough to provide substantial heat. Microinverters were developed to easily integrate PV modules with the utility grid, and were not designed for off-grid applications.

Your questions raise a larger issue. As your cabin is left unattended for long periods, your PV system must be designed for long-term reliability, using high-quality components with proven performance. Ultimately, coming into a bitter-cold cabin in the dark and having lights that work and a fire ready to light in the wood heater (because you laid it before you last left) beats coming into that cabin in the dark and having no electricity because a timer or a charge controller's auxiliary control circuit had failed and drained your batteries while you were away.

Allan Sindelar • sindelarsolar.com

continued on page 24

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Solar Hot Water Collector Flow

I'm curious about flow rate through solar water heating collectors and how that affects an SWH system's efficiency. On one hand, it seems like a slower rate would allow more heat gain, since the water spends more time in the collector. But I also understand that efficiency is higher with water that is at a lower temperature. So then I assume that more water moving through the collector more quickly (even if it's not getting as hot per cycle), is actually more efficient overall. Either way, how is a pump sized and flow rate optimized for maximum efficiency?

Ralph Warren • Charlotte, North Carolina

A good way to understand the flow rate is to evaluate it conceptually. Hot collectors don't do you any good, but a tank of heated water does. Since collectors are outside, they lose some of their collected heat whenever the collector is warmer than the surrounding air. This is the normal situation when trying to heat a tank of water to 120°F or more. The greater the difference in temperature between the collector and outside air, the greater the heat loss.

Courtesy Taco

A Taco 009F high-head iron pump, suitable for most drainback and larger antifreeze systems.

The flow rate through SWH collectors should be high enough to keep the difference in temperature (delta-T) between the collector's inlet and outlet to about 30°F or less. This low delta-T is achieved with a higher flow rate. A system that has a high delta-T, perhaps 50°F to 150°F, has too low of a flow rate—the result is a hot collector. This difference in the delta-Ts can mean as much as a 50% loss over the day in the hot collector, all due to the extra heat lost to the surrounding air. The lower delta-T, higher-flow-rate collector puts more hot water in the tank, since less heat is lost.

A high delta-T can have numerous causes: a pump or piping that's too small; a heat exchanger without enough capacity; or a pipe obstruction. A low-head pump (less than 10 feet) is sufficient for systems with one or two collectors. A medium-head pump (10 to 20 feet) is appropriate for systems up to six collectors. A high-head pump (more than 20 feet) is normally required for drainback systems and those with more than six collectors. These pump recommendations assume 3/4-inch tubing for small systems and 1-inch tubing for larger systems.

Chuck Marken • *Home Power* solar thermal editor

web extras

For more on collector efficiencies, see "Get into Hot Water" in *HP123*.

For more on pump sizing, see "Pick the Right Pump" in *HP121.*

Passive Ventilation Strategies

I'm planning a high-efficiency home, and trying to keep my energy use very low, hoping to power the home with on-site solar energy at a modest cost. However, in keeping energy use low, especially heating and cooling requirements, the home will be tight enough that it will need ventilation to avoid indoor air quality and moisture issues. I'm looking for *passive* ventilation solutions for tight, well-built homes, as an alternative to a mechanical solution such as an HRV or ERV, which use significant (to me) electricity to run. Can you suggest some options and strategies?

Claire Jones • Sacramento, California

The challenge with passive ventilation is that it's dependent on the pressure differences between indoors and outdoors. That pressure differential can result from wind, from significant differences in temperature between indoors and out, or from special components like solar chimneys that create a stack effect.

The problem is that one can't always count on these pressure differences during the "swing" seasons of spring and fall. Even with a few windows open, if there's no wind and relatively modest differences in temperature across the building envelope, there may be very little air exchange. This is why most building science experts recommend mechanical ventilation. You get the amount of ventilation you want, where you want it and when you want it.

As you note, there is always an energy penalty associated with mechanical ventilation, because fans are needed to move the air and because the fresh air brought in has to be heated or cooled. With heat-recovery ventilators (HRVs) or energy-recovery ventilators (ERVs), the energy penalty is reduced by pre-heating (in winter) or pre-cooling (in summer) the incoming air stream. The best HRVs and ERVs have highly efficient heat-exchange baffles, and they rely on variable-frequency-drive or electronically commutated motors.

With my own whole-house Zehnder HRV, the fans and heat-exchanger core are extremely efficient, and the unit is remarkably quiet. In very cold weather, the greatest energy consumption comes from electric-resistance heaters in the unit to prevent frost buildup.

I keep our HRV operating at a low level all the time and boost it for 10 minutes or 30 minutes when showering or cooking. In the 12-month period from July 2014 through June 2015, our HRV used 459 kWh—an average of 1.26 kWh per day. The vast majority of that energy was consumed in January (112 kWh), February (146 kWh), and March (38 kWh), when it was very cold in Vermont. During most months, our HRV only uses about 20 kWh. In your climate, the defrost cycle should never come on.

In Sacramento, it's sunny enough that you might be able to induce adequate airflow for ventilation by using a solar chimney. This could be a glazed chimney structure extending up above the roof of your house. Sunlight warms the air inside, making it more buoyant so that it rises and draws air from the house up and out.

A passive ventilation system like this requires air inlets around the house to introduce fresh air, and the problem with these is that they don't distinguish between different driving forces. For example, when it is windy, they can introduce more ventilation than intended when configured for the solar chimney. Because such systems are rare, we don't actually know too much about how they work or what the drawbacks might be from not having ventilation at night.

Alex Wilson • *Home Power* building science editor

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Second Battery Bank?

I have approximately 20 kWh (approximately 50% is usable) of AGM deep-cycle battery storage for my off-grid cabin. I'm using a Trace SW4024 inverter with a 220-volt transformer, and have 1,145 watts of rated PV capacity. Last winter, my system shut down several times due to low voltage, even though on the rare sunny day, it produced enough power to fully recharge the batteries. I may be renting the cabin occasionally to renewable energy types, and instead of adding a noisy generator, I'm considering adding an additional battery bank that is the same size as my current 16-battery bank (12 V, 105 Ah each), using a manual transfer switch between the battery banks and the DC side of the inverter.

Is this possible, advisable, or practical? My plan would be to keep the additional battery bank fully charged and, when the inverter low-battery cut-out point for battery bank A is reached, simply throw the manual transfer switch to bank B. My theory is that I could charge B on sunny days, use A for everyday use, and then switch to B as needed, instead of using a generator.

Joe Corcoran • Mena, Arkansas

The important thing to remember in considering your question is that *all* of the nongenerator energy comes from your PV array. The batteries are not a source of energy, but provide only energy storage. And they are not 100% efficient storage—a new battery will be 80% to 90% efficient—so 10% to 20% of the energy input is lost. Plus, batteries have a standing loss—they lose energy just sitting idle. So when you add battery capacity, you are indeed adding storage, but you are also adding load, since you need more charging capacity to maintain the batteries, including their efficiency and standing losses.

It's also important to consider how to best care for your battery bank. The most important thing is to make sure it is regularly and fully recharged. Twice a week is a good minimum interval to fully charge a lead-acid battery—daily is even better. The worst thing you can do is to deeply discharge a battery bank and leave it at that low state of charge for days.

If your system is regularly hitting low voltage disconnect (LVD), where the system shuts down because of low voltage, there's not enough charging capacity relative to your load—you are using too much electricity for your present charging capacity. Adding more storage is not a solution; the two possible solutions are to reduce load or increase charging capacity. The low voltage could also be caused by failing batteries. Having eight paralleled strings of batteries is a battery-killing recipe. It may be time for a new set of batteries; I highly recommend choosing batteries with a high-enough capacity to limit the number of paralleled strings to three (two is better).

Adding more battery capacity will probably make your problem worse, not better. A more successful solution would be to add more PV capacity. While having a "backup battery" might seem like a good solution, it actually adds to your troubles, and you could end up with *two* depleted battery banks and not enough PV capacity to recharge them in a reasonable amount of time. A backup generator—while inefficient, dirty, and noisy—is another solution in this case. But the more PV you add, the less you will need the generator.

Ian Woofenden • *Home Power* senior editor

continued on page 28

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continued from page 26

Inverter Longevity

Another solar instructor and I have a question about grid-tied inverter lifespan. I have read that an average lifespan is 11 to 14 years, and the warranties seem to reinforce this. My colleague believes that 20 to 25 years is more likely for modern inverters. I would tend to believe the latter due to more solid-state electronics in today's ungrounded inverters, but I can find no data to support this.

Jeff Foster • St. Louis, Missouri

While the expected lifetime of a grid-tied inverter will vary depending on its design, component quality, and the environment it is operating in, lifetimes beyond 14 years are likely for most of the high-quality inverters now available.

For power electronics devices, the environment in which they are installed has a significant impact on their life. I've seen inverters fail in less than a year when poorly installed and exposed to insects and moisture, and I have friends with inverters that I sold them more than 20 years ago that are still working well.

The biggest influence on inverter life is temperature—high temperatures will mostly impact the capacitors, which are usually the lowest-lifetime-rated components used in an inverter. Transformers usually will have a much longer life expectancy depending on their construction and operating temperature, so the life expectancy of transformerless, ungrounded inverters will not necessarily be higher. Since grid-tied inverters are typically designed to operate at very high efficiency levels, the electronic components usually do not operate at the temperature levels that are common in other power electronic applications (such as motor drives or power supplies), where efficiency is not as critical. This allows the components in a grid-tied inverter to be longer-lived.

Typically, grid-tied inverters do not operate 24 hours a day; they usually are "live" only about 12 hours a day, and often operate at high power levels only for a few hours. This helps extend their life expectancy. Grid-tied inverters also do not need to "surge" to start motors, so they have a pretty easy life compared to off-grid inverters, which are used with batteries and operate 24 hours a day, and are frequently subjected to overload conditions.

Some of the newer inverters (such as small microinverters) use special capacitors made for solar applications, which extend the lifetime of the inverter to better match the life expectancy of the solar-electric modules they are connected to. How much longer the life will be extended is uncertain, and we won't really know until they have been operating for a long time, but several companies are offering warranties of up to 25 years.

Christopher Freitas • SunEPI

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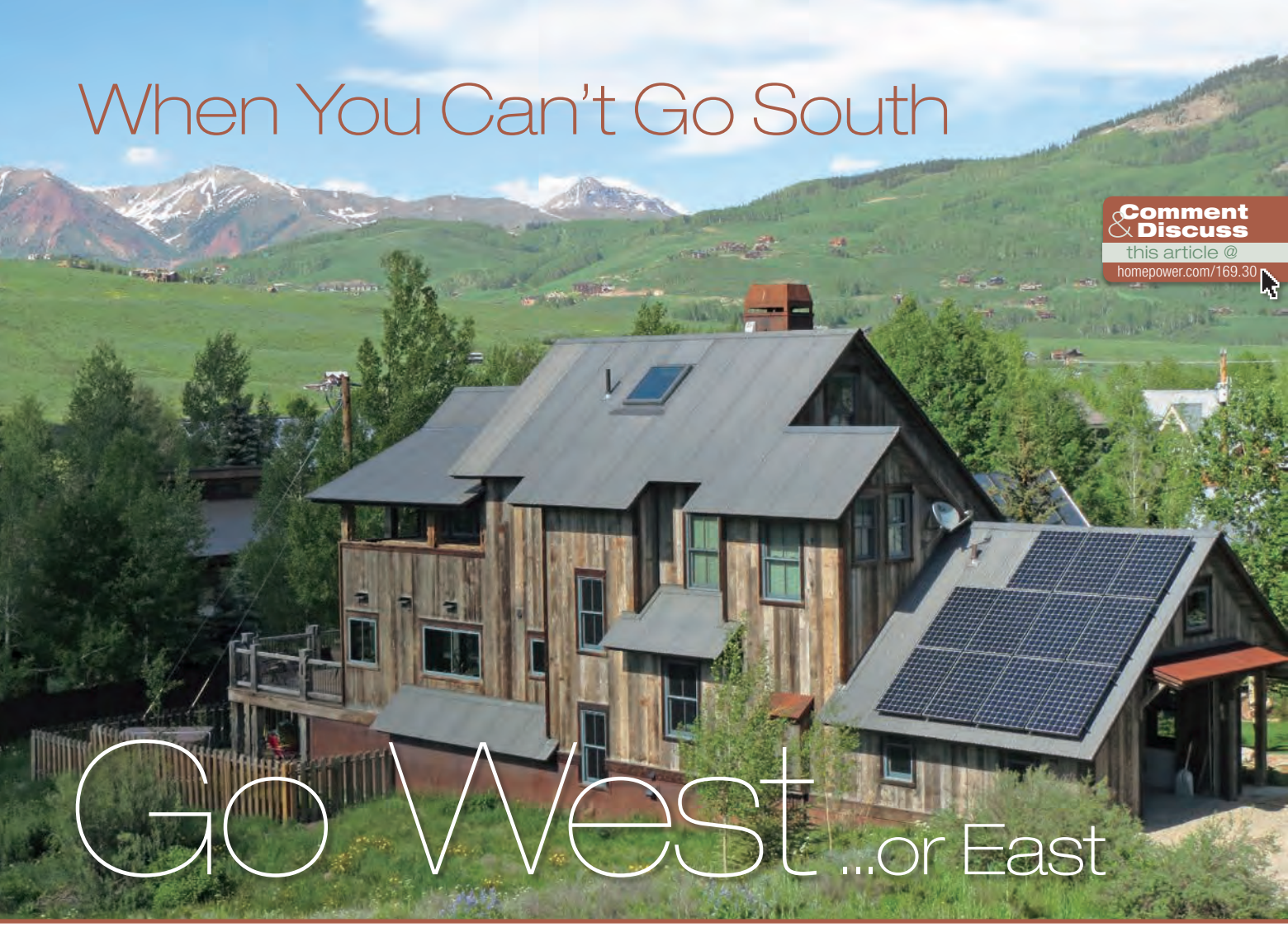

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Go West ...or East

Deviating from an "ideal" southern orientation doesn't have to be a solar deal-breaker, as these Colorado homeowners discovered after putting their PV array on a southwest-facing roof.

Story & photos by Lena Wilensky

The sun shines a lot in Crested Butte, Colorado, a historic mining town in the Rocky Mountains. Bruce and Gretchen Jacobsen bought a vacation home at the edge of town, recently completing a whole-house renovation. They were familiar with PV electricity, having considered installing a system on their home in Seattle. After living in the cloudy Northwest, they didn't want to waste all that abundant Colorado sunshine. Renewables are part of the energy future they would like to see in this mountain community. They wanted to do their part to help reduce their reliance on fossil fuels, and even though there were no local utility incentives in the Crested Butte area, nor state tax credits available, they still wanted to produce clean energy of their own.

Bruce contacted us at Nunatak Alternative Energy Solutions to discuss PV system options for their home, which was in the town's historic district. Unfortunately, there was no south-facing roof. In this part of town, the way the streets and lots are oriented encourages houses to face north or south. Their home is oriented so the steep roofs shed snow to the east and west, leaving the entrances in the north and south walls relatively snow-free. (In snow country, you don't want snow shedding on your main entrance. People get injured or killed from roof slides every year, so keeping the roof snow away from walkways is a common strategy.)

A pole- or ground-mount array was one potential strategy, and the Jacobsens' yard was large enough to accommodate two pole mounts. However, the yard had been extensively landscaped after the remodel and has a number of older trees that provide shade and privacy. Being in a historic district also means that every construction project must go through architectural review. Having a ground-mounted array within sight of the street would not fly, and a pole mount on the south end of the yard, which was also near the street, wouldn't have passed, either.

That made us look at the roof again. The larger east-facing roof had a good-sized unbroken area, and there's a little more sun exposure to the east—mornings are generally clear and thunderstorms often roll in during summer afternoons, with cloud cover when the sun is in the west. But the easterly unshaded area was two stories up, and getting a lift to access the steep, second-story roof through the landscaped yard would have been a challenge. When we also considered the long, complex wire run from the east roof to the main service panel on the opposite end of the house, we set our sights to the west.

The west side of the main house had similar issues as the east, but the attached garage roof—which had a slightly southwest orientation, at 250°—looked promising. The unshaded area was similar in size to the east roof we originally considered. The roof itself was much lower, with easy ladder or scaffolding access. The inverter would have a weathertight and relatively warm home inside the garage beneath the array, and the main service panel was located only steps from the garage, inside the home. Our only concern with the west garage roof was that snow sliding off the roof was likely to pile up during the winter and would need to be cleared from the bottom roof edge during "big snow" years. Bruce didn't think that would be an issue, as he has hired regular snow removal in the wintertime, and they could easily clear below that roof edge.

Below: Neither the east-facing roof nor the landscaped backyard were good places for a PV array.

Above: The southwest-facing garage roof provided the best location for the PV array with a 17.3% reduction in energy production compared to a south-facing array.

Maximizing Production

After pricing different array configurations and comparing energy production estimates from each, modeling their performance with PVWatts and PVSim, Bruce decided on SunPower modules for their high efficiency and industry-leading warranty. Instead of having the tiny wire contacts on the front of the PV cell, SunPower modules have a solid copper back contact. This improves their efficiency (imagine the shading from all the little wires on the front of standard PV cells) and gives structure to the delicate silicon cell (less microcracks). The company offers a 25-year hardware, production, and labor warranty—one of the best warranties around.

South vs. Southwest

It can be helpful to compare energy production from a non-optimal PV array orientation (anything other than south) to a south-facing array. While we know a southwest-facing array will not produce as much energy as one facing true south, how much less will it be? We ran some numbers, using the PVWatts calculator, to see just how much a 70° difference in azimuth will really make. Note that, in the system losses calculator, we also adjust the "snow %" loss from 5% (what's generally used for our snowy climate) to 7.5%—a southwest-facing array will take longer to shed snow than one facing south, since it gets less direct sunlight. For example, a 3.6 kW array at a 40° tilt facing true south will produce an estimated 5,605 kWh per year. The same array facing 70° farther to the west will produce 4,632 kWh per year—17.3% less energy.

PV Watts Projections

3.6 kW array, 38.85°N Latitude, 40° Tilt, 250° Azimuth

Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
January	2.63	244	37
February	3.25	272	41
March	4.45	408	61
April	5.36	467	70
May	6.06	530	80
June	6.44	539	81
July	5.77	488	73
August	5.01	425	64
September	5.13	428	64
October	4.36	386	58
November	2.83	245	37
December	2.19	200	30
Annual	4.46	4,632	$ 696

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"PV Array Output at Various Tilts & Orientations" by Justine Sanchez • **homepower.com/155.32**

Because of the roof dimensions, only about eight typical 60-cell modules (16.1% efficiency) would fit, resulting in about 2 kW. They are about 6 inches longer than the SunPower modules, and would have hung over the roof edges. To get more than 2 kW on that roof, we needed to go with a physically shorter, higher power density module from SunPower. Using 11 of SunPower's 21.5% efficiency, 345 W modules allowed another row to fit. This configuration would give a 3.795 kW system—almost double the array wattage of an array designed with standard modules. After comparing upfront costs with production, we decided to go with a slightly lower-wattage, more economical SunPower module—the E20, with 20.4% efficiency, 327 W—for a total array of 3.597 kW.

Installation Details

The corrugated metal roof required specialized mounting feet. We had Direct Power and Water configure its Easy Feet to mount over the top of the corrugations. The easy foot acts as a bridge, with the top of the bridge just touching the tops of the corrugated ridges. The "feet" of the bridge sit directly in the corrugated valleys. Instead of attaching to rafters, the Easy Feet have special fasteners that attach directly into the roof decking. With four fasteners per foot and appropriate roof decking, each foot has a pullout strength similar to flashed lag-bolt shingle roof attachments. A mastic seal on the bottom combined with long-lasting roof sealant on the fasteners create a watertight seal.

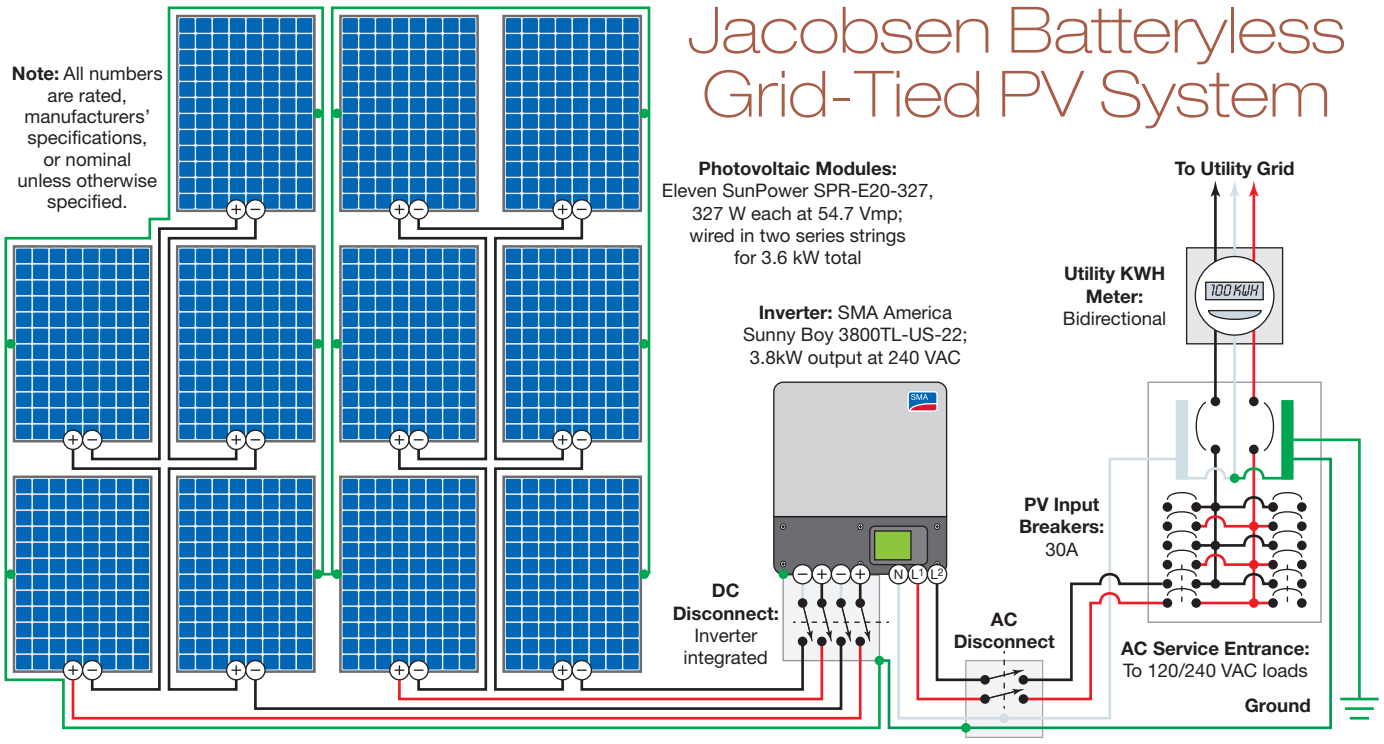
Direct Power & Water Easy Feet bear weight in the roof corrugation valleys but attach through the tops.

In sunny conditions, a Sunny Boy inverter with Secure Power Supply can provide some backup energy during daytime utility outages.

web extras

"Backup Power without Batteries" by Orion Thornton • homepower.com/159.72

Jacobsen Batteryless Grid-Tied PV System



Because of heavy snow loads in this area, we have to pay particular attention to the rack's allowable span between attachment points. Many rack products cannot meet the loading requirements of this region's extreme environment. Or if they do, some specify an excessive number of mounting feet, such as every 12 inches along the rail—not a good solution. We used Unirac's SolarMount rack, which is engineered to hold up to these kinds of loads. Our design snow load (100 pounds-per-square-foot ground snow load; 40° roof) called for mounting feet every 42 inches along each rail. The overhang on the ends needed to be limited to 16 inches or less. We used WEEBs for grounding the modules to the rails, and ran the PV wires through the roof to a pass-through box inside the garage, where we transitioned to THWN-2 wire.

We chose an SMA America Sunny Boy transformerless inverter with a secure power supply (SPS) outlet. The SPS is an electrical outlet that can provide electricity from the array, powering a small load when the sun is shining and the grid is down. Normally, when the grid is down, batteryless PV systems also shut down. This inverter also shuts down in that it cannot send any power to house loads or back onto the grid, but it can energize one dedicated outlet. The SPS can power a maximum of 1,500 W of loads, and is dependent on the PV array's output.

This inverter also has two separate MPPT channels, which meant that our layout of 11 modules—one string of five modules and one string of six modules—would work. A single series string would have exceeded the *National Electrical Code* restriction of 600 VDC for dwellings. But since the inverter has dual MPPT input, we split the array. SunPower's residential monitoring system provides system production data and remote Web-based monitoring.

Tech Specs

Overview

Project name: Jacobsen residence

System type: Batteryless, grid-tied solar-electric

Installer: Nunatak Alternative Energy Solutions

Date commissioned: November 2014

Location: Crested Butte, Colorado

Latitude: 38.85°N

Solar resource: 5.5 average daily peak sun-hours

ASHRAE lowest expected ambient temperature: -23.8°F

Average high summer temperature: 82.4°F

Average monthly production: 386 AC kWh (est. by PVWatts)

Photovoltaic System Components

Modules: 11 SunPower, SPR-E20-327, 327 W STC, 54.7 Vmp, 5.98 Imp, 64.9 Voc, 6.46 Isc

Array: Two series strings—five-modules and six-modules, 3,597 W STC total; 273.5 and 328.2 Vmp, 5.98 Imp each string, 324.5 and 389.4 Voc, 6.46 each string Isc

Array installation: Unirac SolarMount mounts with DPW Easy Feet installed on 250°-facing roof, 40° tilt

Inverter: SMA America Sunny Boy 3800TL-US-22-240, 3,800 W rated output, 600 VDC maximum input, 175– 480 VDC MPPT operating range, 240 VAC output

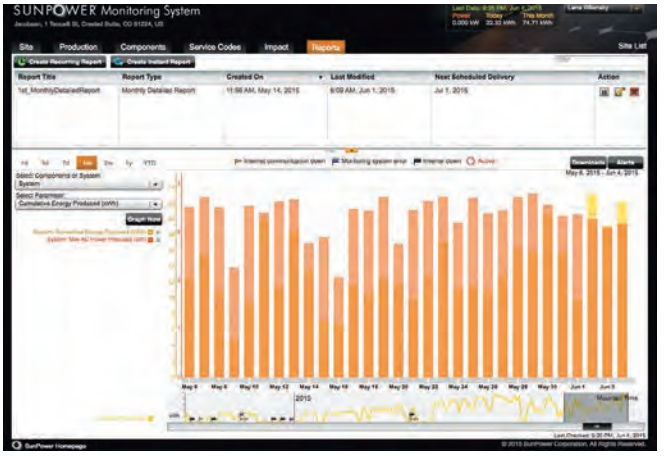
System performance metering: SunPower monitoring system

Installation Hurdles

The Town of Crested Butte requires a Design Review committee to approve the planned system. Although the rules on paper for PV systems are somewhat restrictive, in practice the committee has allowed most PV system proposals. Since this PV array was roof-mounted and not facing the street, the committee passed the project through relatively painlessly. The structural engineering was a breeze, as the recent remodel included bringing the building up to current building code. The only catch was that the town also required a separate $499 building permit to install the PV system. This cost is in addition to the required state electrical permit. Fortunately, this turned out to be one of the last projects the utility approved before raising its net-metering fee from $30 to $350. Overall, solar fees for systems within the Town of Crested Butte now exceed $1,000, and this is on top of the 4% sales tax (another $800 for a $20,000 PV system). While this town is not alone in its fees, it is definitely not encouraging solar growth. Hopefully more people with a vision for clean energy will speak up and we'll see some of these policies change in the near future.

The PV array went up smoothly, and the inverter, secure power supply outlet, and monitoring system were all hung on the interior garage wall to shield them from the area's chilling temperatures. The wire run from the inverter to the main service panel turned out to be the most cumbersome part of the installation, as a large section of drywall had to be removed to enter the main panel correctly.

The system had to pass a number of inspections before it could be commissioned. The state electrical inspector had to inspect all of the grounding and connections under the array, as well as some of the modules installed. We had to get a wiring rough-in inspection before we covered up the drywall in the house, as well as a final electrical inspection. The building inspector also had to inspect the system. Once that was complete, we called in the utility to change the existing electrical meter to a net-metering model. We also needed to test the inverter's anti-islanding function, ensuring that it wouldn't backfeed the utility lines when the grid goes down. The monitoring system went in without much to-do, and after giving Bruce a quick rundown on the PV system and a reminder to keep the bottom edge of the roof clear of snow, the system was online.



SunPower monitoring software displays production from the southwest-facing PV array.

Sunny Power Supply

Since its commission in November 2014, the system has had peak power production of 3.8 kW a couple of times in the spring. At an elevation of almost 9,000 feet, less atmosphere and cold temperatures can make higher-than-STC output from a PV array. Light reflection from snow on the ground also contributes to increased irradiance, boosting production. The system's cumulative production this year has suffered due to the wettest spring the region has experienced in 100 years, but the longer, sunnier summer days ahead may help make up for it.

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Creating A Resilient Home




by Alex Wilson

A resilient home can weather whatever comes its way, and still provide its inhabitants with what they need to survive—and thrive.

Thermal Resilience

Whether the climate in your area is getting hotter, cooler, wetter, or drier, the ability of your home to deal with changing conditions is an important aspect of its resilience. A key tenet of resilience is that houses be able to maintain habitable conditions in the event of an extended power outage or interruption in heating fuel—this is referred to as passive survivability. In the absence of energy input, a resilient house shouldn't get too cold in winter or too hot in summer—it should keep residents safe, which is different from comfort.

Although there is debate about what constitutes safe conditions, since that varies depending on the age, health, and metabolism of the occupants as well as relative humidity, a reasonably safe temperature range is 50°F to 90°F. This goal can be achieved with a highly insulated building envelope,

Gauge Your Risk

The vulnerabilities you'll focus on depend upon where you live. In low-lying coastal areas or an inland river valley, flooding might be your greatest concern. In seismically active regions, structural resilience may be the focus. In Tornado Alley, providing shelter from those storms is wise.

Here are resources to help assess vulnerabilities in your area.

Floods: Along the Atlantic and Gulf Coasts, a new resource from the National Oceanic and Atmospheric Administration is the Coastal Flood Exposure Mapper • http://bit.ly/NOAAfloods

Floods, hurricanes, tornadoes: Federal Emergency Management Agency • fema.gov

Earthquakes: U.S. Geological Survey • earthquake.usgs.gov

Drought: National Drought Mitigation Center • droughtmonitor.unl.edu

General information: American Red Cross • redcross.org/prepare/location/home-family

Images ©istockphoto.com/ (L to R): Bryngelzon, David Parsons, Minerva Studio, SlobodanMiljevic

Insulation Recommendations by Climate Zone (R-Values)

Climate zone[1]		Windows[2]	Foundation		Walls[3]	Roofs[3]
			Slab	Walls		
1-2	Hot, humid	3	0	5	20	60
3-4	Moderate	4	5	10	30	60
5-6	Cold	5	10	20	40	60
7-8	Extreme cold	6	20	30	50	80

1. Climate zones defined by the U.S. Department of Energy and the International Energy Conservation Code
2. Unit R-values for windows, based on NFRC measurements
3. Whole-wall and whole-roof R-values account for framing

along with passive solar heating and natural cooling. As would be expected, more insulation is required in colder climates (see "Insulation Recommendations" table).

In addition to insulation levels, passive solar gain and cooling-load-avoidance measures are very important in ensuring passive survivability. Window area should be greater on the south side of the house (in the northern hemisphere) than on the east and west, and thermal mass should be provided to store passive solar heat.

In new construction, house size is another very important consideration. Building smaller, more space-efficient houses is an excellent way to keep heating and cooling requirements minimal—even though the energy use per square foot may be higher.

Addressing Inefficiencies

One of the main tenets of making a home more resilient is to address inefficiencies, such as air infiltration or water-wasting fixtures, all along the way. One way to identify inefficiencies is to do a whole-house energy and water use audit.

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Passive Extras

"Passive Solar Home Principles" by Scott Gibson • **homepower.com/163.50**

"Passive Solar Design from a Passive House Perspective" by Katrin Klingenberg • **homepower.com/166.44**

"Designing a Passive Solar Slab" by Robert Riversong • **homepower.com/136.60**

"Low Thermal Mass Sunspaces" by Gary Reysa • **homepower.com/158.70**

"Cooling Your Home Efficiently" by Claire Anderson • **homepower.com/154.84**

Courtesy William Sikora

In a heating-dominated climate, solar gain and good insulation can keep a home cozy without much energy.

© istockphoto.com/ duckycards

In a cooling-dominated climate, earth-coupling and shading the home from the sun can make a home comfortable without much energy input.

Energy Resilience

Electricity. Generators can offer electricity resilience as long as fuel lasts, but the greatest resilience is from PV systems with battery banks. (Electricity generated from microhydro systems can also provide resilience, given a constant stream flow and good head, but good hydro resources are uncommon.) All off-grid systems include batteries, but the majority of PV systems are batteryless grid-tied, which won't work during a power outage.

For a grid-tied PV system, the resilient PV solution can operate in grid-tied mode normally, but switch to stand-alone if the grid goes down. In this case, the power requirements during a power outage can be limited to critical loads, thus minimizing the size of the battery bank.

A lower-cost option is the SMA America Sunny Boy TL inverter with secure power supply (SPS) that provides power during power outages, only while the sun is shining on the array. This option can provide daytime recharging for cell phones and laptop computers, power other small loads, and even power a freezer or refrigerator.

For those who already have a batteryless grid-tied PV system without SPS, a battery-based system can be added through AC-coupling. The second system can operate without the grid, and essentially fools the batteryless system into thinking it is the grid and still operating. In this way, AC loads can continue running up to the capacity of the combined systems during the day, and up to the capacity of the battery-based system when there's no sun.

With its Secure Power Supply feature, SMA America's line of TL-US inverters can provide up to 1.5 kW of AC power when the grid is down but the sun is shining.

Courtesy SMA America

Energy Extras

"Sizing a Grid-Tied System with Battery Backup" by Flint Richter • **homepower.com/139.66**

"Adding Battery Backup to Your PV System with AC-Coupling" by Justine Sanchez • **homepower.com/168.38**

"Backup Power without Batteries" by Orion Thornton • **homepower.com/159.72**

"Taking a Tiny House Off Grid" by Allan Sindelar • **homepower.com/167.34**

"Portable PV" by Jeffrey R. Yago • **homepower.com/168.28**

Courtesy SunReady Power

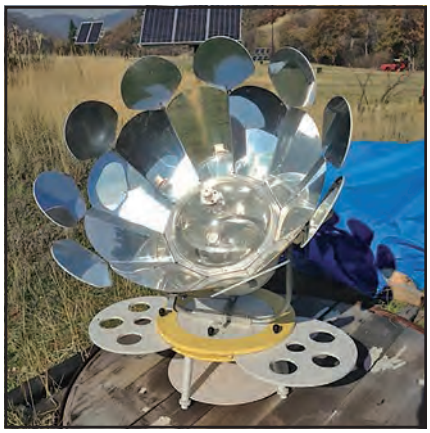
Portable solar power systems can provide emergency power for communication, lighting, and battery charging.

Courtesy OutBack Power

This AC-coupled system includes battery backup, integrated with a batteryless grid-tied photovoltaic system.

Water Heating. The most resilient water heating option uses solar-thermal collectors. Solar water heaters can be passive—thermosiphoning or batch-type (integral collector-storage)—or they can be pumped, using electric pumps and controls. With the latter, PV-powered pumps provide simple control: When it's sunny, the pump operates, circulating water through the collectors.

Including a heat-exchanger in a wood heater is another option for resilient water heating, particularly for winter months when wood heating is likely to be in use. Note that modifying a clean-burning wood heater with a heat exchanger for water heating may affect performance and increase emissions. Some advanced European wood heaters include integral water heating, but these are very expensive.



Kathleen Jarschke-Schultze

Solar ovens like the StarFlower can bake without combustible fuel and without heating up the home.

Solar Hot Water Extras

"Solar Hot Water System Types & Applications" by Chuck Marken • **homepower.com/141.48**

Shawn Schreiner

A solar water heating system can often provide adequate hot water, even without utility power.

Cooking. During a utility outage, how will you cook? A gas range can cover this, as long as the natural gas line isn't turned off (often done during natural disasters to avoid fires) or you don't run out of propane. You'll have to light burners with a match, and most modern gas ovens won't work without electricity, because of the glow-bar. Efficient wood cookstoves (and even cooking atop a wood space heater) are other options, though during the summer, adding that heat to the house is a problem. Outdoor grilling during the summer avoids overheating the house.

I have a small BioLite camp stove that uses wood (small twigs) and includes a small fan powered by thermo-electric technology (heat-to-electricity); this stove includes a USB port for charging a cellphone while cooking. Solar ovens are a backup option, especially for summertime power outages, but cooking is limited to daytime and full sun is usually required.

Courtesy Eben Fodor

The same energy that grows your fruits and vegetables can also dry your harvest.

Cooking Extras

"The StarFlower" by Kathleen Jarschke-Schultze • **homepower.com/165.60**

"Savor Summer: Drying Produce with the Sun" by Eben Fodor • **homepower.com/119.58**

Resilient Water Supplies

In rural areas, access to potable water is often the biggest problem during power outages. Most of us have 240-volt, deep-well, submersible pumps that can't operate during outages, so we have to drive somewhere to fill up jugs for drinking water, and we may haul water from a creek to flush toilets.

Water-pumping options. High-performance hand pumps can deliver water from the same wells served by submersible electric pumps. Bison Pumps and Simple Pumps are positive-displacement pumps, in which lift is created through valves that open when the piston is lowered (by lifting the pump handle) and seal when the piston is raised (by pushing down on the handle).

These pumps fit onto standard well casings in the same wells served by electric pumps and with a few strokes of the pump-arm, water is delivered to a bucket or to the house through a potable-water hose. In cold climates, weep holes that are drilled into the pipe below frost depth allow water to drain back into the well, preventing freezing, but keeping the pipe mostly full so that water is delivered quickly. Some of these pumps can lift water from a static-head depth of more than 300 feet.

PV-direct solar water pumping to a large cistern or other storage container is also great option to improve a home's resilience. If positioned well, the stored water can be gravity-fed to the house or point of use.

Water-Pumping Extras

"Solar-Powered Water Pumping" by Roy Butler • **homepower.com/164.60**

"Appropriate Technology for the Developing World" by Ian Woofenden • **homepower.com/133.80** (Solar water purification)

Solar pumping systems can be AC-powered, DC-powered, or PV-direct (batteryless).

Roy Butler

Rainwater Extras

"Catching the Cloudburst" by Heather Kinkade • **homepower.com/125.38**

"From Well to Rainwater" by Stephen Hren • **homepower.com/149.58**

Having on-site rainwater collection and storage is a valuable addition to a home's resiliency.

Courtesy saferain.com.au

Rainwater harvesting. Even in areas with fairly low annual rainfall (less than 20 inches), rainwater can provide a great backup water supply. For every inch of rainfall on 1,000 horizontal square feet of roof, about 600 gallons of water can be collected. To depend on rainwater for 100% of your water needs, at least 20 inches of annual precipitation is usually needed, though that depends on the size of the roof and the seasonality of rainfall. Rainwater is usually collected from the roof (metal roofing is best), filtered, and stored in a tank (cistern). To use rainwater for drinking or cooking, further filtration and purification is advised.

Water storage. An even simpler backup water option is storing adequate water for emergency use. For potable uses (drinking, cooking, brushing teeth), a minimum of 2 gallons per person per day is recommended. So, having a week's worth of water on hand for a family of three would require 42 gallons. Water should be stored in sealed containers out of direct sunlight in a freeze-proof location.

Composting toilets. Flush toilets account for a large percentage of our home water use. That can be eliminated with a composting toilet, which requires no water. Be sure to get one that does not require electric input, or with electrical components powered by a PV module. The simplest sanitary "emergency" toilet is a sawdust toilet—which can be a 5-gallon bucket, a lid, and some carbonaceous cover material, like mouldered leaves, sawdust, or peat moss, and an outdoor compost bin. The beauty of the bucket is that it is simple, easy, and inexpensive. (See the *Humanure Handbook* by Joseph Jenkins.)

Resilient Transportation

Issues of resilience extend to the broader community and include access to key services. These vulnerabilities need to be addressed at the land-use planning level, and they include such strategies as increasing housing density and creating more walkable and bikeable communities. Often, zoning bylaws need to be changed to permit mixed-use development that makes walkable communities more feasible.

As we seek to make our own home and farm more resilient, we will be trading in our 12-year-old hybrid Honda for a plug-in hybrid or electric vehicle that we can charge using surplus electricity generated by the PV system on our barn. Two to 3 kW of the PV modules on our roof will power all of our around-town driving, including commuting into work when it's too cold to bike the 14-mile round-trip. Because we don't (yet) have a battery bank for our solar system, we hope to configure the plug-in hybrid or EV so that we can use it to provide emergency power during outages.

Electric bikes, scooters, and motorcycles also offer a more resilient form of transportation if they can be recharged by an on-site solar-electric system (that also has batteries). Some people may choose to fuel their diesel engines with waste vegetable oil or make their own biodiesel, although both require a feedstock and the latter requires additional chemicals to process the vegetable oil into usable fuel.

Courtesy Brammo

Electric-powered vehicles come in many sizes and shapes to meet different needs of range, climate, load capacity, and charging resource.

Transportation Extras

"Solar Electricity at Home & On the Road" by Kevin Johnson • **homepower.com/117.88**

"Fueling with Sunshine" by Brad Berman • **homepower.com/165.42**

"Personal Electric Vehicles" by Ted Dillard • **homepower.com/144.58**

Electric cars are becoming more commonplace, and can be charged directly from solar-electric systems.

Courtesy Tom Moloughney

Flood Resilience

When considering home locations, avoid places prone to flooding. Significant building restrictions apply in FEMA 100-year flood zones (places expected to flood, on average, once every 100 years—or that have a 1% chance of flooding in any given year). Avoid these locations when building, as per codes, insurability, and resilience. But it makes a lot of sense to go further and avoid the 500-year flood zones (places with a 0.2% chance of flooding in any particular year).

Elevate mechanical & electrical equipment. To protect equipment, keep mechanical and electrical equipment out of basements and above flood elevations. FEMA typically calls for mechanical equipment to be installed (or moved) above the base flood elevation (BFE), defined as the 100-year flood elevation. For greater resilience, go well beyond that—keep mechanical equipment at least 5 feet above that elevation (BFE+5), or at least 2 feet above the 500-year flood elevation.

Relocating mechanical equipment may be an opportunity to upgrade that equipment or even rethink how you heat and cool your home. It could be an opportunity, for example, to replace an aging furnace with a high-efficiency air-source heat pump. Improvements to the building envelope can often mean a smaller heat pump, with less energy consumption.

Implement wet floodproofing measures, which allow floodwaters to enter and flow through a house. While seemingly counterproductive, this strategy protects the house from potentially more-damaging forces from the water, which can collapse walls. In flood-prone areas, keep living

areas well above the base flood elevation by building on piers or leaving openings in the concrete foundation walls to allow water to enter. Breakaway walls can be added that floodwaters will easily push aside. That floodable, ground-level space can be used as a carport or for storage. In flood-prone areas, full basements are best avoided.

Wet floodproofing measures also include using interior materials that can get wet and then dry out again without being damaged or growing mold. This means avoiding cellulosic materials, such as wood floors, wood subflooring, and paper-faced drywall. If floodwaters are expected to last for more than a day during flood events, even wood studs should be avoided in favor of metal studs. Wall coverings and paneling should also be avoided, as they can trap water. Materials that can get wet and then dry out include concrete floors, tile floors, and fiberglass-faced drywall.

When fuel tanks are in a floodable basement or ground-level space beneath an elevated living area, they should be securely anchored to concrete. This will prevent them from floating and breaking pipes that connect them to heating systems.

Wind Resilience

Many areas have the potential for tornadoes and hurricane-force winds. That makes designing homes (and their RE systems) that meet the nation's most stringent hurricane codes a smart move.

- Provide building geometries that reduce wind resistance and uplift potential. Consider hip roofs instead of gable roofs; limit overhangs at the eaves; and provide entry doors on the more-protected lee (downwind) side of a house.
- Incorporate hurricane straps and other steel anchoring systems to hold wood-frame structures to the foundation and tie the different frame elements together. Shear panels at the house corners can provide racking resistance.
- Install wind-rated roofing, and use hurricane-code-compliant nail spacing.
- Install impact-rated windows or exterior hurricane shutters in hurricane-prone areas. Tempered-glass or laminated glass windows are more expensive than standard windows, but that additional cost can quickly be recovered if a major storm occurs.
- PV array mounts should be appropriately engineered to code and to withstand wind forces.

Fire Resilience

With drought conditions becoming more frequent, protecting a home from fire is becoming especially important. If you're in forested fire country, around your home, select materials and plants that help inhibit fire rather than spread it. Immediately around the home, create a 30- to 100-foot buffer zone that's free from brush and other debris. Choose noncombustible materials for the home's exterior—metal or stone roofs, and adobe, concrete block, or concrete stucco finishes. Surprisingly, most houses that burn down during wildfires do so when embers enter attics through soffit vents. Select ember-excluding soffit vents to minimize this risk. Keep debris from collecting under decks—another common way in which houses can catch on fire. Make sure access roads are wide enough to accommodate emergency vehicles. Provide on-site water storage and a portable pump for on-site fire-fighting.

Tornado-Safe Rooms

There is no affordable way to build homes that can withstand tornadoes, which have winds that can easily exceed 200 mph. The solution is to provide a safe room where residents can be protected from collapsing walls or roofs and where they won't be carried away by the winds.

Most such rooms are built of reinforced, poured concrete or concrete block walls with rebar and filled cores. The roof of a safe room can be metal or built of wood beams designed to carry significantly greater loads than standard wood-frame construction. Excellent guidelines for site-built safe rooms are available from FEMA.

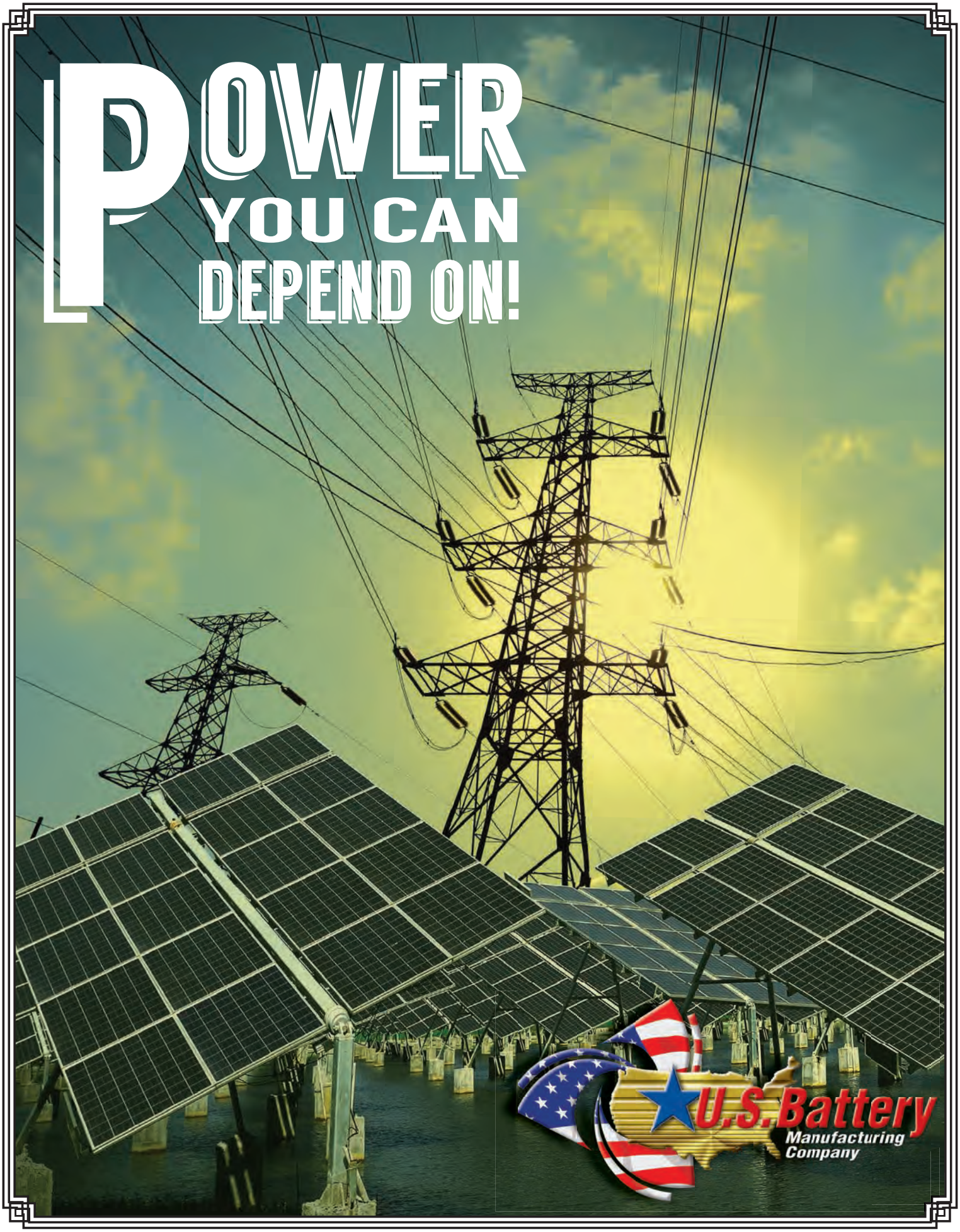
Courtesy Merten Homes

Insulated concrete forms are becoming recognized for their sturdy storm-resistant construction as well as thermal capabilities.

Other Resiliency: Food & Community

Food. The average distance food travels to get to your plate is about 1,400 miles. This vulnerability calls for greater reliance on locally produced food. Growing some of your own vegetables, raising poultry, and supporting local farming all help provide food security.

Community. Strong, tight-knit communities are more resilient and better able to respond to disturbances and interruptions. During a disaster, your neighbor is your first responder. Strategies to build stronger communities include holding regular gatherings that bring people together. In the design of large multifamily buildings, including a common room can provide a venue for community activities.



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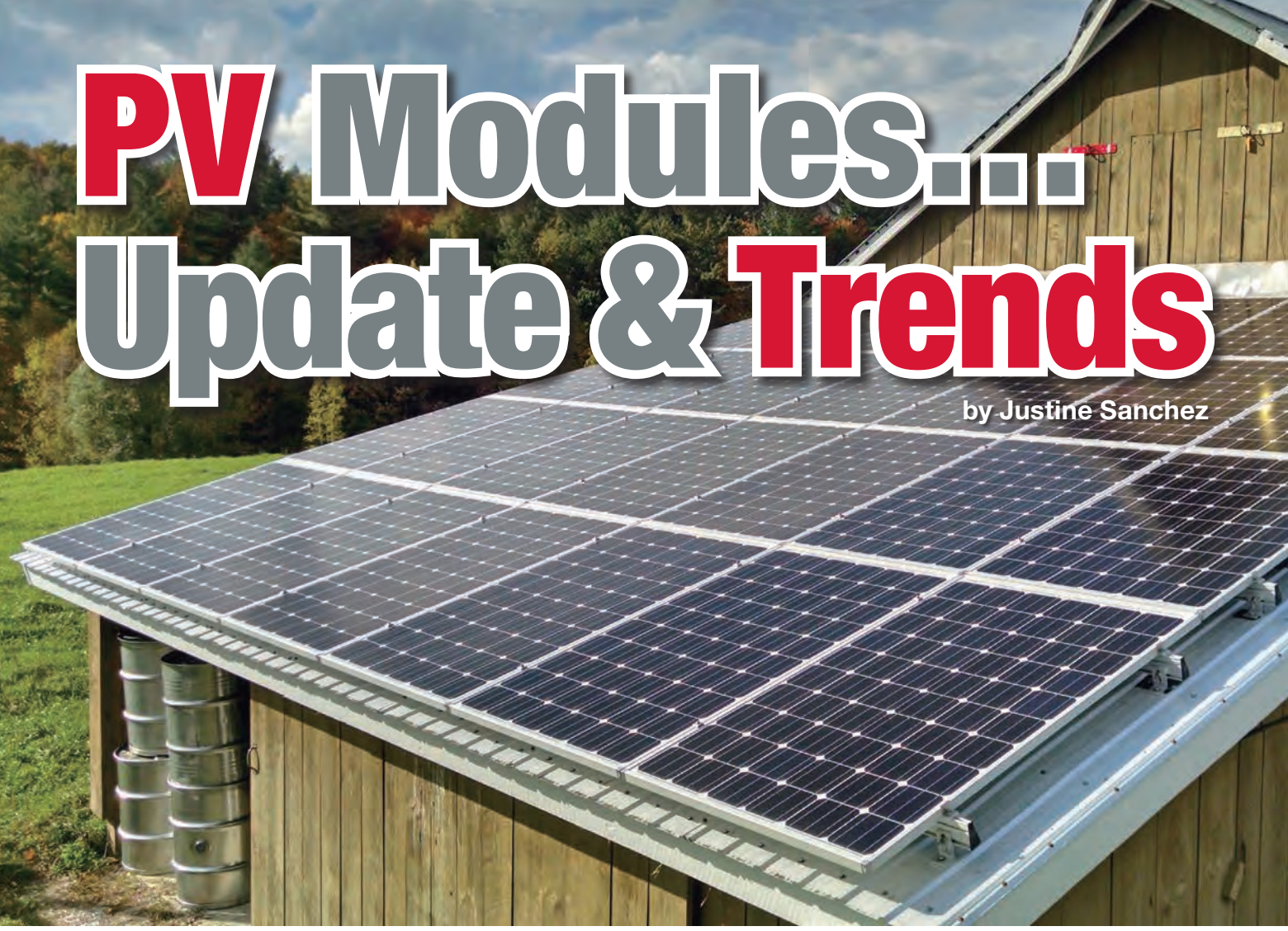
PV Modules... Update & Trends

by Justine Sanchez



Courtesy Same Sun of Vermont

Now that solar technology is cropping up on rooftops across the country, you might be finding your friends and neighbors looking for more information about this "new" industry. Here are some current solar industry statistics and PV module trends for those increasingly common over-the-fence conversations.

The Numbers

According to GTM Research and the *U.S. Solar Market Insight—2014 Year in Review* by GTM Research and the Solar Energy Industries Association:

- "PV was a $13.4 billion market in the U.S. in 2014, up from $3 billion in 2009," says Shayle Kann, senior vice president at GTM Research.
- In the United States, 6,201 megawatts (MW) of PV modules were installed in 2014, up 30% from the previous year. That made 2014 the largest year ever in PV installations.
- Residential PV installation continues to be the fastest-growing solar market segment in the United States, with 2014 marking three consecutive years of greater than 50% annual growth.

For the first quarter (Q1) of 2015 thus far (*2015 U.S. Solar Market Insight Report*):

- During the first three months of 2015, utility, commercial, and residential solar installations represented 51% of all new electric-generating capacity brought online, outpacing even natural gas.
- Residential solar installations grew by 76% compared to the first quarter of 2014, with 437 MW of residential PV installations. That's an 11% jump over the previous quarter, the market segment's previous high-water mark.
- Through Q1 of 2015, nearly 25% of total residential PV installations to date, have now come online without any state incentives.
- PV installations are forecast to reach 8.1 GW for 2015, up 31% over 2014. Growth will occur in all segments, but will be most rapid in the residential market.

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In 2014, PV was a $13.4 billion market in the United States, up from $3 billion in 2009.

Money Trends

PV system costs continue to decline. Retail PV modules average $0.72 per watt (as of Q1, 2015). Although that's not a fluctuation from last year's average, the average cost of a fully installed residential system continues to drop due to decreases in balance-of-system (BOS) and "soft" costs. As of Q1 in 2015, it's at $3.46 per watt, 10% lower than Q1 of last year.

One factor impacting module prices is the ongoing (three years now) trade dispute between the United States and China, resulting in tariffs on Chinese modules. In 2012, an investigation was launched to determine if Chinese module manufacturers were "dumping" (i.e., selling their products in the United States at prices less than fair value) and, if so, to establish antidumping (AD) duties. Additionally, countervailing duties (CVD) were to be determined to address Chinese government assistance and subsidies used to enable Chinese manufacturers to sell modules more cheaply than U.S. manufacturers.

As of July 2015, the Department of Commerce completed its administrative review of the investigation, and imposed duties on Chinese module manufacturers (combined AD and CVD) will range from 21.7% to 259.9%. There is also a separate second investigation, launched in 2014, that is aimed at dealing with companies who moved their production to Taiwan to avoid the tariffs.

Courtesy Yingli Green Energy

Manufacturing Shakeout

While the PV industry as a whole has had fantastic growth over the last several years, it has not been without growing pains. During this same time, the industry has lost dozens of module manufacturers (either closed or exited the PV manufacturing arena). The list includes Abound Solar, Applied Solar, Bosch, BP, Day4 Energy, Evergreen, LDK, Schott, Schuco, Siliken, Solon, Solyndra, and Suntech Wuxi, to name a few.

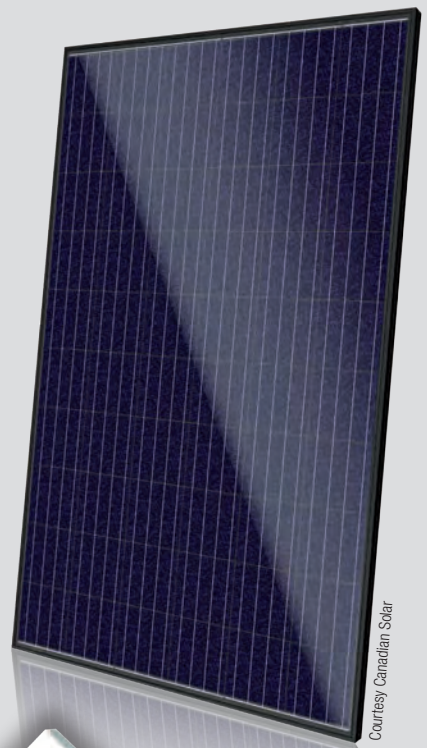
The following PV manufacturing companies have survived to claim the top 10 spots in production numbers for 2014 based on shipments worldwide (source: IHS):

1. Trina Solar
2. Yingli Green Energy
3. Canadian Solar
4. Hanwha SolarOne
5. Jinko Solar
6. JA Solar
7. Sharp Solar
8. ReneSola
9. First Solar
10. Kyocera

Top: Yingli Green Energy's Panda.

Right: Canadian Solar's FANCI.

Below: Trina Solar's DUOMAX.



Courtesy Canadian Solar

Courtesy Trina Solar

Courtesy Same Sun of Vermont

*A PV system raises a home's value by about **$4.17 per watt**...20% more than the current average cost of an installed system.*

While it doesn't directly impact module pricing, the expiration of the federal solar investment tax credit (ITC) at the end of 2016 will impact the PV industry. Currently, PV system owners can recoup 30% of the installed system cost at tax time, but that will no longer be the case should the ITC expire. In an effort to extend the ITC, California U.S. representative Mike Thompson introduced H.R. 2412, the "New Energy for America Act," which includes a provision to extend the ITC for an additional five years. Those interested in supporting this legislation can find more information at seia.org.

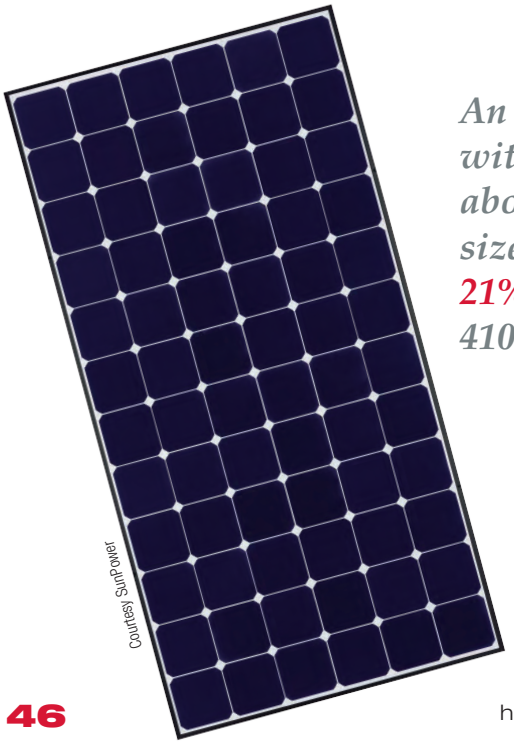
Home values increase beyond the PV systems' cost. In January 2015, Lawrence Berkeley National Laboratory released *Selling into the Sun: Price Premium Analysis of a Multi-State Dataset of Solar Homes*, which examines the sale of homes with PV systems in eight different states. Their findings, which included home sales spanning 2002 to 2013, describe how a PV system raises a home's value by about $4.17 per watt.

Using the current average system cost of $3.46 per watt, that would mean a 3,600 W system that costs $12,500 (or $8,700 after the federal tax credit) could increase a home's value by about $15,000 for resident-owned PV systems. It is important to note that this study and its findings are specific to systems owned by homeowners, and does not apply to leased systems. To our knowledge, an analysis of leased systems and their impact on home values has not been completed.

Tech Trends

PV module efficiency continues to climb. In the last 15 years, average PV module efficiency has gone from about 11% to 16% for typical crystalline silicon modules, to more than 20% for high-efficiency "back-contact" modules, which have no light-blocking metallic traces on front of the PV cells—this increases the available light-collection surface for a higher conversion efficiency. Also more efficient (about 17% to 19%) are conventional modules using "n-type cells," which have

*An 8 kW system using modules with 16% efficiency would require about 535 square feet. That same size system using modules with **21% efficiency** would only take up 410 square feet.*



Courtesy SunPower

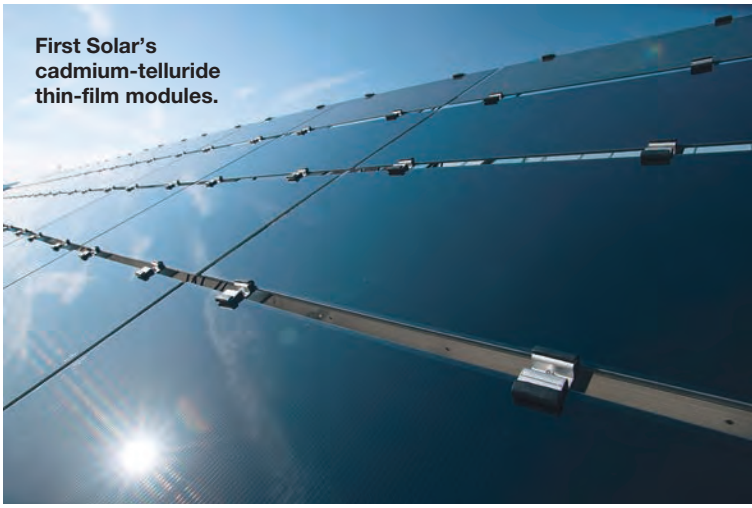
Courtesy Yingli Green Energy

Left: SunPower's X series has back-contact cells.

Right: Yingli's Panda series utilizes n-type cells.

Stion's thin-film modules.

Courtesy Stion



First Solar's cadmium-telluride thin-film modules.

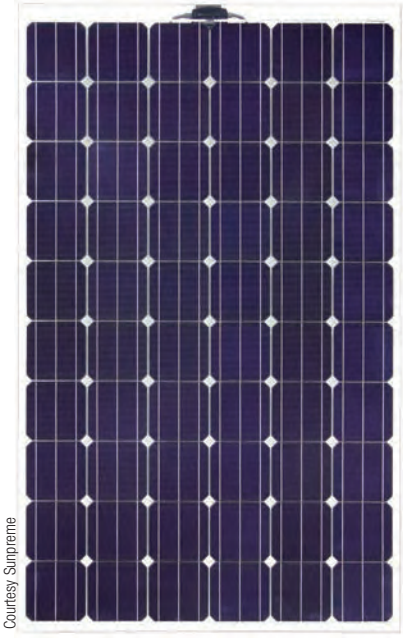
Courtesy First Solar

less light-induced-degradation and are less sensitive to cell impurities that the conventional "p-type cells."

Thin-film PV modules have also come a long way with efficiency, increasing from about 5% to now 16.3% (First Solar's cadmium telluride module). Although First Solar modules are aimed at the utility-scale market, Stion offers thin-film modules with up to 14% efficiency that can be purchased for residential installations.

Bifacial modules, which have efficiencies greater than 20%, are making a comeback. Generally, these modules surround monocrystalline n-type cells with a layer of amorphous silicon (a-Si) and harvest energy on both the back and front of the module. Panasonic offers its HIT Double module with efficiency rated at 20.8%; Prism Solar and Sunpreme bifacial modules have 20.5% and up to 22.9% efficiencies, respectively. Bifacial efficiencies assume energy contribution from the back of the module. To achieve top efficiency, bifacial modules need to be mounted so that the back is not blocked (such as in a shade structure with "perimeter-framed" mount).

Greater module efficiency means generating more electricity in a smaller footprint. With fewer rack materials and a shorter installation time, this can mean lower installation cost per watt. For example, an 8 kW system using modules with 16% efficiency would require about 535 square feet. That same size system using modules with 21% efficiency would only take up 410 square feet. However, because higher-efficiency modules are more expensive per watt, higher efficiency doesn't *always* mean less-expensive PV-generated electricity (see "Ask the Experts" in *HP168* for a helpful comparison).

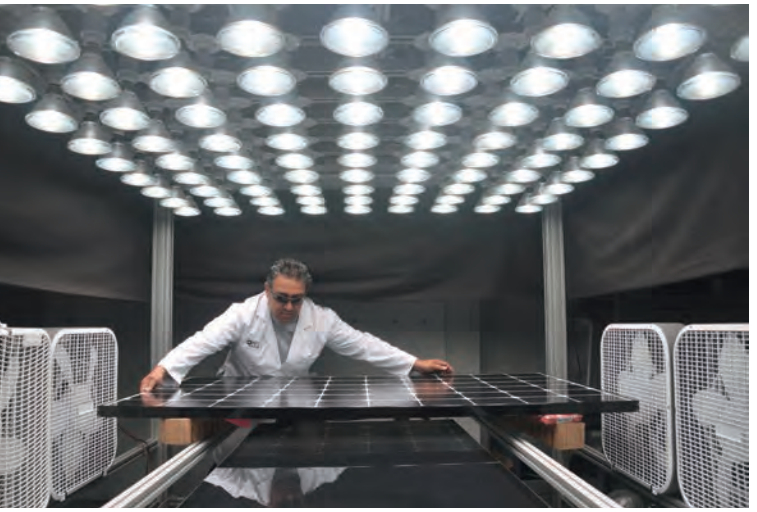


Courtesy Sunpreme

Left: A Sunpreme Maxima GxB 310 W bifacial module.

Courtesy Prism Solar

Right: These Prism Solar bifacial modules are configured to provide ambient light through a shade structure roof.



Courtesy PV Evolution Labs (a DNV GL company)

PV reliability testing from PV Evolution Labs.

An in-progress PV module fire-test over a typical roof covering, conducted at Underwriters Laboratories' Northbrook, Illinois, lab.

Courtesy Underwriters Laboratories

Evolving PV module reliability and quality assurance measures. While module prices didn't decline in 2014 over 2013, module pricing has gone from $4 per watt to $0.72 per watt since 2008. This dramatic price drop has partially stemmed from cost-cutting measures in the manufacturing process, which could impact module reliability. For example, according to the International Energy Agency's "Review of Failures of Photovoltaic Modules" (March 2014), the majority of module failures stem from interconnections within the module (i.e., breaks in the ribbons and solder bonds) or problems with backsheets and encapsulants (delamination).

To counterbalance these types of manufacturing issues, various PV industry stakeholders support establishing third-party accelerated testing facilities—and developing new guidelines to help assure quality in PV modules. Specifically, the International PV Quality Assurance Task Force (PVQAT), co-led by the National Renewable Energy Laboratory, was established to craft quality and reliability standards for module durability, manufacturing consistency, and even certify full PV systems to verify PV system design, installation, and operation. This international effort is well underway but, typical of volunteer efforts, will take some time to build consensus before standards are released. Check out PVQAT progress at pvqat.org.

In the meantime, module manufacturers can opt to have their products pushed through accelerated performance testing and be continually monitored by an independent testing facility, such as Intertek, PV Evolution Labs, TUV Rheinland, and Underwriters Laboratories (UL).

PV module fire-class ratings replaced by module "types." Historically, PV modules obtained fire ratings under the UL1703 listing process, and rooftop modules were rated as Class A, B, or C—with most at Class C. Due to new building codes (see the "Fire-Resistance Ratings" sidebar), this approach has become insufficient, since these ratings are only for the modules themselves—and do not take into account the rack system and the roof type. Now, modules

*Residential PV is the fastest-growing solar market segment in the United States, with three consecutive years of **greater than 50% growth.***

Construction & Fire Performance for Various PV Module Types

Type	Glass	Frame	Encapsulant (Super/Cell)	Encapsulant (Cell/Sub)	Substrate	Spread of Flame	Burning Brand
1	Thick	Metal	Thin	Thin	Thick polymer	<6 ft. in 10 min.	C brand
2	Thick	Metal	Thin	Thin	Thin polymer	<6 ft. in 10 min.	C brand
3	Thin	N/A	N/A	Thick	Glass	<6 ft. in 10 min.	C brand
4	Thick	Metal	Thin	Thin	Thick polymer	<13 ft. in 4 min.	C brand
5	Thick	Metal	Thin	Thin	Thin polymer	<13 ft. in 4 min.	C brand
6	Thin	N/A	N/A	Thick	Glass	<13 ft. in 4 min.	C brand
7	Thick	Metal	Thin	Thin	Thick polymer	<8 ft. in 10 min.	C brand
8	Thick	Metal	Thin	Thin	Thin polymer	<8 ft. in 10 min.	C brand
9	Thin	N/A	N/A	Thick	Glass	<8 ft. in 10 min.	C brand
10	Thin	N/A	N/A	Thick	Glass	<6 ft. in 10 min.	B brand
11	Thin	N/A	N/A	Thick	Glass	<13 ft. in 4 min.	B brand
12	Thin	N/A	N/A	Thick	Glass	<8 ft. in 10 min.	B brand
13	Thin	N/A	N/A	Thick	Glass	<6 ft. in 10 min.	A brand
14	Thin	N/A	N/A	Thick	Glass	<13 ft. in 4 min.	A brand
15	Thin	N/A	N/A	Thick	Glass	<8 ft. in 10 min.	A brand

Fire-Resistance Ratings

Over the last few years, the *International Building Code (IBC)* and the *International Residential Code (IRC)* have introduced requirements regulating the fire ratings of rooftop PV systems. Section 1509.7.2 of the *2012 IBC* states that roof-mounted PV *systems* shall have the same fire classification as the roof assembly. Fire classifications for roofs are based on the type of building construction and the area's fire risk. Roofs are classified for fire resistance using a scale of A, B, C, or unclassified. Class A roofs are the most fire-resistant and are often required in wildfire-prone areas or "wildland urban interfaces."

California has more areas and buildings with roofs that require Class A or Class B fire ratings, along with more PV systems installed than the rest of the United States. Most areas of the United States do not require a fire rating for residential construction, and require only a Class C (for office buildings) or B fire rating (for "assembly occupancy" buildings such as restaurants, sports areas, and theaters). However, with other areas expected to follow California's course, an increasing number of states will likely enforce more stringent fire ratings for more areas and buildings.

TÜV Rheinland conducts hail impact tests on PV modules to determine their durability.

Courtesy TÜV Rheinland

*In the United States, **6,201 megawatts** (MW) of PV was installed in 2014, up 30% from the previous year making it **the largest year ever** in PV installations.*

tested under the new UL1703 process receive a "type" classification instead. There are currently 15 types of modules listed, and those types are based on module construction materials (superstrate, encapsulant, substrate, and frame types) along with fire performance.

These module types are used along with PV rack system ratings to achieve the required PV system fire-resistance. For example, if a PV rack has a Class A PV system fire rating using a "type 2" module, then an installer must use a "type 2" module with that mounting system for any buildings requiring a Class A roof. Additionally, manufacturers' installation instructions must be carefully followed to retain that fire-resistance classification.

Higher-impact hail testing for PV modules. As more intense storms become common, there's a greater risk of larger hail and a higher potential for PV module damage. Historically, PV modules have been tested with 25-millimeter diameter (~1 inch) hailstones striking the modules at 23 meters per second (51 mph). In response to extreme weather events, more stringent hail tests such as the "hail stone impact test level 4" (HW4) and a "high-grade hailstone impact test" have been developed. HW4 uses 40 mm (1.6 in.) hailstones at 27.7 mps (62 mph); the high-grade hailstone impact tests modules with 45 mm (1.8 in.) hailstones at 30.7 mps (68.7 mph). After testing, the modules are checked for performance degradation and mechanical damage. It is likely that modules will increasingly be tested with these newer tests so manufacturers can market their durability.

What's Next

As a whole, the PV industry continues to enjoy sustained growth and technological developments each year. It is encouraging to see system costs drop year after year, accompanied by increased safety and durability measures, as well as a focus on improving system quality assurance. In many regions, PV systems have become cost-competitive with utility energy prices, and it is expected many more areas will experience the same trend. As a result, the solar revolution continues, and we get to increasingly experience the joy of helping our friends and neighbors join our solar community.

web extras

"PV Module Selection" by Justine Sanchez • **homepower.com/163.42**

"Solar Equipment Innovations" by Rebekah Hren • **homepower.com/157.38**

"Choosing PV Modules" by Justine Sanchez • **homepower.com/152.40**

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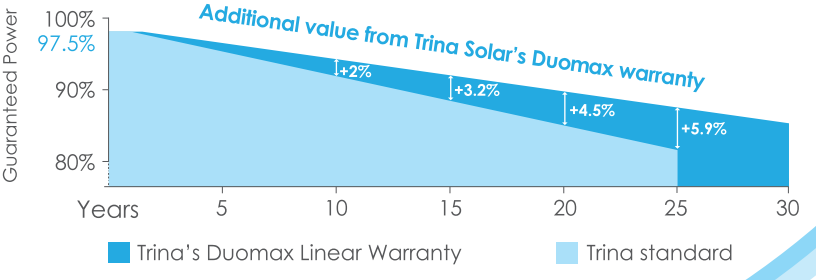

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For more information, call 1.800.696.7114 or visit www.trinasolar.com

Back to the Land

With PV Power & A Passive/Active Solar Home

Juanita and Jack Clay with their PV-powered, passive solar home.

Story & photos by Khanti Munro

A one-of-a-kind passive and active solar home was always in the cards; Jack and Juanita Clay just needed to come home. Both seasoned educators originally from suburban Connecticut, the Clays had spent more than two decades teaching abroad. From Iran to Romania, Switzerland to Ecuador, the couple embraced a nomadic international lifestyle, jumping from one boarding school to the next—somehow raising two kids in the process. However, having grown up hiking and skiing stateside, in Vermont, the Clays decided to make their homestead in the Green Mountain State.

They sought mountain views, enough land to provide hardwood for heat, clearings with plenty of sunshine, and flexibility to build a home "outside of the box." In the 1980s, they purchased an 18-acre farm in Middletown Springs that filled the bill—ample space with breathtaking views, west of Rutland, Vermont.

Their extensive travels and familiarity with living with less and traveling lightly in combination with riding out the oil crisis of the 1970s fueled a growing desire to establish a lighter environmental footprint. In Juanita's words, "Why burn oil when the sun's out there? Building a solar home seemed like the obvious thing to do." They were betting that the long-term economics would be worth the challenges and costs of researching, designing, and building a solar home.

The challenge was efficiently heating and cooling a home in the Northeast, which can experience wide temperature fluctuations—wintertime temperatures can drop below zero and summertime temperatures can be upwards of 90°F. Their research showed the best way to mitigate high heating and cooling costs was to use the earth to help regulate the home's temperature.

However, they didn't want to live in a windowless box or a cave; they preferred the house to be aboveground for the views, and wanted some unique architectural angles and lots of light—ideally available in every room. It took about 20 years for the Clays to slowly build their solar residence.

The Home

With an exquisite piece of land in hand, the Clays set upon finding a home design that balanced form and function. While they admired the thick, more organic wall shapes associated with handbuilt homes—strawbale with plaster, earth-sheltered concrete, or cob/rammed earth—they had their doubts about long-term moisture resistance and structural integrity, especially in the Northeast. The home had to be able

to withstand the New England weather, but also reduce external energy input—electricity, heating oil, and propane.

The home needed to be livable and fit the Vermont landscape. In addition to ample daylight, they wanted exposed wooden beams and a spacious garage for two vehicles and storage. It had to accommodate family, yet be small and efficient enough to make sense for just two. After much deliberation and research, they settled on a unique "active" solar design by solar home designer Norman Saunders.

Aiming for 100% Solar

The selected design, as featured in books such as *Super Solar Houses: Saunder's 100% Solar, Low-Cost Designs* (Shurcliff, 1983), pairs passive solar with fans and thermostats to move heat to different thermal storage locations. Common features include both high and low thermal mass (a "heat sandwich"); and an almost full-length south wall/roof greenhouse. The goal is to meet heating needs solely with solar energy. This strategy is not for everyone, though, as it requires a lot of space for thermal mass, as well as more controls and homeowner involvement than conventional homes.

With a full three stories of south-facing glazing, the home gathers an abundance of solar energy.

Despite the large surface area of south-facing glass, interior spaces are protected from overheating by the use of well-placed thermal mass and fans that distribute the heat.

The Clays' three-level, 2,300-square-foot home features a gambrel barn shape with locally sourced post-and-beam framing and superinsulated (R-40+) 8-inch structural insulated panels (SIPs). The SIPs provide a contiguous thermal barrier, reducing thermal bridging. The south wall's glass façade is enormous, spanning the whole width of the house, and rising from the foundation floor to the upper section of the gambrel roof. From straight-on, it almost appears as though the entire house is made of glass. Upon first glance, one might think anyone living inside would be uncomfortable; that there is so much south-facing glazing that overheating in the warmer months is a given, and freezing during colder months is inevitable.

However, that glazing is actually an integrated greenhouse. About 6 feet from the outside greenhouse wall, there is another three-layered, custom-constructed glass wall, with sliding doors. Amidst the drying laundry, a scattering of succulents bask in the hot, dry air—that is, before the heat gets convected up the middle channel of glass to the thermal storage in the attic. The greenhouse collects some heat itself, but since most of the heat is redirected before entering the living space, it also acts as a temperate buffer zone for the home.

Some of the direct solar irradiance hits the living space, but the majority is directed to the attic. Oversized posts and beams were used in the structure to allow the option of adding additional thermal mass (barrels full of water) to the attic, although the Clays never did due to concerns about leaks and excessive weight above their bedroom.

During the colder winter months, temperature-controlled fans pull the warmed attic air through large ducts to the thermal mass in the basement—18 tons of water, mostly

The glass south wall is separated from the living area by a full-height greenhouse that collects the solar-heated air.

The greenhouse zone allows for sunny hanging-out and clothes drying.

contained in about eighty 55-gallon reclaimed juice-storage drums. Despite the voluminous, somewhat unwieldy footprint of all the water, it has superior thermal conductivity compared to sand or stone. While the Clays' home doesn't achieve its goal of relying exclusively on solar energy for its heating needs, the mass of the water, combined with a well-insulated envelope, create a comfortable baseline. On a few occasions during multiday winter power outages, the temperature inside the house never dipped below 55°F, with no sun or backup heat source. During the warm summer months, the stored heat in the attic is released to the outdoors by opening large gable-end temperature-controlled air vents.

The home and its construction were not without challenges. The Clays will attest to the frustration of entrusting contractors with successfully implementing unfamiliar building methods, such as the three-layered glass wall and extensive venting and controls. In the absence of regular oversight, mistakes were common and sometimes costly to remedy. Some contractors reverted to standard practices and ignored guidance when faced with new architectural methodologies. And the Clays acknowledge their own shortcomings with the Saunder design—most notably forgoing the thermal mass in the attic. In Jack's words, "Despite the extra-strong framing, the thought of 10 tons of water above our bedroom spooked us a little bit regarding the weight and somewhat inevitable leak potential with steel drums."

For the first few years after the home was completed, a variety of thermostatically controlled switches combined with a custom software program operated the many fans and vents to keep air moving to the desired locations. The Clays worked directly with Saunders for about 10 years, sending him collected data for him to analyze and update the software appropriately. However, the main control board was eventually damaged from a power surge, and a combination of difficult-to-find replacements, in addition to the realization that no control is "smart" enough, led to a more involved approach for the Clays—manual operation of the fans and vents to suit their comfort levels.

The greenhouse zone varies in width along the south wall.

Excess heat is mechanically exhausted through gable-end vents.

Eighteen tons of water act as thermal mass to store and moderate heat.

Adding Renewable Electricity

The Clay home effectively captures solar energy to help with heating, but until recently, they had not addressed their electrical usage. The home consumes about 420 kWh per month—less than half the regional residential average. Jack and Juanita rounded out their solar endeavors with a batteryless grid-tied, 4.2 kW PV system that meets 100% of their annual electrical needs. The home and surrounding land had a generous solar window, but there were design challenges when planning the solar-electric system.

Despite the standing-seam, south-facing gambrel roof, the Clays decided against a roof-mounted system to give better access to the array for maintenance and snow removal. They also had concerns about the long-term effects of snow and ice from a rooftop array sliding onto the southern glass wall. The grounds around the home were open fields, but the fairly steep slope away from the house would have made a contiguous ground mount difficult.

The home's septic tank and leachfield, as well as the "million-dollar" southern view, also made siting an array more challenging. To avoid altering the landscape and the view, a pole-mounted array was sited downhill to the west of the house. Fifteen 280-watt modules was the largest array that could be installed on a single static pole (the Clays had no interest in a tracking array and its associated moving parts), and just so happened to be a great match for their needs. To assist in seasonally tilting the very large pole mount, a custom cable was fabricated and attached to the upper strongback of the rack for greater control during the tilting process. To meet *National Electrical Code* requirements regarding DC conductor accessibility, vinyl-coated mesh screening was attached to the lower portion of the array

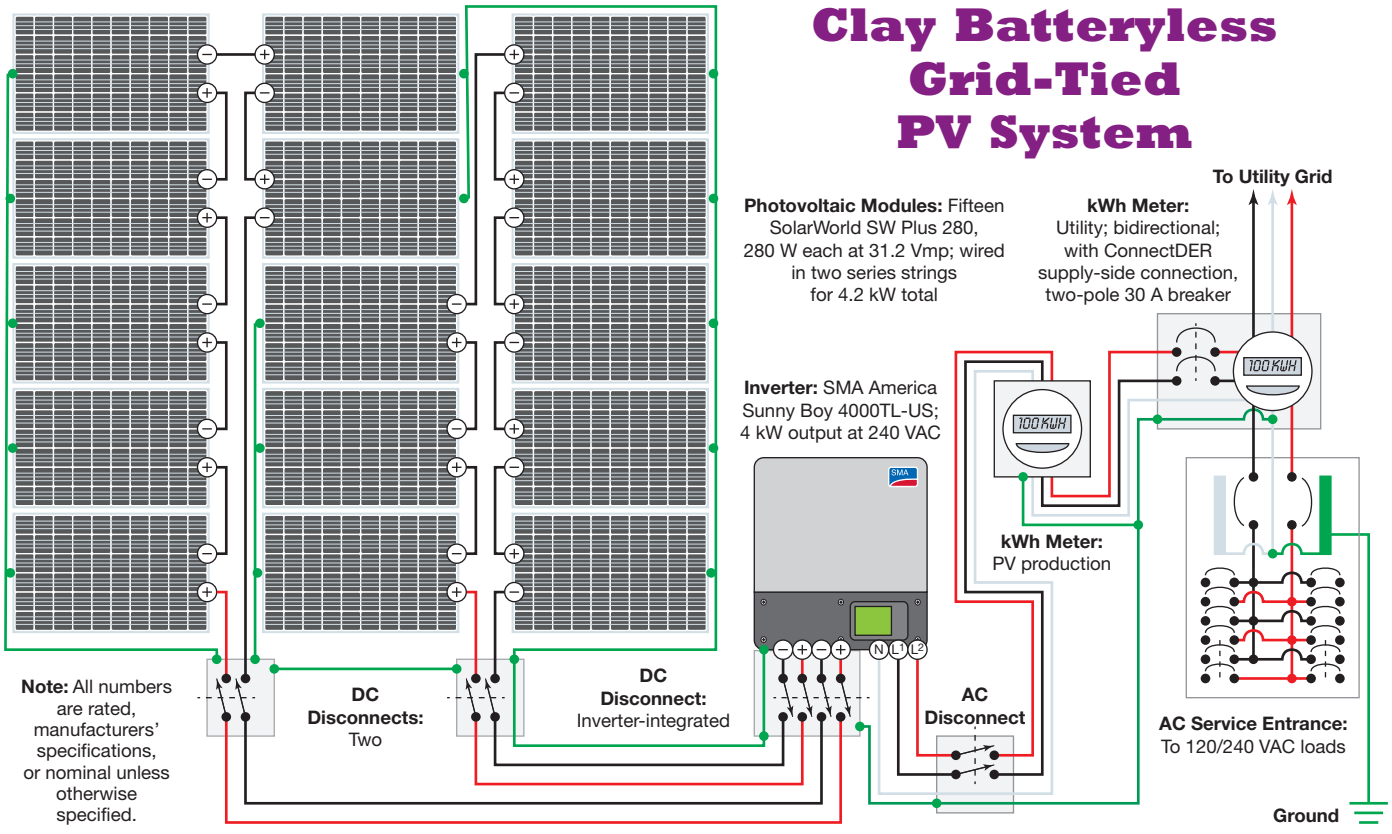
AC conduit from the inverter in the garage was run on the outside of the home—and under the front steps and behind the siding trim to be out of sight—because the basement was

Fifteen SolarWorld PV modules totaling 4.2 kW.

Above: To comply with *NEC* requirements for ungrounded PV systems, a two-pole disconnect was installed for each of the two source circuits.

Right: The DP&W top-of-pole, adjustable-tilt mount sits on 8-inch schedule-80 steel pipe. Note the covering protecting the wiring where it is at a reachable height.

Clay Batteryless Grid-Tied PV System



Right: The PV output connects to the utility with a supply-side connection using a ConnectDER collar on the utility kWh meter.

Below: The SMA America Sunny Boy 4,000 W inverter has integrated DC disconnects and individual MPPT for the two incoming PV strings.

Tech Specs

Overview

System type: Batteryless, grid-tied solar-electric

Location: Middletown Springs, VT

Solar resource: 4.3 average daily peak sun-hours

ASHRAE extreme min. temperature: -15°F

ASHRAE 2% high temperature: 84°F

Average monthly production: 410 AC kWh

Utility electricity offset annually: about 100%

Photovoltaic System Components

Modules: 15 SolarWorld SW Plus 280 monocrystalline, 280 W STC, 31.2 Vmp, 9.07 Imp, 39.5 Voc, 9.71 Isc

Array: Two series strings (7 modules for 1,960 W STC; 8 modules for 2,240 W STC); 218.4 and 249.6 Vmp, 9.07 Imp; 276.5 Voc and 316.0 Voc, 9.71 Isc

Array installation: DPW top-of-pole: TMP15-G mount on 8 in. schedule-80 steel pipe, adjustable tilt

Inverter: SMA America Sunny Boy SB 4000TL-US, 4 kW rated output, 600 VDC maximum input, 125 - 500 VDC MPPT operating range, 240 VAC output

System performance metering: SMA Sunny Portal, via Speedwire inverter card

nearly full of water drums. Interconnection was made with a ConnectDER, a connection device installed in-line between the utility net meter and its socket (see "Methods" in *HP167*), allowing the utility interconnection point to be outside of the house.

PV System Costs

Item	Cost
SolarWorld SW Plus 280 PV modules	$4,500
SMA America Sunny Boy SB4000TL-US inverter	2,400
DPW Top-of-Pole mount	3,700
Wire, conduit, trenching, concrete, array screening	4,000
Balance of system & misc. electrical, monitoring	2,500
Labor	4,200
Total	$21,300
Vermont SSRE Incentive	-1,050
Federal Tax Credit	-6,075
Grand Total	$14,175

To accommodate the 15-module array—a less-common single-pole configuration, a transformerless inverter with dual-channel maximum power point tracking (MPPT) was specified. This can better handle the two differently sized source circuits (one with seven modules; another with eight modules) and their lower-than-typical operating voltages.

Now that their solar home is complete, the Clays are exploring the possibility of adding cold-weather heat pumps and, to deal with occasional power outages, battery backup for their PV system.

web extras

"Sun-Wise Design" by Dan Chiras in *HP105* • **homepower.com/105.38**

"Passive Solar Home Principles" by Scott Gibson in *HP163* • **homepower.com/163.50**

"Methods: Streamlined Supply-Side Interconnection" by Khanti Munro, with Phil Parrish in *HP167* • **homepower.com/167.16**

PV Disconnects ...Continued

by Ryan Mayfield

Code Corner in *HP168* discussed the first set of requirements in the *National Electrical Code (NEC)*'s Article 690, Part III, "Disconnecting Means." In this column, I'll continue through the disconnect requirements, including the requirements for fuses, combiner boxes, and labeling.

Article 100 contains a definition of disconnecting means: "a device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply." This is important, as the requirements for disconnecting means as applied in Article 690 are very specific in what is considered acceptable for PV systems.

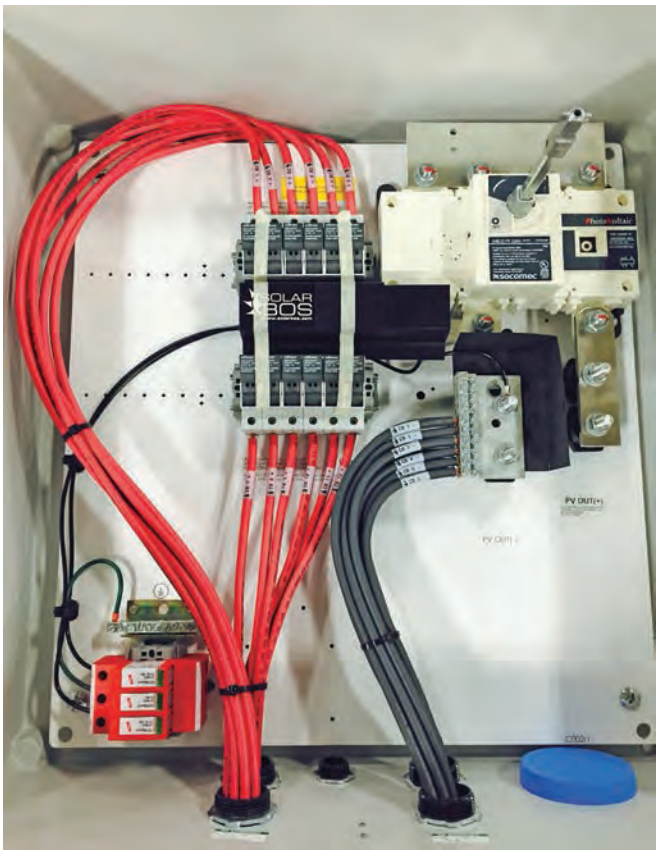
Previously, we detailed the first sections that relate to disconnects. Jumping back into 690, Part III, 690.16 covers the disconnect requirements for fuses and fuse servicing. 690.16(A) requires a disconnecting means for fuses that can be energized in both directions. Such fuses in source circuits must be capable of being disconnected independently of other PV source-circuit fuses. This *NEC* section will come into play when a DC combiner box is installed to combine multiple source circuits prior to the inverter input connection. To meet this requirement, a disconnect needs to be placed in such a way that the current can be interrupted and then allow for the disconnection of any one of the fuses. There is no mention of any specific equipment or method of disconnection, other than the requirement that this function be performed independently.

The next section, 690.16(B), details specific requirements for the disconnecting means to perform fuse servicing. To service fuses, a disconnecting means must be "within sight of and accessible to" the fuse holders. (See Article 100 for definitions for both "accessible" and "in sight from.") In addition, if the disconnect is more than 6 feet from the overcurrent device, a directory showing the location of each disconnect must be included at the overcurrent device location. And, finally, all non-load-break disconnecting means shall be marked "Do not open under load."

The need for DC combiners in smaller residential-type systems has been dwindling with the use of module-level electronics (DC optimizers and microinverters), inverters with integrated disconnecting combiners and multiple MPPT string inverters. In the case of multiple MPPT inverters, even the largest residential applications can forego the need for DC combiners because they can have each set of modules on an independent MPPT, separate from other strings on other MPPTs. Therefore, it is becoming less common to see three or more strings connected in parallel prior to the inverter input and, given the exceptions in 690.9, fusing isn't required for arrays with only one or two strings in parallel—specific to grid-direct inverters.

Depending on the equipment selection, DC combiners can also be eliminated in commercial applications. But in both residential and commercial cases, there may be a need for combiners and you need to verify that the equipment installed is set up to meet these requirements. The use of

With the disconnecting means integrated into the same enclosure that houses the series string fuses, disconnecting combiner boxes offer a simple solution to comply with *NEC* 690.16(B).



Courtesy Solar BOS

continued on page 60

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disconnecting combiner boxes listed to the UL1741 standard is the easiest way to meet all these requirements with a single piece of equipment.

In 2014, there were a number of additions to 690.17. The general requirement is that the disconnecting means for all ungrounded PV conductors must consist of a manually operable switch or circuit breaker. The opening paragraph was changed in 2014 to include an allowance for power-operable switches with a manual option. The 2014 changes list 10 potential disconnecting means that are acceptable. As you read through the list, you will notice that all consist of either DC-rated devices or PV devices listed for use in PV systems. For the DC combiner application, this isn't too difficult to meet. There are many options for DC-rated disconnects and disconnecting combiner boxes, all listed and identified for PV applications.

Article 690.17(B) specifies that the disconnecting means must simultaneously disconnect all ungrounded supply conductors. Many PV systems are now being installed with transformerless inverters, which means both the positive and negative conductors on the PV side are considered ungrounded. Therefore both conductors must be disconnected simultaneously. As with the DC ratings mentioned earlier, this isn't a major roadblock considering the components available, but rather a point installers need to recognize when specifying equipment and installing systems. The disconnecting means must also be externally operable without exposure to live parts. This isn't a new *Code* requirement despite its being highlighted in 2014; rather this is a relocation of an existing requirement.

For those installing grounded DC systems, the next section, 690.17(D), is important. The general requirement is that the grounded current-carrying conductor—typically the negative for grounded PV systems—cannot be installed on a switch if the operation of that switch leaves the grounded conductor in an ungrounded, energized state. If this is the case, the conductors marked as bonded to ground would not have a reference to ground once the switch is activated; technicians working on the system could treat them incorrectly and be injured.

Some exceptions to this rule exist for grounded PV systems. The first exception is for conductors installed as part of a ground-fault protection device (GFPD). The conductor's bond to ground is removed when the system is reacting to a ground-fault situation. The other exceptions occur when switches that are properly rated for current and voltage conditions are only used for maintenance and only accessible to qualified personnel. These exceptions exist because there are cases where a technician may want to purposefully open the current-carrying conductor to ground bond for testing and maintenance purposes.

Finally, the requirement for labeling is still included in 690.17. For disconnecting means where all terminals may be energized in the open position, a label must be included that states:

Ryan Mayfield

Specifically worded warning labels are required for DC disconnects that may leave energized terminals on both sides of an open switch.

WARNING
ELECTRIC SHOCK HAZARD
DO NOT TOUCH TERMINALS
TERMINALS ON BOTH THE LINE AND LOAD SIDES
MAY BE ENERGIZED IN THE OPEN POSITION

This is very specific language for very specific disconnects. Only the PV DC disconnects should need this label, since DC capacitors located within the inverters will keep the load side of the disconnect energized for up to five minutes. On the line side (or source side) of the disconnect, the PV array will continue to be energized as long as there is sunlight striking the modules. Therefore, if a technician flips the disconnecting means and is unaware of the hazards, they could start working on the load-side conductors connected to an inverter while the conductors are still energized.

I have seen this warning label applied to AC disconnects, too. But this would be unsuitable for grid-interactive inverters, since, on the AC side, there are no capacitors keeping the conductors "live" for any amount of time. Once the AC disconnect is thrown, only one side, presumably the line side of the switch, will be energized from the source. Of course, prior to working on them, all technicians should confirm the energized status of conductors.

Disconnecting means are an important consideration for all PV installations. Properly identifying the locations, ratings, and labeling during the design and installation phases will help eliminate potential errors and re-work later.

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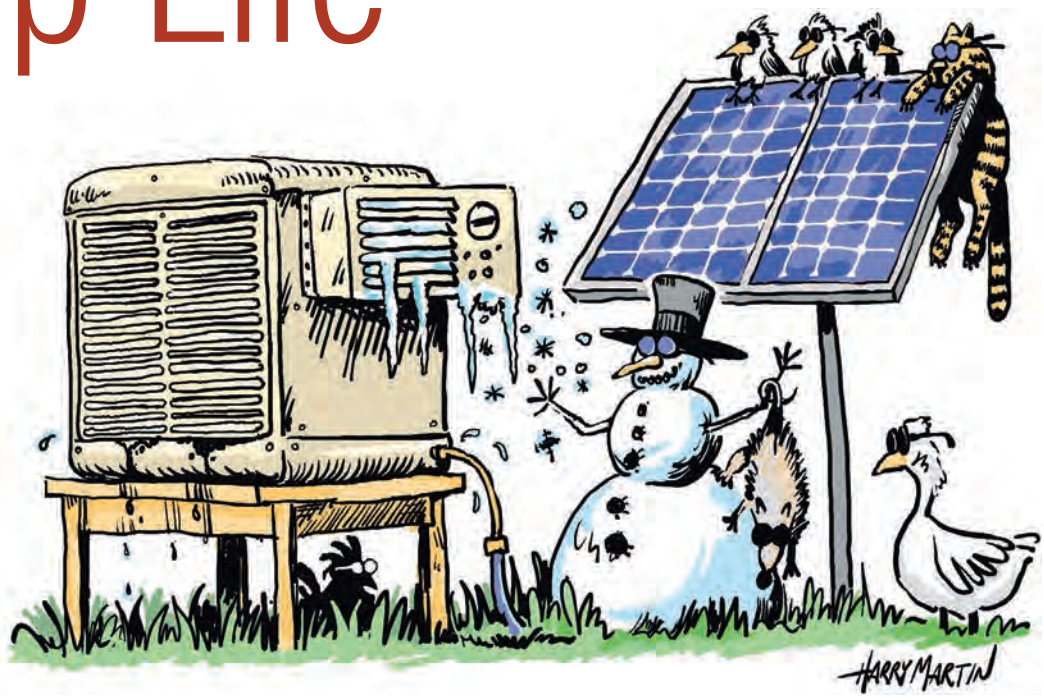
Swamp Life

by Kathleen Jarschke-Schultze



In the winter cold, we draw back the curtains during the day to let in the warmth of the sun. At night, we close the curtains to keep built-up heat inside the house. The high heat of summer has us doing the opposite, with a few more tricks.

Passive Maneuvers

When we moved into our home, the first thing we did was replace all the single-pane windows with double-pane low-e windows. Replacing just the 5-by-7-foot window in the living room made a difference of 5°F overnight heat retention. I heightened that effect by sewing a Warm Window covering for the big window (*H&H133*). The other windows have curtains and some have Venetian blinds.

As I mentioned, we close the curtains at night in the winter. On summer nights, we draw back the curtains and open the windows to allow the cool air in. During the day, we close and then curtain them.

The trick is to open the windows when the temperature difference between the indoors and outdoors is more than 5°F. So, if we wait too long, or the temperature stays high past sunset, the accumulated warm air in the house stays where it is.

For energy-conservation reasons, we don't run fans overnight to move air—at dusk, there's no sunlight on the PV modules and we lose the daily downslope, down-canyon breeze, so there's no wind on our turbine. During the summer, we also lose our creek-driven microhydro power.

Swamp Thing

About 14 years ago, we purchased a used evaporative cooler, also known as a swamp cooler because it puts moisture into the air. Oddly enough, it would not work in a swamp. But they work great in hot, dry climates. Some units are so large they can cool a whole house, although ours can't.

Basically, it is a metal box with a water reservoir in the bottom. A float valve (like in a toilet) keeps the water replenished. A small recirculating water pump pushes the water to the top of the box, where it is distributed to three sides. These sides are metal louvered and lined with pads called excelsior, usually Aspen wood, over which the water trickles when the pump is running. A large "squirrel cage" fan in the unit blows air into the house, drawing the hot, dry outside air through the wet pads. The unit's float valve is supplied by a small hose, which must be left on while the cooler operates. Evaporative coolers can use 3 to 15 gallons of water a day. The pads need to be replaced every few years, but are easy to find and not expensive.

Bob-O cut a 10-by-20-inch rectangle in our dining room wall and snugged up the cooler so its front, controls, and vents are easily accessible. The evaporative cooling effect can lower the temperature as much as 30°F. An added bonus is that the constant air movement caused by the fan can make you feel 4°F to 6°F degrees cooler than it actually is.

We used the cooler for a number of years, then went to an auction at the local fairgrounds and bought another used swamp cooler for $70. This one is mounted in a window at the

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other end of the house. With both coolers on, we get an inside to outside temperature differential of about 20°F. As I write this, it is 108°F outside and 81°F inside.

For an evaporative cooler to work efficiently, there must be an opening for the air to escape to avoid back-pressure. By leaving a window cracked, we can direct the cooled air into that room. This type of cooler is most efficient the hotter and drier the outside air that is pulled through the pads.

Before sunrise, with all the windows still open, we also turn on only the blowers of the coolers, not the pumps. This draws the night-cooled air into the house.

Cooling Calcs

Air-conditioner output is rated in British thermal units (Btu), but evaporative coolers are rated by CFM (the cubic feet per minute of air that the cooler can blow into your home). A simple formula can help estimate the proper size of swamp cooler you need. Figure the cubic feet of space you want to cool, and then divide that number by two. The quotient will give you the CFM rating for the proper-sized swamp cooler.

For example, if you have a 1,200-square-foot home with 8-foot-high ceilings:

1,200 sq. ft. × 8 ft. = 9,600 cubic ft.

9,600 ÷ 2 = 4,800 CFM needed for optimal cooling

Most evaporative coolers run on 120 VAC and can be plugged into a regular outlet. They use 75% less electricity than an air conditioner. There are even DC evaporative coolers on the market that can use PV modules to run the units directly (see southwest-solar.com). Ours are run on PV, too—it just goes through our house's battery pack and inverter first.

They can be placed in a window and do not require extensive ducting. This is definitely an easy DIY installation.

Where we live, these coolers work well, but they will not work where the humidity is high. The higher the humidity, the less efficient they are. In our dry climate, we like the inside humidity the swamp cooler provides. We feel less dried out, and it's been shown to prevent wood and furniture from drying out also.

The moist pads are also fairly efficient air filters, trapping some dust and pollen when the air is drawn through. Since the pads are constantly trickling with water from above, trapped particles are flushed and settle in the bottom of the cooler.

Last summer, we bought a portable evaporative cooler at the annual valley-wide yard sale extravaganza. We have found that it is less efficient than our outside-mounted models. The problem is that the unit recirculates the moist air in the room, instead of drawing in less-humid air from outside. There is a little trap door on top of the unit that you can put ice cubes into to cool the exhaust air. It's good for short-term cooling. We were just glad we didn't buy it new.

We've always been cool people and our evaporative coolers are helping us stay that way. With more than a week of 103°F-plus temperatures this year, we are very glad to have our setup in place and working—and running on renewable energy, of course.

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RMS Voltage

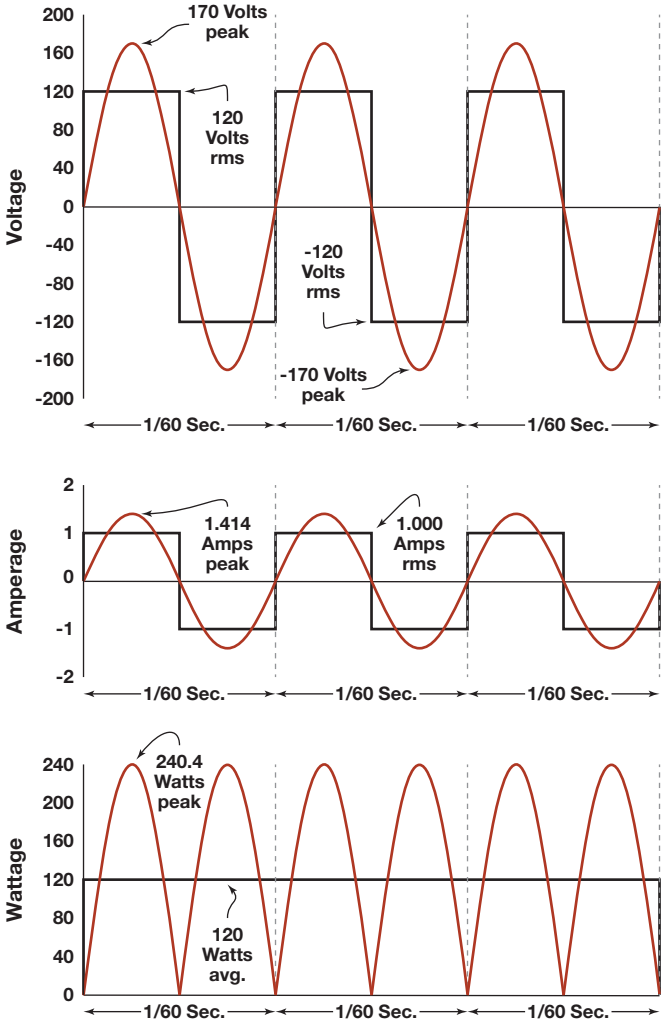
A circuit's voltage is an indicator of the force behind the current in that circuit. To talk meaningfully about that voltage (and current), we need terminology and a way of looking at electricity values to understand and compute the things we want to know—like power.

With alternating current (AC) electricity, we need a way of describing the electricity that will hold true throughout our calculations. In the U.S., the electricity "standard" (the effective voltage) is 120 volts AC (VAC) with a sine waveform (a graph showing the variation of the voltage measurement against time). But the peak voltage value is about 170 V. This peak occurs only for a moment—during each positive and negative swing of the waveform. Unfortunately, the effective voltage can't be calculated by using an average—with AC electricity, the average is always zero, since the positive and negative portions of the waveform cancel each other.

A quality true RMS meter can detect minor variations in voltage sine-wave.

Ben Root

RMS Voltage & Its Effect On Amperage & Power



Instead, the effective voltage is described by calculating the square root of the mean (average) of the voltage squared. This is where the term "root mean square (RMS)" comes from. You square the peak voltage, divide that squared number by two, and then take the square root of that average. This is easily done for a true sine waveform.

$170^2 \div 2 = 14{,}450$ (the mean of the square)

$\sqrt{14{,}450} \approx 120$ VAC (RMS)

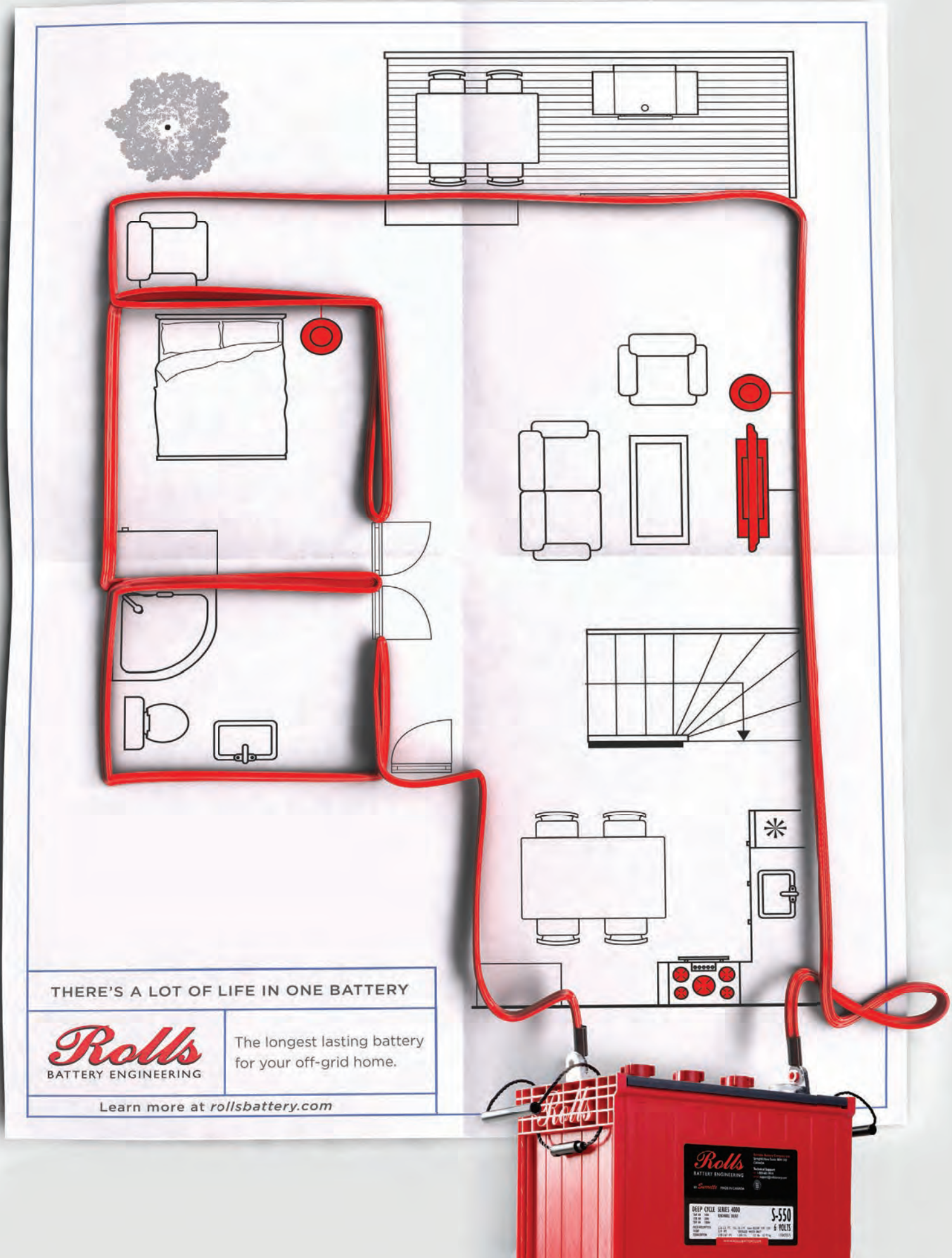
Now we have a number that we can use practically and meaningfully in our calculations. For example:

120 VAC (RMS) **× 1 A** (also RMS) **= 120 W**

When measuring RMS voltage and current in an AC waveform, quality meters do these precise conversions from peak to RMS instantaneously. These meters are also able to compute and display true RMS figures, even when the waveform is not precisely sine wave, or if the negative and positive peaks are not at the same voltage. These are much deeper calculations than we can go into here.

Less expensive meters use a simple algorithm to estimate RMS voltage. That algorithm holds up fine if the sine wave is pure or very close to pure, so for people who are measuring household currents without the need for true RMS, the cheaper meters will work just fine.

—Michael Welch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