SINCE 1987

PERFORMANCE MONITORING FOR ON-GRID SOLAR-ELECTRIC SYSTEMS

home power

SOLAR › WIND › HYDRO › DESIGN › BUILD

DIY Solar Success

With the Right Know-How, Savings Can Be Huge

Solar-Powered Water-Pumping Primer

How Green are "Green" Building Materials?

Nov. & Dec. 2014, Issue 164
$5.95 US • $5.95 CAN
homepower.com

HuP® SOLAR-ONE® BATTERIES

Highest cycles.

Warranted for 2100 cycles at 80% Depth of Discharge (DOD) (or an estimated 4000 cycles at 50% DOD).

Thickest plates.

Solidly constructed with 0.31" thick positive plates and industrial terminals and hardware.

Longest warranty.

7 year FREE cell replacement. 3 year pro-rated.

Solidly constructed with 0.31" thick positive plates and industrial terminals.

With more usable battery capacity and the longest standard warranty in the industry, the HuP® Solar-One® battery is the clear choice for dependable and resilient solar energy storage. Shipping is FREE in the continental United States to a commercial business with a forklift. To find the right HuP Solar-One battery for your needs, contact your RE professional or Northwest Energy Storage.

Northwest Energy Storage
800-718-8816 • 941-474-0110
www.hupsolarone.com

EnerSys®
Power/Full Solutions

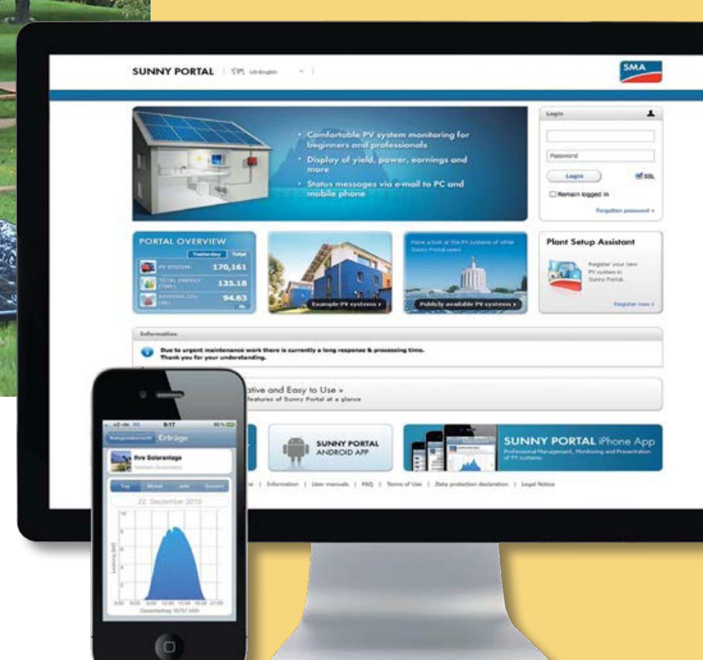
contents

46

38

Main Features

30



On the Cover

The Hampel family in front of their 6.1 kW grid-tied PV array that sits on home-built, tilt-adjustable racks. See the story on page 38.

Photo by Amy Joan Hampel

contents

november & december 2014

Up Front

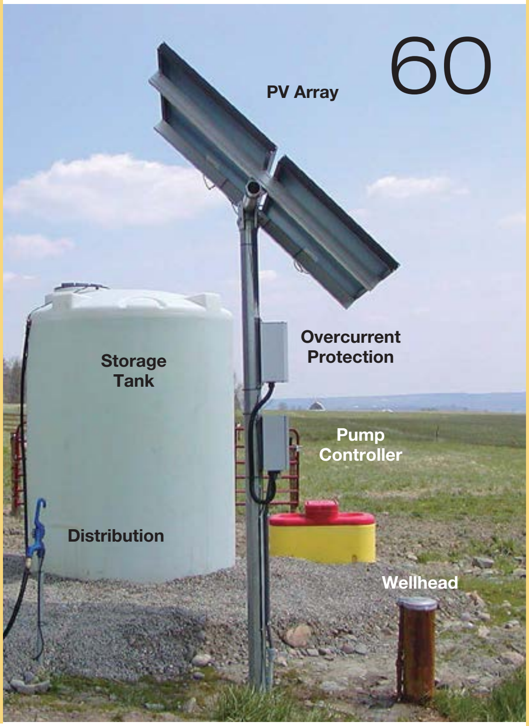
Photos (clockwise, from opposite page, bottom right): Courtesy SMA America; Amy Joan Hampel; ©istockphoto.com/ISerg; ©istockphoto/fcafotodigital; courtesy MidNite Solar; Roy Butler

More Features

54

68

60



In Back

Home Power (ISSN 1050-2416) is published bimonthly from offices in Phoenix, OR 97535. Periodicals postage paid at Ashland, OR, and at additional mailing offices. POSTMASTER: Send address corrections to Home Power, PO Box 520, Ashland, OR 97520.

Solar Motivations

©istockphoto.com/akinbostanci

Solar electricity now "pencils out"—substantially in some places. PV module prices have dropped dramatically, and low installed cost and significant incentives make a PV system not only a way to use clean energy and lock in electricity costs, but a quality financial investment as well.

My home state of Washington is not among the top 10 states in solar capacity per capita. But the current pricing and incentives result in some residential system purchasers going cash-positive in five to six years.

Ask yourself what you have spent money on in the last decade that has been cash-positive. Almost everything we spend money on provides some benefit, but does not have a positive financial return.

Everywhere I turn on my homestead, I need to do things that cost money—clean, paint, repair, upgrade, complete, and build—with no hope of financial return. Meanwhile, every well-installed PV system on the planet is *producing* energy when the sun hits the array. And because it offsets outside energy costs, there is a financial return and a point where the system "pays back" its installed cost. In the early years, we would routinely say that the payback would be "way out there." Today, it's very much within our reach, depending on the size of the system you choose, and the incentives available.

I informally surveyed some solar installers in a few states and found that the costs and incentives vary a lot depending on state and utility. Some states, like Indiana, have minimal incentives, so recovering system cost may take 20 years or more. Kansas utilities limit total renewable energy input and credit customers' excess monthly generation at the average utility cost—not a good deal for the customers with PV systems.

Other states and utilities have friendlier policies and programs for renewable generation. Some Massachusetts customers might get a five- to six-year payback, and an Arizona installer reported paybacks in the eight- to 10-year range. New Mexico, Montana, and Louisiana are reportedly in the same five- to 10-year range, with Oklahoma in the 10- to 20-year range.

What motivates PV system buyers? Environmental concerns are high on the list. Wanting to be independent and an interest in high tech are also motivations. A newer motivation is the value of stabilizing energy costs. Can you imagine someone offering to lock in the price of gasoline for you 20 years ago? You would still be paying a buck a gallon. When you buy a PV system today, you are locking in your electricity costs for the life of the system—30 to 50 years or more.

Public perception of the financial and security values of PV systems is lagging behind the reality. But people are gradually realizing that buying a solar-electric system is investing in a rare product—one that combines longevity, low maintenance, and energy production. For me, this has been a winning combination for decades for a variety of reasons, and these days, the financial picture is becoming compelling for more and more people—maybe you are next!

—Ian Woofenden, for the *Home Power* crew

Think About It...

"Anything else you're interested in is not going to happen if you can't breathe the air and drink the water. Don't sit this one out. Do something."

—Carl Sagan, American astronomer & astrophysicist (1934–1996)

Quick Rack™

The No-Compromise Rail-Free Mounting System

Save time and money on every installation
and sell more solar with Quick Mount PV

Quick Mount PV Quality

- Engineered for strength and simplicity
- Works with standard module frames
- Superior waterproofing with patented Elevated Water Seal technology
- Certified UL System Fire Class Rating A, Type 1 Modules

Cost Savings on Every Job

- Quick and easy to install
- Minimal tools required for installation
- Ground up to 300 contiguous modules with a single grounding lug

Sell More Solar!

- Pack more jobs on each truck and complete more installs per day
- Proprietary design software accurately configures the array to ensure code-compliance
- Clean, distinctive look generates more referrals

Quick Mount PV®
RESPECT THE ROOF

quickmountpv.com | 925.478.8269

contact us

Home Power—independently published since 1987

Publishers	**Richard & Karen Perez**
Executive Editor & CEO	**Joe Schwartz**
Managing Editor	**Claire Anderson**
Art Director	**Ben Root**
Senior Editors	**Michael Welch, Ian Woofenden**
Senior Technical Editor	**Justine Sanchez**
Building Technology Editor	**Alex Wilson**
Solar Thermal Editor	**Chuck Marken**
Transportation Editor	**Bradley Berman**
Advertising Directors	**Kim Bowker, Connie Said**
Operations Director	**Scott Russell**
Data Manager	**Doug Puffer**

Home Power magazine
PO Box 520 • Ashland, Oregon 97520 • USA

homepower.com

facebook.com/homepower

twitter.com/homepowermag

Subscriptions

To subscribe, renew, change, or inquire about a subscription:

800-707-6585 or **541-512-0201**

subscription@homepower.com

homepower.com/subscribe

Back Issues

Interested in past *Home Power* content beyond the offerings at HomePower.com? Our "Premium Access" subscriptions include download access to *Home Power*'s online archive—more than 160 complete digital back issues in PDF.

Individual back issues are not available for purchase at this time.

Submissions

For inquiries and information related to editorial submissions, write to us at:

submissions@homepower.com

homepower.com/writing

Website

homepower.com

Send your comments regarding the site to:
web@homepower.com

Ask the Experts

To have your technical questions considered for publication, send them to:

asktheexperts@homepower.com

Letters to the Editor

Email your comments and suggestions to us at:

mailbox@homepower.com

or write to the address above.

Marketing

Promotional opportunities and offers:

marketing@homepower.com

Advertising

For inquiries and information related to advertising in *Home Power* or on homepower.com:

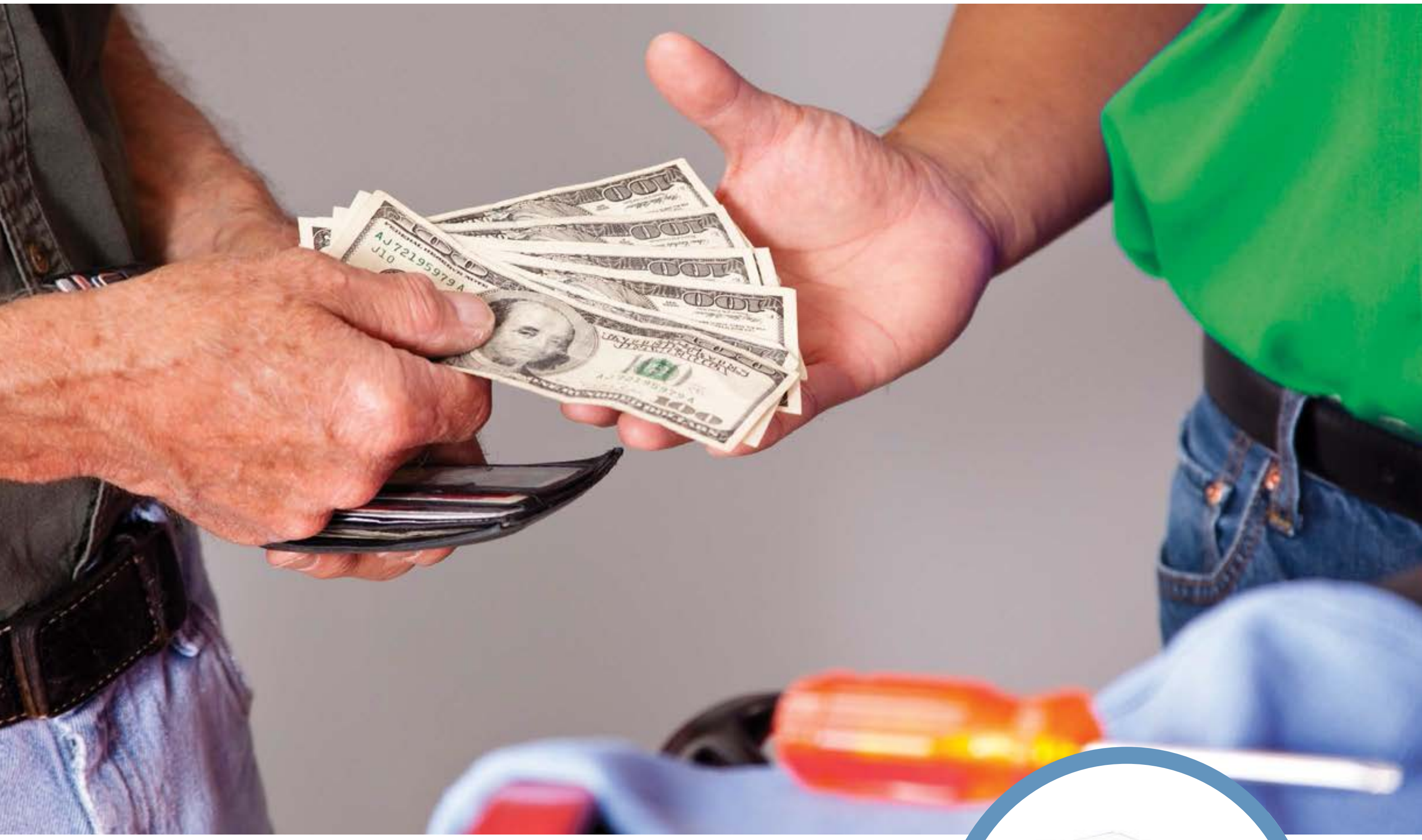
Western States:
connie.said@homepower.com
541-326-5773

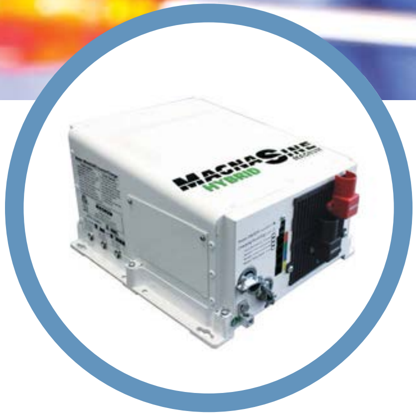
Eastern States:
kim.bowker@homepower.com
541-858-1791

homepower.com/advertising

Interior paper is made from 85%–100% recycled material, including 20%–30% postconsumer waste.

REPAIR COSTS GETTING TOO EXPENSIVE?
MAYBE IT'S TIME TO REPLACE YOUR INVERTER.





If repair costs on your existing Sine Wave inverter are getting too expensive, it might be time to replace it with a new MSH-RE Inverter/Charger from Magnum-Dimensions. The MSH-RE's hybrid technology make it an optimal choice for your renewable and backup power needs.

MSH-RE Series Hybrid Technology:

Most inverters only use one source of energy to power loads, either from incoming AC power – utility or AC generator – or from the batteries. The MSH-RE Series combines the energy from both sources to power loads. This allows the inverter to recharge the batteries when there is surplus power or deliver more power to the loads if they require more than the AC input can supply by itself.

MSH-RE Inverter/Charger Features:

- 120 VAC 60 Hz output
- Two 60 amp AC inputs: Grid input at 60A and Generator input at 60A
- Load Support parallels the inverter output with incoming AC sources allowing it to run larger loads from smaller generators
- Works with any Magnum-Dimensions accessory, including the AGS, remotes, and the Magnum-Dimensions router.

To learn more about Magnum-Dimensions products, visit www.magnumenergy.com

MAGNUM DIMENSIONS

Sensata Technologies

The World Depends on Sensors and Controls

contributors

this issue's experts

Home Power Managing Editor **Claire Anderson** lives in a passive solar, (almost) net-zero-energy home she and her husband designed. She and her family are developing their 4.6-acre homestead to incorporate rainwater harvesting, graywater reuse, organic food and flower gardens, and maybe a milking goat or two.

Elsa Johnson is the director of IINA ("life" in Navajo) Solutions (iinasolutions.com), a nonprofit that improves quality of life for rural Navajos. She cofounded the Plateau Solar Project with Mark Snyder to bring solar electricity and clean water to 40 low- or no-income remote Navajo elders.

Justine Sanchez is *Home Power*'s principal technical editor. She's held NABCEP PV installer certification and is certified by ISPQ as an Affiliated Master Trainer in Photovoltaics. An instructor with Solar Energy International since 1998, Justine leads PV Design courses and develops and updates curriculum. 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.

Roy Butler is the owner of Four Winds Renewable Energy. His home and business have been powered by wind and solar since 1997. He sits on the NABCEP board of directors, and is a NABCEP-certified PV installer and an IREC Certified Small Wind Master Trainer.

David Laino puts his aeronautical and mechanical engineering knowledge to work designing wind turbines for Endurance Wind Power, and for fun, sailing on the Chesapeake Bay in Maryland.

Mark Snyder, owner of Mark Snyder Electric (marksnyderelectric.com) and cofounder of the Plateau Solar Project, is a master electrician and solar homebuilder. He's designed, installed, and optimized renewable energy systems for 37 years.

Willi W. Hampel is a Wisconsin-based professional engineer with 30 years of experience designing medical diagnostic imaging equipment. He has almost 40 years of experience installing and maintaining residential wind turbines and now is journeying into the wonderful world of solar energy.

Chris Magwood has been dedicated to making beautiful and high-performance buildings without wrecking the planet since building his first house in 1998. He has authored several books on sustainable building, most recently *Making Better Buildings*, and is a director at The Endeavour Centre, a sustainable building school in Peterborough, Ontario.

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.

Rebekah Hren is a licensed electrical contractor in North Carolina and a NABCEP-certified PV installation professional. Her focus is system performance, quality control, and *Code*-compliance. Rebekah currently works for Solar Energy International and for solar farm developer O2 Energies.

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.

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.

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.

Brian Mehalic is a NABCEP-certified PV professional, with experience designing, installing, servicing, and inspecting all types and sizes of PV systems. He also is a curriculum developer and instructor for Solar Energy International and an independent contractor on a variety of PV projects.

Contact Our Contributors

Home Power works with a wide array of subject-matter experts and contributors. To get a message to one of them, locate their profile page in our Experts Directory at homepower.com/experts, then click on the Contact link.

There's Something in the Water

On the Web

Like us on Facebook.
facebook.com/homepower

Follow us on Twitter.
twitter.com/homepowermag

Share us everywhere!
homepower.com/articles

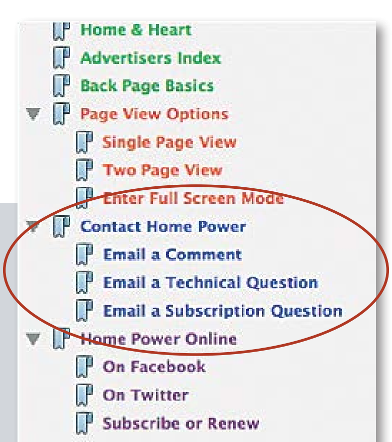
Shawn Schreiner

Renewable energy enthusiasts have long trumpeted microhydro as the holy grail of home-scale energy resources. If you're lucky enough to have a suitable water resource on your property, your energy worries are over—along with your energy bills.
homepower.com/microhydrobasics

Start with the hydro basics articles, then dig into *Home Power's* article archives for the best microhydro info on the Web.

Geek Speaks

Although we do our best to define technical terms, abbreviations, and acronyms wherever used, you may occasionally come across one that still has you stumped. Visit **homepower.com/glossary** or click the Glossary link in the footer of any website page. To add a term or help us improve the definitions you find there, email glossary@homepower.com.

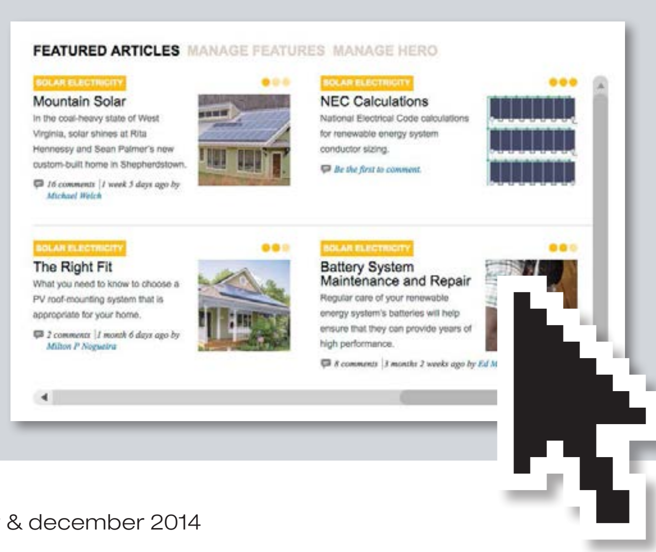


Howzat?

Ever reread a paragraph in *Home Power* a second or third time, but it still doesn't seem to square? Well, we're not the type to leave you twisting in the wind. *Home Power's* digital edition comes equipped with a lifeline at the ready. Scan the blue bookmarks in the left margin of your PDF window and click on Email a Technical Question. Print-edition readers get the same result by typing asktheexperts@homepower.com into their email message's To: field. Either approach puts your question in front of our full editorial staff. They're eager to help.

Follow the Dots

Perhaps the biggest editorial challenge at *Home Power* is tailoring our content to our readership's wide range of experience with renewable energy and building technologies. We want to keep you interested without talking over—or under—your level, and that's no small task. Now you can find the right fit at HomePower.com by paying attention to the simple coding system, which classifies each article as • Beginner, •• Intermediate, or ••• Advanced. Watch for the dots, and learn at your pace.



IronRidge

XR Rail Family

Courtesy IronRidge

IronRidge (ironridge.com) expanded its line of rails for PV module roof mounts. There are several models, each for a specific design load. The XR10 is the lightest and is for systems installed in locations that receive little or no snow. It can accommodate 6-foot rail spans (the distance between supports). The XR100 is designed for a range of snow and wind loads, with a span capability of 8 feet. The heavyweight XR1000, for extreme climates and high snow and wind loads, can span up to 12 feet. The IronRidge website offers detailed load and span tables.

Quick Mount PV

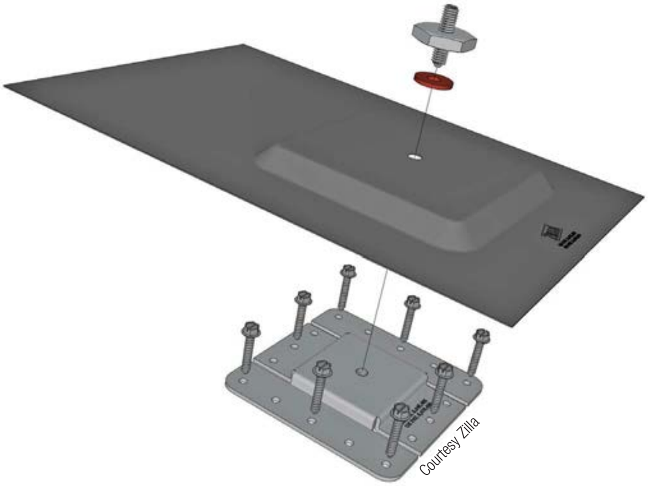
Rail-Free Mounting System

Quick Mount PV (quickmountpv.com) released Quick Rack—a rail-free mounting system for standard module frames (no custom grooved module frame required) on composition shingle roofs. The system includes base mounts, clamps, and array skirts. Modules can be installed in either portrait or landscape orientation. Quick Rack features integrated flashing and grounding (one ground lug can ground up to 300 modules). Included is the Quick Rack Designer software, which uses project location and module make/model to help generate a *Code*-compliant Quick Rack design, engineering report, and detailed parts list.

Courtesy Quick Mount PV

Zilla

Double Stud XL Flashing



Courtesy Zilla

Zilla (zillarac.com) introduced Double Stud XL Flashing to create a watertight roof attachment for any PV rack system on a pitched composition shingle roof. This flashing can attach either directly to structural roof supports or to the roof sheathing, eliminating the need to locate rafters. It is available in either a black or mill finish. Standard tools and hardware are used to secure the flashing to the roof.

—Justine Sanchez

Solar & Efficiency Pair Up for the Navajo Nation

"Nowhere in America are there more people without electricity than on tribal lands," says Elsa Johnson of IINA Solutions. It's estimated that nearly 20,000 rural Navajo homes do not have electricity—and are lacking typical household services many of us take for granted. The Plateau Solar Project (PSP)—a pilot project of IINA Solutions, Mark Snyder Electric, and Global Solar Water Power Systems (GSWPS)—is changing that by providing solar-electric systems, water, sanitation, and meaningful employment.

Like thousands of other rural Navajo families, the George family lived for years without running water or electricity in their home near Canyon Diablo, Arizona. The family of five shared a small, two-bedroom dwelling built with railroad ties, their only lighting from a single kerosene lantern. Twice a week, the Georges made a 50- to 70-mile journey through desert canyons on washboard dirt roads to get firewood and water. They'd never owned a refrigerator—or even a lightbulb—and only had an outhouse for bathroom facilities. Today, thanks to the PSP, the George family lives with electricity and running water in a modest, energy-efficient off-grid home powered by the sun and wind.

Solar strategies, such as a tracked PV system and solar air heating (not pictured), pair up with a well-sealed and -insulated building envelope to create an energy-efficient off-grid house.

Anthony Zarembski

The new, 1,400-square-foot home's construction was funded through a Bureau of Indian Affairs and Navajo Rural Housing Development special project. The home is fairly conventional—with 2-by-6 construction and fiberglass insulation in the walls (R-19) and attic (R-30). But infiltration in framing often reduces performance. To remedy this, 1/2-inch-thick P2000 rigid-foam insulation provides a whole-house thermal break, adds R-2.2 to the insulation, and reduces infiltration significantly. While the house isn't oriented for passive solar gain (Navajo tradition dictates that a home's front door face east), overhangs are designed to reduce summer heat gain through the windows.

The remote site, located on rugged Navajo land near Flagstaff, Arizona, and 15 miles from the nearest utility line, posed design challenges for meeting the home's energy needs, thus the focus on energy efficiency first. Next was implementation of renewable energy systems—a small wind-electric turbine and 1.2 kW off-grid PV system provide electricity for the home's few loads (LED and compact fluorescent lighting, an Energy Star refrigerator, and a few other small electronics).

Three SolarRoofs Skyline 10-05 solar air collectors coupled to a ducted recirculating system with a blower fan provide the main space heating. This is supplemented by a wood heater and 750-watt infrared heater mounted on an interior 13-by-8-foot brick (thermal) wall. Water is heated by a 750-watt diversion load from the wind-electric system (and from the PV system, when the batteries are on a float charge). Cooking is done on a propane stove, with the wood heater serving as the backup. In the summer, a GSWPS Silent Aire combination evaporative cooler and ventilator cools the house, using nighttime air from the outside.

Unique to the house is an Enertopia Multi-Purpose Utility Structure (EMPUS) Bump—an insulated 4-by-8-foot room attached to the house. The EMPUS serves as the home's central energy station, containing the inverters and batteries for the wind and PV systems. The unit is insulated to R-30 and climate-controlled via its own solar hot air collector, which serves a heating and cooling function, depending on the season. A 500-gallon water tank absorbs heat from the Solar Aire heater/cooler. The combination of solar heating/cooling and insulation helps the EMPUS maintain temperatures between 45°F and 85°F, despite chilling winter lows and sweltering summer highs.

Once the unit reaches 85°F, it transfers up to 750 Btu of excess heat into the house via a blower fan. A thermostatically

continued on page 18

continued from page 16

controlled infrared wall-mounted heater in the living room uses surplus electricity from the RE systems to heat the thermal wall for up to three hours—even after the fire has gone out in the wood heater. A ventilation system built into the EMPUS unit controls the humidity in the house and ensures adequate air exchanges between the interior and exterior.

Sensors throughout the house monitor and log data on temperature, humidity, and power consumption. This data is shared with several agencies to track the home's performance. The George family pays a $35 monthly fee to MSE to cover servicing, maintenance, and component replacement in the RE systems.

Off-Grid Hybrid System

Five 240 W Day4Energy 60MC-I PV modules are mounted on a Zomeworks passive tracker. Along with adjusting the array tilt four times a year, at the equinoxes and solstices, the tracker has an "early wake-up" system (patent pending by Mark Snyder), which faces the tracker east before sunrise and helps optimize the system's production.

A 1 kW Navajo Niyol wind generator from Cherokee WindPower takes advantage of cyclonic winds that sweep the plateau at night, contributing some electricity to the hybrid system's mix.

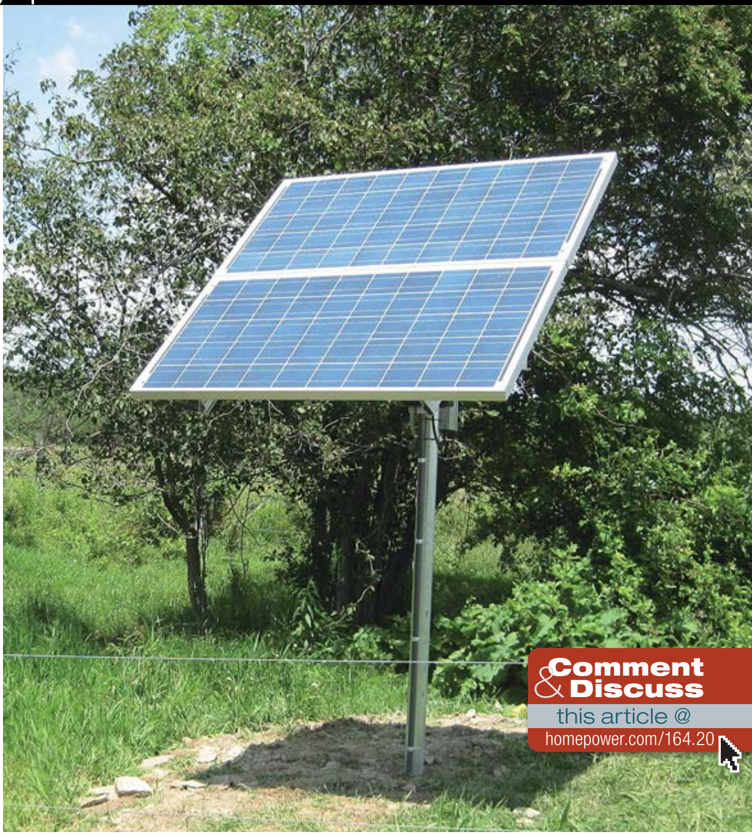
The wind turbine and PV system are each paired with a MidNite Solar Classic charge controller (200 & 250, respectively). Mark worked with MidNite Solar to beta-test the MidNite Solar charge controllers with Navajo language prompts to monitor activity and alert maintenance crews as needed. Eight 6-volt, 325 amp-hour 6CRP400 series RE batteries from Crown Battery provide energy storage.

So far, the PSP has brought renewable electricity to more than 40 Navajo elders. They've trained eight Navajo workers to plumb, rewire, and retrofit houses, and to maintain existing RE systems. But, says Mark, this is just the first step. MSE and IINA Solutions are looking for additional partners to help them bring power—and hope—to underprivileged tribal communities here and across the world.

— Mark Snyder, Mark Snyder Electric
& Elsa Johnson, IINA Solutions

Sizing a Solar Water-Pumping System

A solar water-pumping system can be a cost-effective, dependable method for serving your remote watering needs, whether it's for irrigation, animal grazing, or potable use. For more details, see "Solar-Powered Water Pumping" on page 60.



Roy Butler

A farmer in western New York plans to use solar-pumping to water 120 beef cattle. The water source is a drilled well located at the base of the hill, 1,800 feet from utility power. A surface-mounted 1,500-gallon polyethylene storage tank was installed at the top of the hill. The tank's inlet is 71 feet above the ground level at the wellhead. To connect to the well, 340 feet of $1\frac{1}{4}$-inch poly pipe is needed (this common size tends to work well with most flow rates). A float switch is installed in the tank and is wired to the pump controller.

The storage tank will gravity-feed four 300-gallon stock tanks that are 25 to 40 feet lower. There are mechanical float valves in each stock tank to regulate the water level. This is a seasonal operation from April through October—no freeze-proofing is needed.

Additional Specifications

Well depth: 180 ft.

Static water level (SWL): 35 ft.

Recovery rate: 14 gpm

Anticipated drawdown: None, if pumping rate is kept below recovery rate

Water requirements: 120 beef cattle at 15 gpd each = 1,800 gpd

Avg. daily sun-hours (annual* average): 4.1 (246 daily sun-minutes) **A seasonal sun-hour average could be used, but could result in overestimating the gpd produced.*

Estimated pump flow: 10 gpm

Total dynamic head (TDH):

- 35 ft. from SWL to ground level (pump is at 170 ft., but only the SWL counts)
- 71 vertical ft. from well ground level to the storage tank inlet
- Head loss from 170 ft. of 1 in. drop pipe in well: 2.93 per 100 ft. from table × 1.70 = 4.98 ft. (see table in "Solar-Powered Water Pumping," this issue)
- Head loss from 340 ft. of 1.25 in. pipe to tank: (0.88 per 100 ft. from table × 3.4 = 2.99 ft.

Total TDH = 35 + 71 + 4.98 + 2.99 = 113.97 ft.

Pump sizing: A Grundfos sizing table or online calculator shows that the 11 SQF-2 pump will provide 10 gpm at 120 ft. and require 500 W. The calculator accounts for PV array losses, so there's no need to upsize.

Output: 246 sun-minutes per day × 10 gpm = 2,460 gpd, which exceeds the water requirements.

Proposed Solar Water Pumping System

Grundfos 11 SQF-2 pump

Two 250 W modules in series (Vmp 62.2)

Pole-mounted PV array

CU200 pump controller with a Grundfos float switch in the storage tank

—Roy Butler


ENERGY STORAGE
UNLEASHED
Trojan
L16RE-2V
SMART
CARBON

Water Pressure

I just read the water pumping Q&A in "Ask the Experts" (*HP163*), where an expert addressed Jim Yannaccone's questions about several water pumping issues.

There was a lot of good advice in the article, but it brought to mind an issue that's bugged me for years: Why do we seem to need such high pressures in our water systems? High pressure equals high pumping costs, and that equals more expensive pumps and more solar-electric modules.

Most of us have seen old farmhouses with attached water towers. Often these were only 20 to 30 feet high, meaning the head, when the tank was near empty, was only going to be as little as 5 to 15 feet at a shower nozzle. This is only about 2 to 8 pounds per square inch (psi).

It seems like that would make showering impossible, but it does not. I lived for 20 years with no pump, relying on gravity to pressurize my water system. The water source was a spring, and it was located lower than the peak of my roof—the pressure was only 2 to 3 psi. I was still able to have a great shower. Here's how:

To reduce pipe friction, I used 1-inch main lines, and 3/4-inch lines to the shower. I figured I wouldn't get a decent flow at the shower if I used a "modern" washerless shower control, because they have tiny orifices. I used an old-style shower control—the kind that used rubber washers. I picked the one with the largest orifice I could find.

The disadvantage to showering with low water pressure was that if someone ran water in a sink or flushed the toilet while someone else was showering, they would hear very loud shouting or screaming coming from the shower!

I suggest using an elevated storage tank instead of relying on a pressure tank. A 40-gallon pressure tank will only provide about 12 gallons of water with a 30 to 50 psi pressure switch setting. If you're able to run your home on 2 psi, that same tank would provide almost 40 gallons of water, but that's usually not nearly enough to keep you in water.

You can place a 500-, 1,000-, or even 2,500-gallon tank on land that's only 5 to 10 feet higher than your highest showerhead—this is much more likely to be available than

Ian Woofenden

This simple pressure system provides "city" pressure reliably, and at much lower cost and complexity than an elevated tank. The pump with integrated pressure switch and the pressure tank can be scaled up to match the water demand.

the 100 feet suggested in the recent "Ask the Experts" response. This would provide you water for days or weeks when the sun isn't shining. If you don't have that much elevation available, consider building a water tower. Even if you only stick a fairly small tank up there, you'll be way better off than simply using a standard pressure tank setup.

Malcolm Drake • Grants Pass, Oregon

You are correct that standard water pressure used in the United States is far higher than necessary for simple water delivery. One reason for this is fire protection. Fire hydrants are connected to municipal water mains, and require high pressure to supply fire hoses. Pressure regulators are then used to reduce pressure where needed, but there is no energy to be saved there, because it has already been spent to produce the main pressure. High pressure allows use of smaller pipe sizes because the resulting pressure drop becomes relatively insignificant. Small pipe costs far less than large pipe, and is easier to fit into the walls of buildings.

Until the 1970s, most new construction used copper pipe, which is expensive. Energy was cheap then. It was cheaper to apply energy to overcome pipe resistance than it was to use larger-diameter pipes. Our water supply and plumbing standards reflect these factors, and they apply to private water systems, too. State and local codes call for a minimum pressure of 40 psi. You need 2.31 feet of elevation to produce 1 psi. So 40 psi requires nearly 100 feet of tank elevation!

A pressurizing system will cost much less than an elevated tank, and will weigh far less—the 500-gallon tank that you suggest would weigh more than 4,000 pounds! Another challenge to elevated tanks is freeze protection. If you travel south to warmer climates, you will find elevated tanks as you describe, often around roof level. The systems that work well use large, bulky pipes with ball valves and avoid restrictive fixtures. Traditional toilets and washing machines fill more slowly, but will function fine. However, dishwashers will not function, nor will sprinklers, hose sprayers, or tankless water heaters. A greater amount of water will be needed to rinse hair. Owners of gravity systems often add a pressure booster pump to serve modern appliances and fixtures. This tends to conserve water, compensating for the modest energy used.

A water storage tank that is not pressurized must be open to the atmosphere. Air must be allowed in for water to flow out. This can draw in contaminants. State and local codes may require chemical disinfection for such "open" storage systems. A small tank will also get warm in the summer. This may be unpleasant at best, and may support growth of bacteria and algae.

In most situations, there are just too many problems and costs to recommend an elevated tank or other low-pressure gravity-fed water system to supply a simple low-tech household.

If you consider the big picture, a pressurizing system looks like a bargain.

You are correct to use large pipe to minimize pressure drop. Use one size larger than the minimum pipe sizes required by plumbing codes. Use PEX (flexible) pipes and other means to avoid sharp 90° elbows. Agree on this clearly—in writing—with your plumber. You will then be happy with a pressure range of 30 to 40 psi instead of the "normal" (wasteful) range of 40 to 60 psi.

*Windy Dankoff •
Founder (retired), Dankoff Solar Pumps*

More DIY, Please

I subscribed to *Home Power* when the first issues were printed on newsprint. I built an off-the-grid home in western North Carolina in the late 1970s in which I still live.

Though faded, the 6-volt used modules I first bought are still producing the same power as they did more than 30 years ago, and the 12-volt system with connections mounted on plastic breadboards still lights the house (now using mostly 12 V LEDs) and runs an automotive music system. The inverter has been upgraded to a 3 kW sine-wave model that powers tools, small kitchen and household appliances, and some electronics. The PV array has been expanded over the years and includes a motley collection of every type of PV—single crystal, multicrystal, and thin-film. The controller is a Xantrex C40. The battery bank is six Trojan L-16s. It has been replaced four times over the last 30 years. I have no other source of backup energy.

The point of this is that a PV system can successfully be implemented in a modest, homebrew, DIY manner. In the early years of *Home Power*, such systems were the focus. I realize that the solar industry is now mainstream and that today's home applications are far more sophisticated. However, I fear that the impression conveyed by the homes featured in recent issues of *Home Power* is that the era of low-cost DIY systems is over and that only professional implementations in high-end homes are acceptable. This is not true, and it seems to me that at least a section of the magazine should be devoted to modest DIY examples and instructions, or perhaps it is time for a new periodical devoted to such systems.

Paul Hoover • Burnsville, North Carolina

While it's true that solar electricity has entered the mainstream, with grid-tied systems the most popular, Home Power *hasn't forgotten its roots. You'll still find DIY content and smaller off-grid systems featured in every issue of* Home Power. *Here's a sampling of the DIY and off-grid content we have offered just in the past few issues. There are many more articles we publish on energy efficiency and passive solar home design that apply to both on- and off-grid systems.*

"Changing Fluorescent Tubes to LEDs" by Penny & David Eckert • homepower.com/163.16

"Inverter & Battery Cables" by Christopher Freitas & Carol Weis • homepower.com/163.72

"Choosing a Battery-Based Inverter" by Zeke Yewdall • homepower.com/162.44

"MPPT Charge Controllers" by Zeke Yewdall • homepower.com/162.52

"Battery Maintenance" by Christopher Freitas & Carol Weis • homepower.com/161.52

"Determining Battery State of Charge" by Christopher Freitas • homepower.com/161.66

And, of course, in every issue, Kathleen Jarschke-Schultze regales readers with her tales of off-grid living.

Claire Anderson •
Home Power *managing editor*

write to:

mailbox@homepower.com

or Mailbox, c/o Home Power
PO Box 520, Ashland, OR 97520

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

Seasonal Heat Storage

I am interested in applying some of the principles outlined in Chuck Marken's article "Overcoming Overheating" (*HP142*). I am especially intrigued with the idea of routing the excess solar heat produced during the summer to a heat dump for melting winter snow. The question is how to manage the process to store the heat.

We have a second home in the San Bernardino Mountains at an elevation of 7,200 feet, near Green Valley Lake, California. Here, snow can accumulate to several feet—and it can remain for months.

In 2010, we installed nine 4-by-10-foot solar collectors in an antifreeze-based system for space and water heating. To prevent system overheating during warmer months, I cover several of the collectors, which are mounted on the roof. In April, I cover about 20% of the array; by the end of May, about 75% is covered. I reverse that process beginning in August.

While this strategy is effective, it is very labor-intensive and does not accommodate cloudy days well. Lately, we are experiencing more cloudy summer days. Since it is impractical to climb onto the roof to uncover collectors as the clouds come and go during the day, we now find ourselves relying on imported power for domestic water heating. Installing a heat-dump controlled with a thermostat is my next choice for dealing with overheating, since I could still make use of the excess heat.

Walter Farmer • via homepower.com

Beyond heat storage in a bed of sand under a radiant floor, I don't know of anyone who has had success with seasonal storage and retrieval systems. Even sand beds only provide a few days' worth of heating. A successful seasonal thermal storage system is an idea waiting for innovation and, to my knowledge, has been waiting for 40 years.

A heat dump, however, is a pretty straightforward solution. A motorized and dedicated pump that diverts the glycol solution to a radiator or underground tubing is not my favorite solution since it uses up some parasitic energy to dump the heat. I prefer a passive inline radiator—a thermostatic valve diverts the glycol solution to the radiator when the system is running normally and when the fluid is warmer than 170°F. An example can be found at bit.ly/Dissipater.

Ian Woofenden

A heat dissipater, such as this one by Apricus, can be used as a dump load to prevent overheating in a solar water heating system.

You'll need about 8 feet of 3/4-inch hot water fin tube element per 4-by-10 collector—maybe less.

Chuck Marken • *Home Power* solar thermal editor

We normally recommend one Apricus heat dissipater for each 4-by-10 flat-plate or 30-tube evacuated-tube solar collector. They must be located outside—with good airflow—to maximize heat transfer. They can be installed in parallel (not series) to increase energy dissipation.

For winter heating, we normally recommend that the collectors are tilted at an angle that's 20° to 25° greater than the location's latitude. This helps maximize winter, fall, and spring output, while reducing summer output. Another good option is to mount collectors on a south-facing wall at 60° to 70°. In the winter, the collectors will benefit from diffuse radiation from the snow-covered ground, which further helps increase output during the cold months.

Mick Humphreys • Apricus.com

Air- vs. Ground-Source Heat Pumps

I read Alex Wilson's "Heat Pump Primer" in *HP149*, and was surprised about the claim that an air-source heat pump (ASHP) with variable refrigerant-flow attains the same coefficient of performance (COP) as a ground-source heat pump (GSHP). While I can imagine that an ASHP is very efficient down to 20°F, I wonder how ASHP can work well in colder temperatures. I own a fairly new Trane ASHP that is trying to make heat at -5°F, but the COP is marginal. I am interested to know how much more efficient a modern ASHP can be than my Trane. I considered a GSHP, but the cost and complexity dissuaded me.

Mark Dischinger • via email

Several decades ago, ASHPs only made sense south of about 40° latitude—at temperatures below 30°F, the performance dropped significantly. They were little better than electric-resistance heat. But times have changed. The new generation of variable-refrigerant-flow (VRF) ASHPs, often called minisplits or ductless minisplits, now perform reasonably well at temperatures down to -10°F (or even lower). For example, in our well-insulated Vermont house, the 18,000 Btu/hour Mitsubishi model we installed kept us reasonably comfortable—even during last winter's chilly polar vortex—with a COP that averaged about 2.0. On a few of the coldest evenings, with temperatures between -5°F and -10°F, we fired our small wood heater for supplemental heat.

Japanese companies, including Mitsubishi, Daikin, Fujitsu, and Sanyo (now part of Panasonic), have led the charge with these high-performance, cold-climate ASHPs. I hope that American companies, such as Trane and Carrier, will soon catch up with their Japanese competitors. Experts I've spoken to expect a long-term COP of 2.5 for these VRF ASHPs in cold climates. A COP of 2.5 means that for every one unit of energy consumed (as electricity), 2.5 units of energy (as heat) are supplied. That compares reasonably well with GSHPs. The best GSHPs might deliver an average COP of 3.5, but in a cold climate, the performance drops as the ground cools.

An in-depth study by Energy Saving Trust of residential GSHPs and ASHPs showed average GSHP performance to be only marginally better than that of ASHPs—and also showed a wide variation in actual performance. The measured COPs of the GSHP systems studied ranged from 1.55 to 3.47, with a median of 2.31. The COPs of the ASHP systems ranged from 1.2 to 2.2, with a median of 1.83. For systems in which the average "system performance factor" was determined (a metric that includes all electricity use for the

continued on page 28

continued from page 26

components, as well as auxiliary or immersion heaters for space and water heating), GSHPs achieved an average COP of 2.82 while the ASHPs averaged a COP of 2.45.

While modern GSHPs and ASHPs have similar performance, there's a huge disparity in installed cost. In New England, for example, GSHPs can cost five to seven times as much as VRF ASHPs.

Instead of spending the money on a GSHP, I recommend installing one or two minisplit VRF ASHPs and then investing the "savings" into building envelope improvements, such as more insulation, low-e storm windows, etc.

Alex Wilson • *Home Power* building technology editor

Heat Pump Types Compared

	Ground-Source	Air-Source
Description	The ground serves as the heat source in winter & heat sink in summer. Heat is moved into or out of the building using electricity via a refrigerant compression cycle—much like the one in a refrigerator.	The outdoor air serves as the heat source in winter & heat sink in summer. Heat is moved into or out of the building using electricity via a refrigerant compression cycle—much like the one in a refrigerator.
Energy performance	Highest energy performance because ground temperatures are more moderate (warmer in winter & cooler in summer) than the outdoor air. Typical coefficient of performance (COP) of 2.5 to 3.5.	Good energy performance that has improved significantly as the technology has advanced. Typical COP of 2.0 to 2.5.
Cost	Very high cost in most areas, due to digging trenches or drilling wells. Most commonly, tubing is buried in trenches.	Significantly lower cost than for GSHPs because trenching or drilling a well is not required.
Key benefits	Highest energy performance.	Significantly less expensive or competitive with conventional heating in most areas. Manufacturers are typically large companies that will likely be around for a long time.
Key negatives	High cost & complexity of components. Most manufacturers are small companies that may be shorter-lived. Performance may drop over a season as the ground cools or warms.	Vulnerable to power outages. Most models have limited output, so are most appropriate for small, highly energy-efficient buildings.
Bottom line	Most appropriate for small commercial buildings which would have a significant expenditure for heating & cooling equipment.	The top choice for heating & cooling energy-efficient homes.

Wind Speed[3]

When I was in fifth grade, I was told that doubling wind speed quadrupled the force of the wind. However, I've recently learned that the wind's power is proportional to the *cube* of its speed, rather than the square. The first equation in David Laino's article on wind physics in *HP161* says that kinetic energy equals $1/2$ times mass times velocity squared, which raises two issues. First, the article doesn't explain why the velocity is squared, which seems necessary for following the rest of the logic leading to the cube-of-velocity concept.

Second, the coefficient $1/2$ presumably requires that specific units be used, such as kilograms and meters. Can you better explain these?

Malcom Drake • via email

What you learned in fifth grade was correct: The *force* of the wind is a function of the wind speed squared. However, force and pressure are static measures, whereas power and energy are dynamic measures. It is important not to confuse them. Static does not consider motion and dynamic does. Thus, it makes sense that the addition of motion—velocity—to a static value that already has a squared dependency on velocity yields a cubic dependency on velocity.

A presentation of the concepts in the article required accepting the laws of physics at some level. The details of the derivation of the kinetic energy equation were outside the scope of the article, but if we accept Newton's second law of motion—that force equals mass times acceleration (F = ma), and the definition that energy (E) is the integration of force acting over a distance (s)—then we get this calculus equation:

$E = \int F \times ds = \int m \times a \times ds = m\int (dv/dt) \times ds = m\int (ds/dt) \times dv = m\int (v) \times dv$, which leads to $1/2mv^2$

If you are familiar with integral calculus, you'll recognize that both the $1/2$ and the squared terms are the result of integration, with the result that $E = 1/2mv^2$. Thus the $1/2$ term is not a coefficient for specific units—you are free to use any units you choose. If you use SI units (kg, m, and sec) you will get an answer for energy directly in watt-seconds.

The velocity-cubed function of kinetic energy is unique to continuous fluid flow. It also applies to water flow because the mass of the fluid passing through an area depends directly on how much fluid—and how fast that fluid—is flowing through the area. This is not true for the kinetic energy of a solid mass, such as a baseball. The baseball's mass is a constant and thus its energy is only a function of the velocity squared. So take advantage of the power of the cubic by choosing wind power over baseball power!

David Laino • Cofounder, Endurance Wind Power

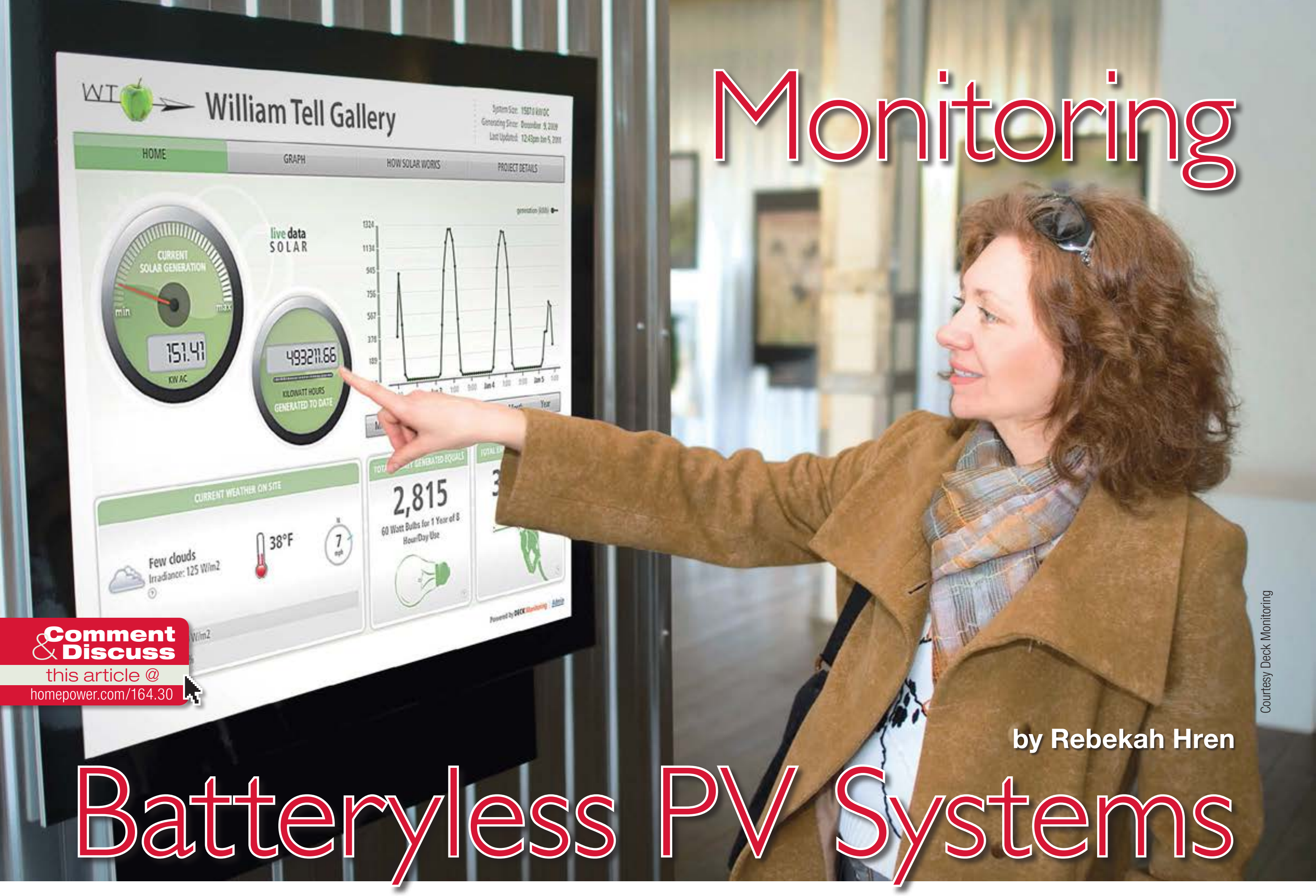
write to:

asktheexperts@homepower.com

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


Deka Solar Saves The Day
The proven, reliable solar battery choice for off-grid power needs in harsh conditions… and just about everywhere else!
From the South Pole to the Serengeti, the Earth's harshest environments are a perfect match for Deka Solar Batteries. Offered in advanced Gel, AGM and flooded technologies, Deka Solar batteries are the proven choice for all your renewable energy applications.
SOLAR
MK POWERED®
Available through MK Battery distribution centers across North America, Europe and the Asia Pacific region • U.L. Recognized Components • Competitive Warranty • ISO9001 Quality System Certified • Made In The USA
© MK Battery 2014
Deka SOLAR PHOTOVOLTAIC BATTERIES
www.mkbattery.com
MK Battery - An East Penn Manufacturing Co. Subsidiary

Monitoring Batteryless PV Systems



Courtesy Deck Monitoring

by Rebekah Hren

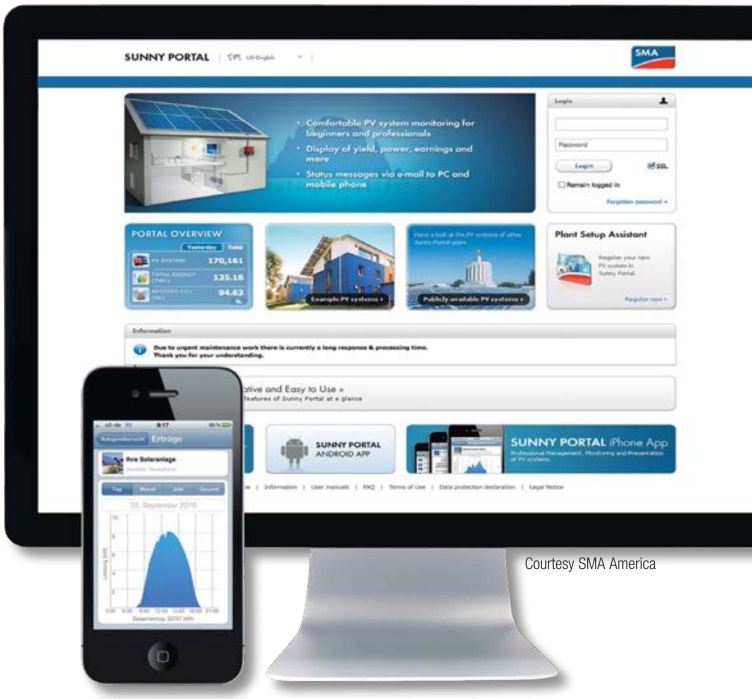
A monitoring system can help assess PV system performance in real time or over a duration of time, and provide on-site and remotely accessible information for system owners and installers, and the general public.

Monitoring allows you to obtain real-time data about your system anywhere you can access the Internet and/or email. In the past, Web-based PV system monitoring was an expensive add-on (to an already-expensive system) and thus often left out. The days of checking out the inverter's screen on the garage wall to see how much renewable energy a PV system is generating are quickly falling behind us. Modern grid-tied PV systems, whether installed with module level power electronics (MLPEs), or string inverters, now come with affordable (and in some cases, free) options for gathering and viewing the system data on a computer, smartphone, or tablet, either in a local network or via an Internet Web portal.

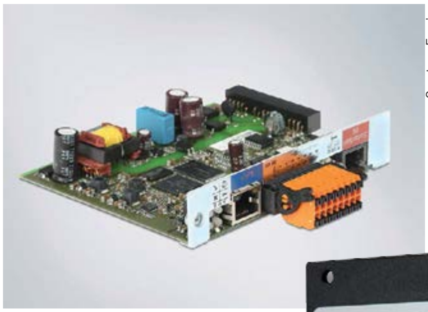
Monitoring systems can alert owners to a problem when it occurs, instead of waiting to be surprised with an unusually high electricity bill. Many monitoring systems can send email alerts to the system owner and installer when production isn't meeting projections, or when inverters or other equipment are offline or showing other errors.

Monitoring can also show household electricity use and PV system production, which can help homeowners manage consumption habits. Monitoring can be fun and engaging, and provide great publicity and educational opportunities for an otherwise static system.

Batteryless PV monitoring systems provide Web portals for remote, online access to the system through a computer, smartphone, or tablet.



Courtesy SMA America


Courtesy Fronius

The Fronius Datamanager is a wireless data logger that comes preinstalled in new inverters, and can be retrofitted to older models.

Courtesy Solectria

Solectria's SolrenView DAS Gateway can monitor up to 16 inverters and owners can opt to share data publicly.

Monitoring Costs

In most cases, for typical residential PV systems, a Web portal (the website provided for a system to document its production) is provided free from the inverter or MLPE manufacturer, but the hardware that enables data monitoring often needs to be purchased. (Fronius and SolarEdge are two manufacturers providing Web portals and inverter-integrated hardware for a completely free monitoring solution.) Companies that specialize in leasing residential PV systems, such as SolarCity and Sungevity, include their own branded monitoring as part of the packaged PV system. More complex and highly customizable Web portals likely have a yearly subscription fee—especially for larger PV systems with a lot of data, and those using portals hosted by third-party providers unaffiliated with the inverter manufacturer.

Hardware for basic monitoring of a residential system shouldn't cost more than a few hundred dollars. There are myriad low-cost and high-quality inverter-provided monitoring solutions available. If monitoring is a key consideration for a system, it can be a driving factor in equipment selection, because Web portals vary greatly in their layout and user-friendliness. Taking time to look through the publicly available portals (see Resources) can help you decide which manufacturer provides the best solution for your system.

Monitoring Components

Data loggers and/or communications gateways capture data and may be able to relay the data to the Internet. Inverters are connected to integrated or external data logging or gateway communications devices. Data loggers can record data to memory and often display it (see "Data Display Options"). A communications gateway sends data to a Web portal but may not record it locally. Data is transmitted in intervals—most commonly every 15 minutes—but varying from one minute (for "real-time" display) to daily. A gateway may transmit data wirelessly or be hard-wired to a router.

Net energy meters measure the AC energy exported to the grid from the PV system, and energy used from the grid, to show net consumption or production. Because the meter is positioned between the loads and the grid, a net energy meter does not measure PV production alone.

PV production meters are positioned between the inverter and the loads to measure only the PV system's AC energy production. Note that some utilities or third parties (especially residential leasing financiers) may require installation of a revenue-grade PV production meter. (A revenue-grade meter conforms to American National Standards Institute [ANSI] Standard C12.20 and provides readings with ± 0.25% accuracy.)

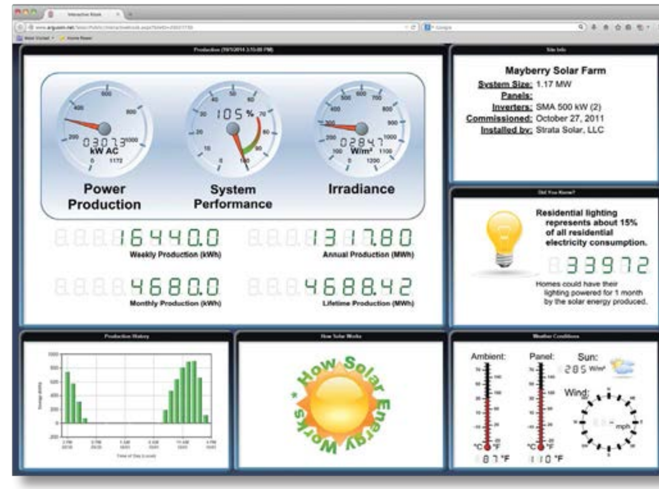
While net-energy meters and PV production meters both look like the ubiquitous kWh meter, it's their position in the system that defines what they are monitoring: A net meter (left) is placed between the AC service entrance and the utility grid connection, while a PV production meter (right) is positioned between the inverter and the AC service entrance connection.


Rebekah Hren (2)

PV system data can be displayed via a wireless tabletop unit, like the SMA America Sunny Beam (below).

Web portals, including this publicly available display (right), depend on network connections but allow a wide variety of data configurations and user interface options.

Courtesy SMA America



Courtesy O2 Energies

Current transducers (CTs) clamp over wires to measure current, and report to a meter or data logger that records the values. They can be very small and installed on individual circuits in a house to measure the energy draw for specific loads. Larger CTs can measure a PV system's production or the building's total electricity consumption.

Network connections are required to send data from the acquisition system to the Internet. The Internet connection can be made wirelessly via a cell or satellite modem, or using a hard-wired connection, such as cable, DSL, or fiber-optic lines. The monitoring system's data logger or gateway is connected to the router (and on to the Internet).

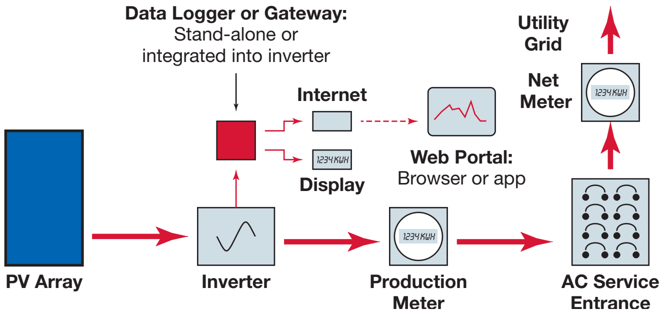
Data display options include local displays or Web portals. Local monitoring on an inverter or remote tabletop or wall-mounted display usually includes array and grid voltage, current, cumulative energy, and power.

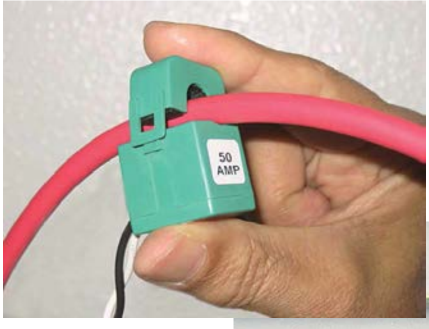
A Web portal is the viewing platform for the PV system data, displayed via a computer, smartphone, or tablet. Multiple portals may be available for one PV system, with one a publicly available version offering a few details, and another (password-protected) providing enough information for maintenance and troubleshooting. Web portals can be branded with logos, and customized with site-specific information such as amount of carbon dioxide offset or the dollar value of energy generated. Reports on historic system production (for days, months, or years) can be created and downloaded from a Web portal as well.

Communications for monitoring can be entirely wireless, or rely on hardwired network cables (like CAT5 or CAT5E Ethernet cables) to move data from the inverter to the data logger or gateway, and on to the Internet via a router. Data from individual inverters can be transmitted over power lines (power-line communications; PLCs); Bluetooth; hard-wired Ethernet cables; or wirelessly.

Power supplies, like AC wall cubes, may be needed for an external data logger/gateway, cellular modem and energy meters. Per the *National Electrical Code*, the inverter AC output circuit must be dedicated to the PV system and cannot provide this 120 VAC power source.

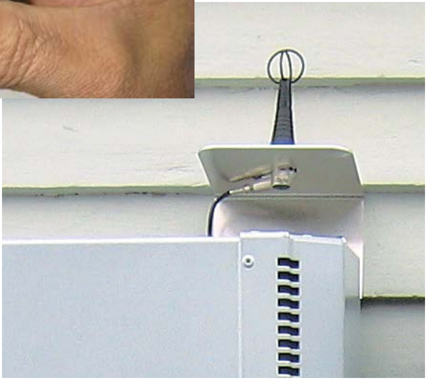
Monitoring Configuration





Courtesy eGauge

A current transducer (left) snaps closed around a wire to measure current via induction.


Ben Root

Data can be conveyed from the data logger to the display or network connection via dedicated cable, wirelessly (right), or over power lines.

Monitoring the Weather

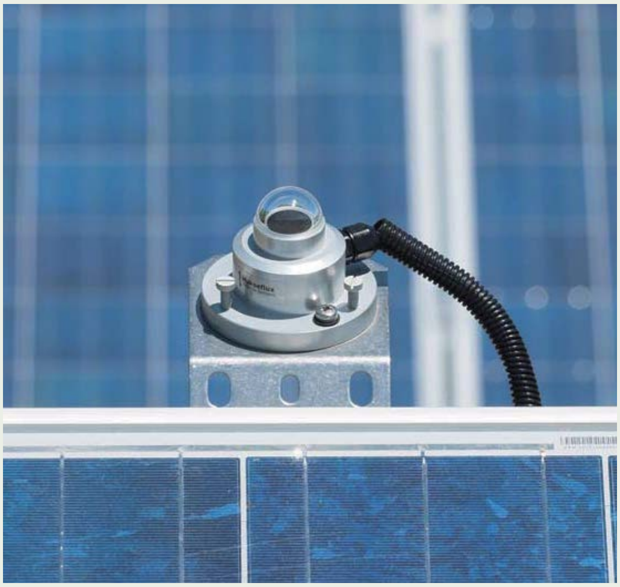
Many residential PV system Web portals can access weather data from a local public weather station—keeping costs lower by reducing the number of monitoring components and sensors. If using your own weather station, be sure that the monitoring system is compatible with the station's sensors. Consider the following components for your weather station:

Pyranometers measure solar irradiance, and are usually mounted in the same plane as the array to measure the actual direct and diffuse irradiance received by the PV modules. This is called plane of array (POA) irradiance. A second pyranometer can be mounted horizontally (a flat plane) to measure global horizontal irradiance (GHI). GHI is the component of historical meteorological satellite data that is mathematically modeled at different tilts to estimate PV system energy production resulting from POA direct and diffuse irradiance.

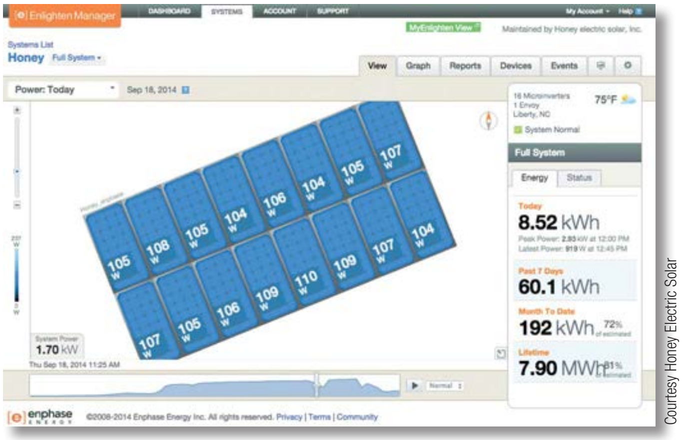
Temperature sensors measure cell temperature from the back of PV modules, while an ambient air temperature sensor is in free air. Cell temperature can be used with POA irradiance values to calculate whether a specific size PV array is producing the expected amount of power. Performance ratio can be calculated by dividing monitored production by expected production. The closer to "1" the ratio is, the better the array's performance. The performance ratio is often prominently displayed on a Web portal, as it provides quick insight on whether a system is performing properly. The performance ratio can be calculated as an instantaneous value based on 15-minute interval power data.

Anemometers measure wind speed, and usually have a vane to measure direction. While wind can help cool PV modules, this data is not necessary for PV monitoring or to calculate a performance ratio. The equipment is normally provided in home weather kits and people who like PV data often have a similar affinity for wind and other weather data.

A pyranometer, which measures solar irradiance, can be helpful for verifying PV system performance in varying weather conditions.



Courtesy Draker Laboratories



Courtesy Honey Electric Solar

Most monitoring systems display very similar data, albeit in different visual interfaces. The biggest difference is that MLPE systems, like this Enphase Enlighten display, allow monitoring of individual PV modules.

Monitoring Capabilities & Different System Types

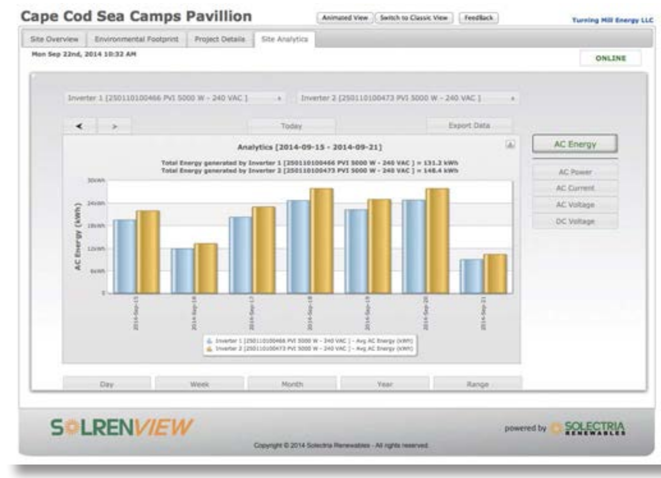
The data hosted by Web portals varies slightly by system topology (i.e. MLPEs vs. string inverters) and by equipment manufacturer, but the data displayed by monitoring portals is very similar across different platforms. For a string inverter system, at minimum, the portal displays kilowatt-hours of production for each inverter on a daily, weekly, monthly, yearly, and lifetime basis. Inverter power, reported at 15-minute or hourly intervals; DC and AC voltage; and current are also commonly measured parameters. The portal will also indicate if there is a potential problem with an individual inverter, for example, if the data is not being transmitted, or the power or energy levels are outside normal thresholds.

For MLPE systems, data provided by a manufacturer's portal is more in-depth, as the module-mounted electronics allow easy access to each PV module's power (current and voltage) and energy data, plus historical system energy data (daily, weekly, monthly, yearly, and cumulative kilowatt-hours). Portals can indicate module-level failures or performance issues, and graphically represent a "bird's eye view" physical layout.

Regardless of system type, reports on energy production history can be downloaded from the Web portal, and most portals can be configured to send emails if the system is offline or other errors occur. Web portal data is also available via smartphones and tablets. Most portals can report data collected from an optional revenue-grade energy meter as well as temperature and solar irradiance from an optional weather station. However, if a revenue-grade meter and/or weather station is a system requirement, double-check with the data system manufacturer to verify that the data can be captured and logged. If not, Web portals can access data from local public weather stations (see "Monitoring the Weather" sidebar).

Courtesy Schneider Electric

Schneider Electric's Conext Monitor 20 can monitor data from up to three Conext RL inverters.



Courtesy Solectria

PV monitoring options offered by inverter manufacturers, such as Solectria's SolrenView (above), offer similar features and customizable views.

String Inverter Systems

Fronius is one of the few residential inverter manufacturers that includes complete monitoring in the purchase price of the inverter. Fronius's Galvo inverters (1.5 to 3.1 kW) have an integrated Datamanager 2 data logger to capture system information, which is relayed to its Web portal. The Datamanager uses WiFi to avoid cables and power supplies, although it can be connected to the router via network cable. The Datamanager includes a smartphone app for commissioning—just take a photo of the inverter's barcode to set up online monitoring. Fronius IG-plus inverters can be retrofitted with the Datamanager 2 card, and the Fronius FE series can provide module-level monitoring with Tigo optimizers. The Fronius Personal Display unit can provide local monitoring of up to 15 inverters, and is available with or without data logging capabilities.

Kaco offers its watchDOG communication card; each can monitor three inverters. Installed inside the inverter, no external hardware is necessary except an Ethernet connection. The watchDOG transmits data to the Kaco Blueplanet Web portal, which is free for systems up to 10 kW (systems over 10 kW are charged $75 per year plus $1 per kW). Kaco's M-series inverters have a preinstalled Energy Management Unit for use with Tigo MLPEs.

SMA America's Webconnect Piggy-back card can collect and transmit data from up to four inverters to the free Sunny Portal website via a hardwired network connection. The card is installed inside the inverter, and uses a hardwired connection to the router—but could be connected by wireless adapter. SMA America also offers the Sunny Beam, a solar-powered tabletop display unit that communicates wirelessly via Bluetooth with up to 12 Sunny Boy HFUS inverters. Ninety days of data is stored in the Sunny Beam and can be transferred to a computer via a USB connection.

Solectria has an optional SolrenView DAS gateway for use with its PVI TL line of residential string inverters. One gateway can monitor up to 16 inverters. The hardwired gateway transmits data to the SolrenView Web portal via the household router. For systems under 10 kW, customized portal access is free for the life of system; owners can choose whether the portal is public or private.

Schneider Electric offers a similar data logger—the Conext Monitor 20 unit for up to three Conext RL residential inverters. Both Solectria and Schneider's gateway devices require an external AC power source.

MLPE Systems

Systems with MLPEs capture module-level data via the module-mounted inverter or electronics, and transfer that data either wirelessly or using PLC. This level of data capture supplies deep details on the PV system's functioning. An individual PV module's power output (including DC or AC current and voltage) can be viewed as it changes throughout the day, and cumulative energy for a day, week, month, or year can be viewed and reported for each module or the whole system.

The Enphase Envoy collects data via the power lines from Enphase microinverters; besides an AC power supply, no additional wiring is necessary.

Courtesy Enphase Energy

The method of data transfer varies by manufacturer. For example, Enphase, SMA America, and SolarEdge's microinverter systems all gather data via PLC from the module-mounted electronics, while ABB/Power-One microinverters transmit data wirelessly to a gateway device.

The **Enphase** Envoy gateway collects microinverter performance data using PLC. A cable transmits data to the router, or an adapter that comes with the Envoy unit can enable a wireless option. The Envoy unit—which requires an AC power source—transmits data to the free Enlighten Web portal. Enphase recommends installing a dedicated circuit for the Envoy power supply outlet so that RF interference doesn't disrupt data communication with the microinverters.

SolarEdge data is collected from MLPEs by the inverter (there is no separate gateway device to install as it is integrated into the inverter). The data is transmitted via cable or wireless to the router, and sent on to the free SolarEdge PV Monitoring Portal. Their portal can also be accessed from smartphones or tablets.

SMA America's Sunny Boy 240-US microinverters require one SMA Multigate-US device for every 12 microinverters. The Multigate-US gathers inverter data via PLC, and is installed prior to the point of interconnection (for example, prior to the back-fed AC breaker), and feeds the microinverters' AC output power collectively into the grid. It filters radio frequency from the power line to avoid data interference. The Multigate is hardwired (no built-in WiFi), but a wireless bridge could be installed to avoid a long cable run. PV system data is transmitted from the site router to the free Sunny Portal. There is a smartphone and tablet app available as well.

Up to 30 **ABB** (Power-One) MICRO inverters can be wirelessly monitored by one CDD gateway device, which requires an AC power source. The CDD gateway is required for commissioning the microinverters, and it wirelessly transmits data via a site router to the ABB Aurora Vision Web portal, provided free of charge and available on mobile devices as well. For both SMA America and ABB microinverters, the gateway device is a required system component and enables system monitoring, thus any installed system comes complete with a data monitoring package.

Resources

Inverter Web Portals & Manufacturer Websites

(publicly available portals linked where available)

ABB Aurora Vision • auroravision.net

Enphase Enlighten • bit.ly/EnphasePublic

Fronius solar.web • solarweb.com

Kaco blueplanet • kaco-newenergy.com

Schneider Electric Conext • solar.schneider-electric.com

SMA America Sunny Portal • bit.ly/SMApublic

SolarEdge • bit.ly/SolaredgePublic

Solectria SolrenView • solrenview.com

Third-Party Monitoring

Deck Monitoring • deckmonitoring.com

Draker • drakerenergy.com

eGauge • egauge.net

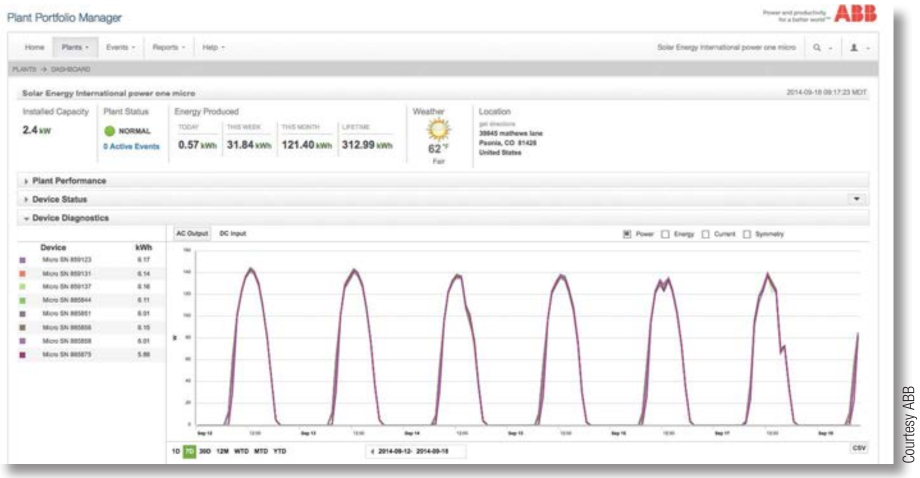
Locus Energy • locusenergy.com

Solar-Log • solar-log.net

Brian Mehalic

The SolarEdge mobile app (left) allows monitoring system performance from almost anywhere. Most portals also provide email alerts.

ABB's Aurora Vision Web portal (below) displays data from each microinverter. The eight inverters in this system appear as overlapping lines on the graph—each inverter's production has been nearly identical for the week shown, indicating that the system is performing well.



Courtesy ABB

Third-Party Monitoring

Third-party monitoring providers, such as Deck Monitoring (now part of AlsoEnergy), Draker, eGauge, Locus Energy, and Solar-Log, offer options to monitor common inverters for systems small or large. For multiple systems monitoring, as an installer might need, choosing a third-party monitoring system means that different inverter brands can be monitored from the same Web portal, potentially saving time and making the installation and programming learning curve less steep. Hardware costs can range from hundreds to many thousands of dollars, depending on the PV system's size and data granularity desired. For smaller PV systems (less than 10 kW and up to 30 kW), third-party Web portal access may be free.

Deck Monitoring, Locus Energy, and Solar-Log all offer a residential revenue-grade energy meter with a cellular uplink, so no on-site Internet connection is necessary. The meter has inputs for direct communication with inverters and transmits data to the third-party's hosted and customized Web portal.

eGauge and Solar-Log offer options for monitoring building energy consumption and PV production. The eGauge power meter can monitor up to 12 electrical circuits, and a building's total electrical consumption, solar generation, and load consumption. With its built-in server, the data can be viewed by any browser. Data is updated as quickly as every second, and the device can record up to 30 years of data in its built-in memory.

Solar-Log's 300 model can monitor multiple inverters up to 15 kW. Small appliances can be monitored individually with networked "smart-plug" devices, and two optional external electric meters can add metering capacity. A wireless model is available for connecting the Solar-Log to a WiFi network and the Solar-Log WEB portal provides basic monitoring free for systems 30 kW or less.

web extras

"Module-Level Performance" by Dan Lepinski in *HP162* • **homepower.com/162.66**

"PV String Inverters—A Buyer's Guide" by Justine Sanchez in *HP160* • **homepower.com/160.32**

"Tracking Your Energy Use With Home Monitoring Systems " by Erika Weliczko in *HP153* • homepower.com/153.68

Grid-Tied PV

For $1.25 Per Watt

by Willi W. Hampel

Amy Joan Hampel

A build-it-yourself, adjustable ground-mounted rack and DIY installation provided deep savings on a PV system for this Wisconsin family.

In 2006, I refurbished a classic Jacobs Wind Electric wind turbine and installed it on our family's property in Merton, Wisconsin. The "Jake" produces an average of 110 kWh per month, offsetting about one-third of our household's total electricity use on a yearly basis. However, in the summer months, when winds average 8 mph, the Jake was only generating about 40 kWh per month. That's when I started thinking about installing a PV system to boost our renewable energy production.

In 2011, the prices of PV modules were continuing to drop. I began researching system components, incentives, and permitting requirements. I set an aggressive goal of designing and self-installing an adjustable, ground-mounted PV system for $1 per watt (after incentives), and began my PV project in earnest.

Choosing a Site, Capturing Incentives

A rooftop array was ruled out for several reasons. First, there was the shade caused by a 70-foot-tall tree near the west side of the house, which severely limited the available solar window. But we were loath to cut it down—the summer shade it provides helps reduce our air-conditioning loads. The largest roof sections face east and west, and while not a deal-breaker, orienting the array to meet Wisconsin's Focus on Energy (FoE) program rebate requirements, which states that modules must be installed within 45° of due south, would have meant mounting them in an aesthetically unpleasing way.

Fortunately, although trees border our property, there was still plenty of room on our 1.3 acres to find a suitable solar window for a ground-mounted system and meet the town's minimum 20-foot setback requirements (see "Finding True South" sidebar). The window wasn't "perfect"—my analysis showed that some shading of the array would occur in December and January from maple trees that lie just outside of our south property line—but that energy loss could be offset by adjusting the array's tilt monthly (see "Optimizing the System").

Once we'd determined that there was a good solar window, we examined our electricity loads (see "Electrical Loads" table) to arrive at a reasonable PV system size. According to our utility bills, our household consumes an average of 321.5 kWh of electricity per month, or 3,858 kWh per year, which costs us about $630. (We use natural gas for our forced-air furnace, water heater, oven, and cooktop. We also have two wood heaters, both of which are used often in the winter.) But besides meeting our existing electrical loads, we also wanted the system to generate enough electricity to recharge a plug-in hybrid vehicle or electric vehicle in the future.

Wisconsin's FoE program offered a cash-back rebate (up to $2,400) for grid-tied PV systems, and we could also take the 30% federal tax credit. Balancing these economic and energy goals, I arrived at a 6.1 kW system, which would max out the FoE rebate and provide extra electricity for an EV. This system size would also maximize the inverter's energy-conversion efficiency and stay within the weight parameters of the wooden rack structure I had in mind.

On January 2, 2013, I applied for Wisconsin's FoE Renewable Rewards program. To be eligible for the program, I had to retain the services of a PV installer to oversee and sign off on the installation. I hired Trang Donovan, who provided me with design reviews, recommendations, and a final system inspection for compliance to the *National Electrical Code*.

Solar energy systems are eligible for a federal tax credit of 30% of the system cost, with no upper limit, until December 31, 2016. I also applied for solar renewable energy credits (sRECs) through Ethos Renewable Power, which would pay $13 per megawatt-hour (MWh) generated.

After the Rewards program application was approved in February 2013, I began sourcing PV system components. The $1-per-watt goal was an aggressive cost target set to achieve a return on investment (ROI) of at least 18%.

Amy Joan Hampel

Courtesy Walter Hampel

Left: The author got his start with renewable energy by building wind turbines with his father. Now he shares wind and solar projects with his own son.

Electrical Loads

Item	kWh Per Month	% of Total
Refrigerator (older model)	100.0	31.1%
Lighting	50.0	15.6%
Central air conditioner	45.0	14.0%
Dehumidifier	40.0	12.4%
Gas furnace	35.0	10.9%
Washing machine	10.0	3.1%
Gas clothes dryer	10.0	3.1%
Computer	10.0	3.1%
Television & electronics	9.0	2.8%
Well pump	7.5	2.3%
Microwave oven	5.0	1.6%
Total	321.5	
Annual Total	3,858.0	

Optimizing the System

I implemented several strategies to make the most of every solar-generated electron at my site.

Adjustable, ground-mounted rack. Although mounting the PV array at a fixed tilt is the most straightforward strategy (and the least amount of work, since you don't have to adjust the rack), it incurs energy penalties. The sun changes its angle from the horizon, being higher in summer than winter, so annual energy output can be increased by seasonally adjusting module tilt. From the sun-path chart I generated (bit.ly/UOsuncharts), I determined an array tilt to maximize the system's energy output for each month. I'd need to be able to adjust the array tilt from a minimum of 19.6° in June to a maximum of 66.5° in December. Over the course of a year, I calculated that the


Amy Joan Hampel

Finding True South

In most cases, modules should point due south to maximize their energy output. I used the solar noon method—the sun is always due south at solar noon and, at this time, a shadow cast by any vertical object (like a plumb-bob string) will run true north/south.

To determine the local time that corresponds to solar noon, find the sunrise and sunset times from a local paper or the Internet. Solar noon is exactly halfway between sunrise and sunset. It's easy to use the National Oceanic and Atmospheric Administration's calculator to find solar noon for your location (bit.ly/NOAASolarCalc). A free solar app, such as SolarCalc or Sun Seeker Lite, can also be used to display solar noon at your location.

You can check the layout with a magnetic compass. The compass reading must be corrected for the magnetic declination, the difference between the direction the compass needle points and true north in your area. The NOAA website also shows the declination.

Left: The author and his son set up a plumb line. At solar noon, its shadow will run exactly north/south.

monthly tilt adjustment would yield about 4.6% more energy compared to a fixed array (see "Estimated Production" table).

In snowy regions like Wisconsin, a steeply tilted array sheds snow more quickly, which is important for maximizing the system's overall production. Following a 4-inch snowstorm, for example, our steeply tilted array is snow-free the following sunny day, while I've observed that it can take more than a week for the snow to melt from a fixed-tilt, ground-mounted PV array that's on a church property 1.5 miles away.

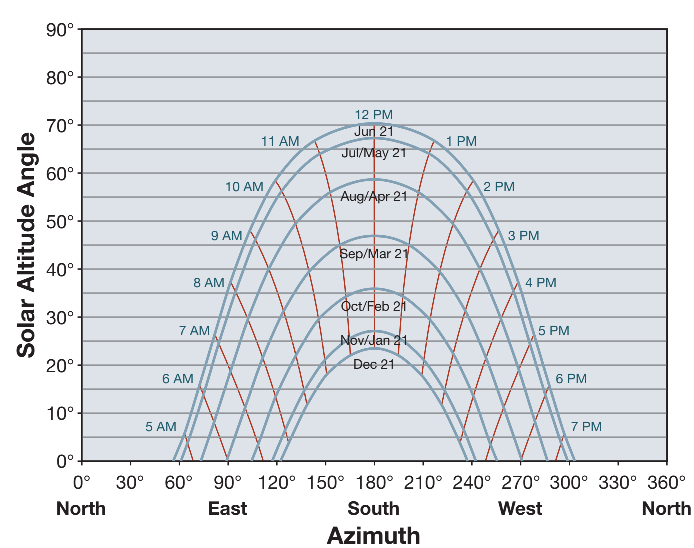
In the summer, a ground-mounted system has better airflow around the array, which means lower module-cell temperatures and higher energy production compared to a similarly sized roof-mounted system. Since PV modules have a negative temperature coefficient, keeping them cooler increases their power output. For example, my modules have a temperature coefficient of -0.41% per degree Celsius (i.e., for every degree above 25°C, the PV modules' power output is derated by 0.41%). Roof-mounted PV modules typically run 25°C or more above ambient temperature, while ground-mounted modules typically run slightly cooler (i.e., my estimate is 22°C above ambient). The annual average high temperature for my region is 13.5°C. For a roof-mounted system, the production hit due to heat would be 338 W [6,100 W × -0.41%/°C × (13.5°C + 25°C) - 25°C]. With a ground-mounted array, the average power decrease would be 263 W [6,100 W × -0.41%/°C × (13.5°C + 22°C) - 25°C]. So in my case, a ground-mounted PV system results in 75 W (338 W – 263 W) more power output per peak sun-hour of operation. This translates into an additional 124 kWh per year (4.52 sun-hours/day × 0.075 kW × 365 days/yr.).

Estimated Production Adjustable vs. Fixed Tilt

Month	Adj. Tilt	Adj. Tilt Production (kWh)	Fixed Tilt Production at 43.1° (kWh)	Production Increase (Adj. vs. Fixed)	Additional Earnings*
January	63.1°	528	497	5.9%	$4.22
February	54.1°	632	616	2.5%	2.18
March	43.1°	771	771	0.0%	0.00
April	31.4°	872	853	2.2%	2.59
May	22.8°	851	789	7.3%	8.44
June	19.6°	918	829	9.7%	12.12
July	22.8°	916	842	8.1%	10.08
August	31.4°	818	788	3.7%	4.09
September	43.1°	795	795	0.0%	0.00
October	54.1°	602	599	0.5%	0.41
November	63.1°	526	502	4.6%	3.27
December	66.5°	448	417	6.9%	4.22
Yearly Totals		8,677	8,298	4.6%	$51.62

Assumptions: 13.2% system losses; 96.5% inverter efficiency; 1.016 DC to AC ratio.
*Earnings calculated at $0.136207 per kWh.

Sun Paths for Merton, Wisconsin



Array tilt angle is perpendicular to peak sun angle.

Amy Joan Hampel (2)

The 6.1 kW array of Helios Solar Works PV modules (above) was sized to maximize the Wisconsin rebate and match the ideal voltage for peak efficiency from the Power-One Aurora 6000 inverter (right).

No batteries, a high-efficiency inverter, and high-wattage modules. I chose a batteryless grid-tied system for several reasons:

- It minimizes system cost (batteries are expensive);
- It increases overall system efficiency (batteries and charge controller inefficiencies reduce the system efficiency by 5% to 10%);
- Our utility's electricity delivery is very reliable, so battery backup would rarely be needed.

There are many batteryless grid-tied inverter choices, but since I was already satisfied with the Power-One 4.2 kW Aurora transformerless inverter used with my Jake, I decided on an Aurora (Power-One) 6 kW inverter for our PV system. The 6 kW inverter can process two PV strings with independent maximum power point tracking, and has a CEC-rated efficiency of 96.5%.

I chose Helios Solar Works 7T2 (305 W) modules for several reasons. First, I wanted to keep my hard-earned dollars in the United States, and these modules were manufactured in Milwaukee—close to home. I could rent a trailer for $20 and drive to the Helios Solar Works factory (a mere 25 minutes away) to pick up the 20 PV modules, saving significantly on shipping costs. Second, putting 10 of the PV modules in series hit the Aurora 6 kW inverter's voltage "sweet spot." And, third, dimensionally, these modules allowed for a reasonable rack wooden header length that would minimize module deflections caused by wind and snow loading.

Maximizing PV output. The voltage of PV modules in series is additive, but the string's current is limited by the lowest module current (Imp)—so it is best to place all the modules with the highest Imp in the same string. Using the manufacturer-provided data measured for each module, I methodically went through the list to select modules to string together. This allowed each series array to perform within 0.3% to 0.4% of their theoretical maximum power output.

Tech Specs

Overview

Project name: Hampel residence

System type: Batteryless, grid-tied solar-electric

Installer: Self-installed

Date Commissioned: July 2013

Location: Merton, Wisconsin

Latitude: 43.1°N

Solar resource: 4.52 average daily peak sun-hours

ASHRAE lowest expected temperature: -11.2°F

Average high temperature (ASHRAE 2% design temp.): 89.6°F

Average monthly production: 718 AC kWh

Utility electricity offset annually: 223%

PV System Components

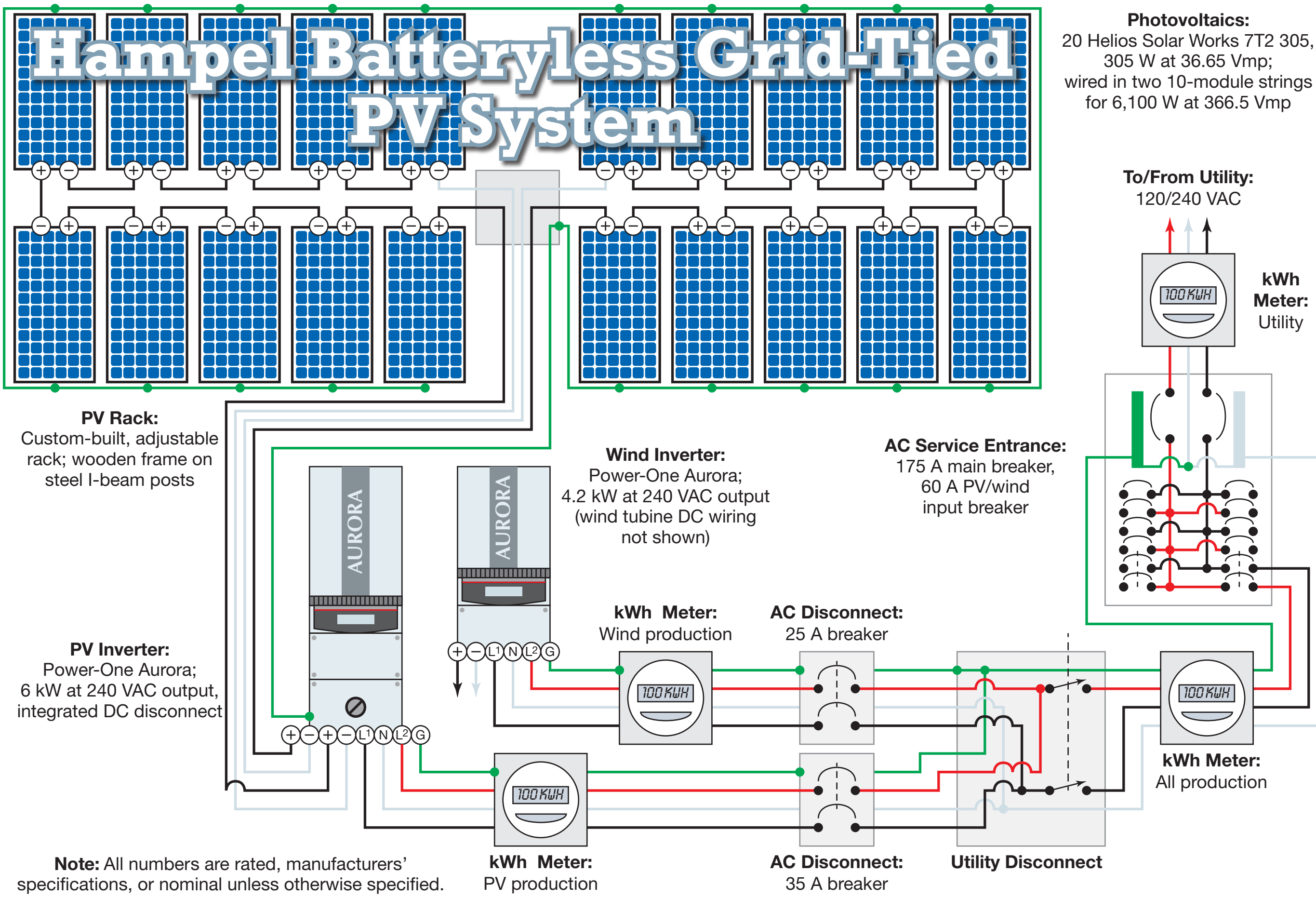
Modules: 20 Helios Solar 7T2 305, 305 W STC, 36.65 Vmp, 8.32 Imp, 45.10 Voc, 8.86 Isc

Array: Two 10-module series strings, 6,100 W STC total, 366.5 Vmp, 8.32 Imp, 451 Voc, 8.86 Isc

Array installation: Custom-designed, south-facing ground-mount rack; 19.6° to 66.5° adjustable tilt

Inverter: Power-One Aurora PVI-6000-OUTD-US, 6 kW rated output, 600 VDC maximum input, 140–580 VDC MPPT operating range, 240 VAC output

System performance metering: Hialeah MTR FM 02S 240V 3 WIRE CL200 kilowatt-hour meter



Minimizing electrical losses. Properly sizing PV electrical conductors can decrease power loss from voltage drop. Generally, the total DC voltage drop should be less than 2%. I used #10 copper PV wire in the PV output circuit, which results in only a 0.7% loss. A tolerable AC voltage drop (inverter output circuit) is between 1% and 1.5% for grid-tied systems. For the inverter's maximum output of 25 amps, the AC voltage drop was 0.7% using #2 AWG aluminum wire.

Build-It-Yourself Rack

I knew I could economize and improve my system's return on investment by building a custom rack structure using locally available, relatively inexpensive lumber and readily available metal components. Had I purchased a manufactured ground-mount rack, I would not have had any chance of achieving my $1-per-watt goal. The most similar manufactured option was a metal rack (about $4,892, with shipping). Besides being more than twice the cost of a home-built rack, this rack would have been much bigger (46 lineal feet versus 33), subjecting the array to more shade because of its length, and was not as adjustable, as it only went to 50°—I wanted my rack to tilt to 66.5°.

The most complex part of the custom-rack design process was calculating loads (see "Design Loads" sidebar). I also needed to create a simple yet durable tilt method that would accommodate some design imperfections, since nothing would be dimensionally "perfect." Pillow blocks—bearings used to provide support while allowing rotation—used with 2-inch-diameter, schedule-40 pipes, would allow each of the roughly 1,500-pound rack assemblies to be adjusted. The additional cost for this method was $360; it will likely be recovered in about seven years when assuming the additional 4.6% output that results from being able to adjust the array monthly. During the array's expected 25-year lifetime, the tilting feature has an ROI of 14.3%—well worth the extra design effort and expense.

The racks that hold the PV modules each consist of two 2-by-12 headers mounted onto a 2-inch-diameter pivot pipe. Six 2-by-12 joists sit on joist hangers between the headers,

Amy Joan Hampel

Once the footing locations were laid out, a post-hole digger with an 18-inch-diameter auger drilled the three holes for the I-beam footings.

and were glued and screwed together. Eight 1-by-4 stiffeners were glued and screwed to the joists. Joints were sealed and the counter-bored lag screws were topped with silicone caulk before the entire rack was coated with deck stain to protect it from degradation.

The support structure had to be robust to support the two wooden racks. The horizontal force of the wind on the center I-beam support was calculated to be 3,470 pounds. A 4-by-8 inch I-beam made from ASTM A992/A572 (grade 50) steel provided a two-to-one safety factor. The 18-inch-wide, 4-foot-deep concrete footings were also designed to handle this wind loading with sufficient margin, and were excavated below the 4-foot frost line to ensure that the structure would not shift from freezing and thawing. Rebar in the bored holes increased the loading capability.

Both wooden racks were pre-assembled to ensure proper fit, then taken apart for assembly on the tilt structure. Before mounting the PV modules, a strip of aluminum-foil tape was bonded to the top of each 1-by-4 stiffener. Each module was mounted to the wood frame using 5/16 stainless steel hardware through four of the specified module mounting holes. Modules were spaced 1/4 inch apart. A #6 bare, stranded copper wire serves as an equipment-grounding

Amy Joan Hampel

Top: With the help of friends, levels, ladders, stakes, and 2-by-4 supports, the I-beams were centered in the footing holes and leveled.

Courtesy Edward Castillo

Right: The two pivot pipe/pillow block assemblies were set up beforehand to their correct lengths and then used as fixtures to properly space the I-beams.

Below: The finished rack assembly, ready for paint before the modules are mounted.

Amy Joan Hampel

Design Loads

I used the 2012 *International Building Code (IBC)*'s guidelines for design loads, and used the worst-case snow load for Waukesha County of 30 pounds per square foot—approximately 18 inches of wet snow. Since each tiltable 10-panel array section has an area of 211.56 square feet, the vertical snow-load force would be 6,347 pounds (211.56 ft.^{2} × 30 lbs./ft.^{2}). However, this loading is highly unlikely since the modules will be tilted greater than 43° in the winter months.

The *IBC* contains multiple references to the American Society of Civil Engineers' *Minimum Design Loads for Buildings and Other Structures (ASCE 7-10)*. It says the wind speed that the array's support structure should withstand in Wisconsin is 105 mph. In more than eight years of anemometer data at 110 feet up the Jake turbine's tower, the maximum recorded was 70 mph. The calculated worst-case wind pressure against each tiltable array is 23.2 pounds per square foot. Therefore, the worst-case wind loading on the rack structure is 4,908 pounds (211.56 ft.^{2} × 23.2 lbs./ft.^{2}). The final load on the rack structure is the weight of the modules themselves—572 pounds per array.

To ensure that the critical joints (where the 2-by-12 joists met the 2-by-12 headers) survive the worst-case loading, each joint was connected with four 3/8-inch-diameter by 5-inch-long counter-bored lag screws; one 2-by-12 triple-zinc steel-face mount joist hanger; four #9 by 2 1/2-inch-long strong-drive SD screws through the joist hanger; and all-purpose wood glue.

web extra

Check out how Willi arrived at his design-load calculations at **homepower.com/164.38**.

Amy Joan Hampel (2)

Modules were positioned accurately before the mounting-hole locations were transfer-marked onto 1-by-4 wooden stiffeners and mounting holes were drilled. Stainless steel hardware was used to secure the modules to the wooden frame.

Each rack's tilt angle is adjusted via a set of metal arms. This tilt feature enables the array to produce 4.6% more energy on an annual basis.

conductor (EGC); each module was connected to the EGC with a WEEB ground lug. The 10 modules in each string were connected in series using their MC4 quick-connect plugs.

The inverter was installed in the existing wind turbine inverter shed. The shed already had 240 VAC and a subpanel with a spare circuit breaker location. Mounting the inverter in the shed gave a short PV output circuit cable run (approx. 58 ft.) and protection from the weather, animals, and vandalism.

Economics & Performance

My original target for the PV system was $6,100 (or $1 per watt), after incentives. The final cost came in at $7,661 (or $1.25/watt)—not too far off-target. The tilting feature has been working flawlessly. Adjusting the two arrays takes less than five minutes; I actually look forward to it, as I know tilting increases our PV array's monthly electrical output. Our grid-tied system is net-metered with a monthly true-up. Rather than paying electric bills, we are now receiving

PV System Costs

Description	Cost	% of Total
20 Helios Solar Works PV modules	$5,530	38.5%
Power-One 6 kW inverter	2,113	14.7%
Other (travel, equipment rental, misc.)	2,039	14.2%
Rack parts (home-built)	1,954	13.6%
Balance of system	1,253	8.7%
Permits	740	5.1%
Labor (food for volunteers)	555	3.9%
Consultation/inspection fee	190	1.3%
Total	$14,373	
30% Federal tax credit	-4,312	
WI Focus On Energy incentive	-2,400	
Net Cost	$7,661	

PV System Performance

Month	Performance (kWh) PVWatts Predicted*	Actual Measured
July	916	911
August	818	883
September	795	771
October	602	654
November	526	449
December	448	402
January	528	467
February	632	760
March	771	831
April	872	741
May	851	901
June	918	848
Totals	8,677	8,618

*See the table on page 40 for system assumptions.

Amy Joan Hampel (2)

Willi's engineering background enabled him to design a custom tiltable rack for his family's PV array, saving them money upfront and reducing the system's payback period.

In its first year of operation, the PV system has produced within 1% of the original estimates.

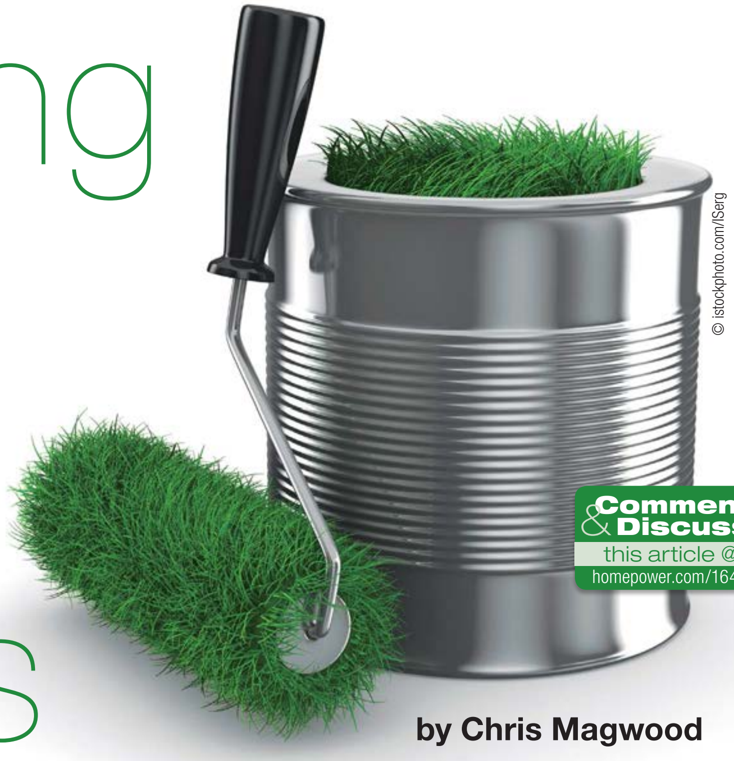
Component Manufacturers

Inverter: Power-One • power-one.com

PV modules: Helios Solar Works (no longer in business)

monthly checks from the utility. In its first full 12 months, our grid-tied PV system generated 8,618 kWh—within 1% of that predicted by PVWatts. In that time, the system has earned \$1,286 [(\$0.136207/kWh × 8,618 kWh) + \$13/MWh × 8.618 MWh)] worth of electricity, resulting in a system payback of about six years. Under our grandfathered net-metering agreement with the utility, we are paid at the residential retail electricity rate for any surplus electricity that our PV system produces each month. If the earned credit for our PV-produced electricity is less than \$25, it is carried over to the next bill. So far, though, we've been receiving monthly checks from the utility.

Assessing Green Building Materials



Comment & Discuss this article @ homepower.com/164.46

by Chris Magwood

The notion of "building green" has become mainstream in recent decades, thanks to the efforts of a small number of builders on the fringe of the building industry.

But in the rush to jump on the green bandwagon, not much time gets spent considering what it means to create a more sustainable building. Some think a label declaring a material to be "green" is all that is required—but figuring out how to make a measurable difference in our environmental impact takes a bit more effort.

The Tools to Do It Right

With almost everyone selling some version of green, it is up to each homeowner and builder to do the research to make better choices. That research must go beyond the product sales sheet to examine how the product is made. Here are some common-sense factors to apply to decisions.

High-performance doesn't necessarily equate to "green"—for example, petroleum products, such as foam insulation, have high embodied energy and major impacts on ecosystems.

Concrete has advantageous building and thermal properties, but is high in embodied energy and very high in carbon dioxide emissions.

Petroleum

Products made from petrochemicals have a large ecological footprint. Regardless of any "green" marketing, crude oil is responsible for vast amounts of ecological damage—and all petrochemical products bear a share of that harm. And most petrochemical products will persist in the environment long after their useful life as building materials.

Example: Foam insulation carries a dire environmental footprint in its manufacturing, and in its use and eventual disposal.

Heat

Products manufactured using high quantities of heat have large environmental impacts. They consume a lot of fuel and create a lot of pollution in the process. The greater the amount of heat required, the greater the impacts.

Example: Portland cement requires heating limestone to 1,100°F in the calcining process, and then to 2,640°F to sinter the material.

Manufacturing

The more complex the manufacturing process, the more impacts the product is likely to have. Natural materials, such as straw bales, which require little or no modification prior to use, are likely to have fewer impacts.

Example: Cereal straw is cut in the field during the harvesting process and compressed in a simple mechanical baler.

Toxins

Products that contain toxic ingredients are unhealthy. Many products that offgas toxins are commonly used in buildings. At best, any toxic ingredients in a product are deemed to be "stable" in their final form. But those toxic ingredients have effects and impacts in the manufacturing process and to construction workers that predate their "stable" form—and are likely to have effects after their useful life in the building.

Example: Even low-VOC paints and stains contain a wide range of chemicals that are toxic during manufacturing and in the home, including glycol ethers, formaldehyde, biocides, amines, monomers, acrylic polymer latex, titanium dioxide, ammonium hydroxide, benzisothiazoline, methylisothiazolin, benzene, and toluene.

© istockphoto.com/anandoart

Straw bales are an agricultural "waste" product, with low embodied energy and good thermal performance.

Lumber is a renewable resource, albeit slow to regenerate. Its embodied energy depends on the distance between origin and use.

© istockphoto.com/Emily Norton

Forest products may travel long distances between their material harvest and end use, which drives up their embodied energy.

© istockphoto.com/kozmoat98


Fiberglass Batt
© istockphoto.com/BSimplyCreativePhotography


Mineral Wool
© istockphoto.com/Marek Walica


Cellulose
© istockphoto.com/stocksnapper


Polyurethane Foam
© istockphoto.com/BanksPhotos

Comparing Materials

In the pursuit of energy efficiency, products that have negative impacts on the environment are too often given a green thumbs-up only because of energy savings. Nowhere is this more evident than with insulation products, where a myriad products make selection difficult. The table below examines some of the eco-considerations of insulation—and shows just how difficult it can be to weigh all of the parameters when you're building green.

Impacts & Attributes of Common Insulation Materials

Conventional Choices	R-Value (Per Inch)	Embodied Energy (MJ / kg)	Embodied CO_2 (kg / kg)
Fiberglass: Batts, rolls, or loose-fill made by melting & spinning glass into fine fibers	3.6 – 4.14	Very high: 28	Very high: 1.35
Mineral wool: Batts, rolls, or loose-fill made from melted & spun mining tailings	3.5 – 4.0	High: 16.6	Very high: 1.28
Cellulose: Shredded recycled newsprint mixed with borax fire retardant	3.6 – 3.8	Very low: 0.94	No source found
Polyurethane spray foam: Isocyanate & polyol resin mixed to become expanding, lightweight foam that hardens	5.5 – 6.5	Extremely high: 101.5	Very high: 3.48
Alternative Choices			
Cotton batts: Shredded recycled denim mixed with polyester fibers to form batts	3.7	Unknown	No source found
Hemp batts: Hemp fiber spun, often with a little polyester fiber	3.2 – 3.7	High to very high: 10.5 – 33	No source found
Cementitious foam: Magnesium oxide with calcium & silicate forms a low-expansion foam that hardens	2.6 – 4.1	Moderate: 3	No source found
Straw bales: Dried stalks from harvested grain plants	1.5 – 2	Very low: 0.24	Very low: 0.01
Hempcrete: Chopped hemp bound with lime, formed into blocks or stuffed into walls	1.5 – 2.5	Low: 2.0	No source found

Transportation

Products that travel long distances have larger environmental impacts because of fossil fuels used in their transport. The heavier the material and the longer the travel distance, the greater the impacts—especially for materials that are moved by trucks.

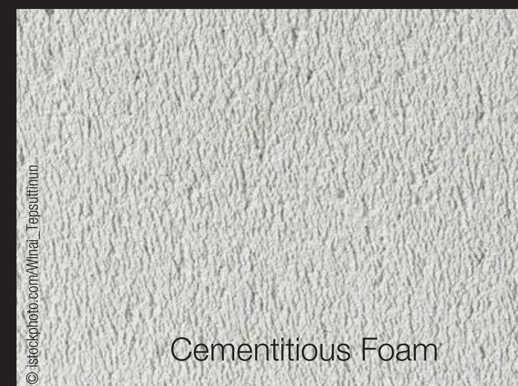
Example: Lumber is often shipped across the continent, and can sometimes double its travel distance as it makes its way from mills to distribution centers to retailers, resulting in high amounts of fuel used.

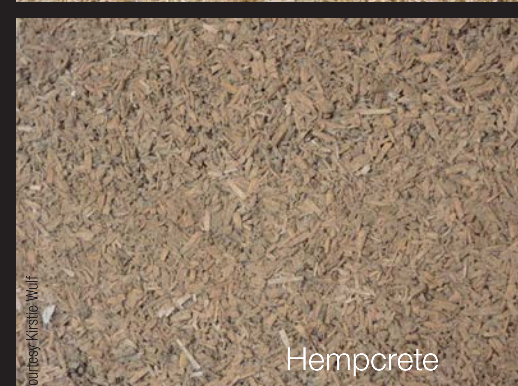
Planned Obsolescence

"Maintenance-free" often means that something will last for a specific length of time and then need to be replaced. Materials that require some maintenance can often be refurbished repeatedly over decades or even centuries, but most materials that require no maintenance cannot be repaired, and end up as landfill.

Example: Vinyl siding is often touted as being maintenance-free, but cracks, splits, and warping cannot be repaired. Within a couple of decades, entire vinyl siding installations will need to be replaced.

Toxicity	Installation	Recycled Content & Recyclability	Production & Biodegradability
Formaldehyde offgases; particles dangerous to lungs	Poorly installed batts compromise performance	Most do not use recycled content; offcuts landfilled	Not biodegradable
Formaldehyde offgases; particles dangerous to lungs	Poorly installed batts compromise performance	Offcuts landfilled; no recycling programs; from leftover mining slag	Not biodegradable
Borax can be a skin & respiratory irritant	Dust levels can be dangerous for installers & leave residue	Typically 100% newsprint	Biodegradable at end of life
Petrochemicals have typical crude oil extraction & processing pollution	Isocyanates & other chemicals cause respiratory, skin & eye problems; spray foam offers consistent performance	Most have no recycled content	Blowing agents major greenhouse gases; not biodegradable; removal or reuse of building components is difficult
None	Particulates not carcinogenic. Poor installation compromises performance	Recycled clothing scraps; polyester fiber in mix prevents easy recycling	Cotton typically not organic
None	Poorly installed batts compromises performance	Polyester fiber prevents easy recycling	Renewable ag resource; low soil & water impacts; polyester prevents biodegrading
None	Spray-in likely to result in consistent thermal performance	Can be crushed into harmless sand at end of life	Mining process has soil & water impacts
None	Continuous bales likely to result in consistent thermal performance	Completely biodegradable	Monocrop ag impacts on soil & water; renewable ag resource
None	Installation likely to result in consistent thermal performance	Biodegradable	Lime harvest has soil & water impact; low-impact & renewable ag product





Complexity

Complexity in a product, assembly, or system often leads to malfunction, breakdown, and waste. When parts of a complex building fail, it can lead to cascading problems. Simpler systems that rely on time-tested principles tend to be more long-lived.

Example: Basement foundations in wet areas often rely on automated sump pumps, which have several components that can wear or fail and rely on a continuous electricity supply to function. When they do fail, flooring, walls, insulation, and mechanical devices in these spaces can be ruined. On-grade foundations keep all these elements well above the water line and don't need any mechanical devices to stay dry.

Labor

Using human labor is more sustainable than machine-made or machine-installed. Both environmentally and economically, craftsperson work is the least impactful.

Example: Plasterers using local ingredients in a wet plaster system can have dramatically lower impacts than drywall, tape, and "mud" manufactured and shipped from a central factory.

Ben Root

Often, it's the final energy performance of the structure that dominates its classification as being "green." But this is only one aspect of an ecofriendlier building.

Overall Design

People make the buildings—the materials are only a part. A building is a manifestation of human ingenuity and relationships. It takes the right people to make a building that approaches sustainability, and finding them is equally important to material choices.

Example: Straw-bale walls built poorly by an inexperienced builder can have greater compromised energy efficiency than well-built stud-framed and conventionally insulated walls.

If a product claim sounds too good to be true, it probably is. There is no perfect building material. If a material scores lots of "green" points in one or two areas, it probably has drawbacks in others. Find out both the pluses and minuses before making a decision.

Find trustworthy sources to help your decisions. Third-party certification (especially those overseen by boards that aren't dominated by industry representatives) is a good way to ascertain a product's environmental claims.

Beautiful buildings tend to receive care and maintenance, and last a long time. If nobody cares about a building, even if it scores lots of sustainable points for its material selection, it is more likely to have a short lifespan. Create something that future generations will appreciate, and they will shepherd it through time.

Setting Sustainable Goals

Greenwashing—where environmentally harmful products and materials are marketed as being green—is a large barrier to reducing our impact. Without considering the entire life cycle of the elements in our buildings, we cannot know if we are minimizing our impacts.

Homeowners or builders must first establish their environmental goals, and then consider materials that perform well without undermining overall environmental performance. Environmental merit can be judged in three categories:

Low overall energy consumption in the finished building. This may be the most comprehensive way to judge the "greenness" of a material or system. Energy Star, EnerGuide, and a host of energy modeling software programs can be used to compare energy impacts of materials and systems.

Reduced toxics or environmental impacts. Using recycled material, reducing embodied energy, responsibly harvesting and producing, durability, and reducing or eliminating waste are all included in this metric. The Inventory of Carbon & Energy (download at bit.ly/ICEdwnld) is a free database for comparing embodied energy of materials. Free software programs like the Athena Institute's Life Cycle Assessment (athenasmi.org) can help with understanding environmental impacts over a material's life span.

Creation of a nontoxic interior environment. Clean air and water; proper humidity and ventilation; access to natural light; comfortable interior temperatures; and reducing or eliminating radon are included. Greenguard (greenguard.org) is a reliable third-party rating system for a product's impact on indoor air quality; the Pharos Project database (pharosproject.net) has in-depth information on chemicals in building materials.

These three areas constitute a building's life-cycle analysis. Ideally, for each product, materials research follows the path of all materials and systems—from harvesting raw ingredients to manufacture, transport, and use, to waste and disposal issues.

Per ton-mile, ships use only 1.3% of the fuel consumed by trucks. However, goods are usually transported over longer distances, resulting in high embodied energy.

© istockphoto.com/GBlakeley

Trains use only 0.8% of the fuel used by trucks to move freight; shipping by train significantly reduces a product's embodied energy due to transportation.

© istockphoto.com/Zview

Transportation Impacts

An average house uses about 175 tons of materials, so transportation impacts can be a high proportion of the building's total embodied energy. The distance materials must travel to reach your building site, the weight of those materials, and the mode(s) of transportation all impact a material's embodied energy and "greenness." The U.S. Department of Energy estimated the following for freight transportation in 2006:

Trucks: 4,074 Btu (0.3 gal. diesel fuel) per ton-mile

Rail: 330 Btu (0.0025 gal. diesel fuel) per ton-mile

Ship: 571 Btu (0.004 gal. diesel fuel) per ton-mile

The raw materials for construction products are often close to the point of manufacturing, but distances to point-of-use can be quite long. If your project needs 1 ton of insulation material, as little as 30 gallons of diesel fuel might be consumed if you are 100 miles from the manufacturer—or as many as 900 gallons of diesel might be used if the material has to cross the entire country to reach you.

Materials that travel by rail or sea have lower impacts per travel mile, but tend to cover long distances. For example, 1 ton of insulation coming from China may travel upward of 6,000 miles and use as little as 24 gallons of diesel fuel. However, that insulation must travel from a sea freight terminal to its final destination—which may be hundreds or thousands of miles away by truck. Only thorough research can give you an accurate sense of the transportation impacts.

Comparing Like to Like

Once choices are narrowed to a particular product or system, there can still be major impacts based on brand or supplier. Consider lumber products: While embodied energy and life-cycle figures are similar for all trees, the specifics of how and where they were harvested and processed can reveal a wide range of impacts. Poor cutting practices can be devastating to local ecosystems, destroying wildlife habitat, encouraging soil erosion, and negatively affecting waterways. Milling operations can be major polluters of air and water, and transporting lumber over long distances consumes vast amounts of fossil fuels.

Third-party certification programs for lumber can help you determine if forestry practices are in place to minimize impacts. If you buy uncertified wood, you have no idea where that wood is being harvested, what forestry practices are in place, and whether or not it was milled appropriately. Here are some tips for selecting "greener" lumber.

Keep it local. If possible, visit the harvest site and the sawmill. Many small mills cannot afford to be certified "sustainable" by a third party, but still use very sustainable practices.

The Forest Stewardship Council (FSC) provides third-party certification of sustainable harvesting and processing of wood products. Lumber with an FSC certification is an indication that environmental impacts may be reasonable.

When available, natural building materials, sourced and processed locally, are often the best bet for "green" solutions.

© istockphoto.com/PenelopeB

The Sustainable Forestry Initiative (SFI) is an industry organization founded as a response to the FSC. While they have made efforts to distance themselves from direct ties to the industry by diversifying their board, the lumber industry is still a central player. They have recently worked to be seen as a legitimate certification and have improved their standards to be similar to FSC.

Industry Pathways

The building industry is at an interesting junction. While most people realize that the status quo is becoming less viable, there is no consensus about what strategies and materials will lead the way.

New products are entering the market daily, all trying to improve upon the mix of environmental performance, affordability, durability, and ease of installation. None are perfect, but many are worth considering. Informed choices will go a long way to encouraging those with the highest environmental standards, helping to achieve buildings with high performance and low impact—and at an affordable cost.

web extras

"The Living Building Challenge" by Juliet Grable in *HP159* • **homepower.com/159.52**

"High Performance Walls" by Scott Gibson in *HP154* • **homepower.com/154.46**

"Green Framing Options" by David Johnston & Scott Gibson in *HP130* • **homepower.com/130.58**

"Forest-Friendly Lumber for Greener Building" by Erin Moore Bean in *HP120* • **homepower.com/120.84**

"The Path to Greener Buildings" by Andy Kerr in *HP135* • **homepower.com/135.62**

Statement of Ownership, Management, and Circulation. 1. Publication Title: HOME POWER 2. Publication #008-699. 3. Filing Date: 9/30/14. 4. Issue Frequency: Bimonthly. 5. No. of issues published annually: 6. 6. Annual Subscription Price: $14.95. 7. Mailing address of known office of publication: 312 N Main St, Phoenix OR 97535. 8. Mailing Address of Headquarters or General Business Office of Publisher: 312 N Main St, Phoenix OR 97535. 9. Names and addresses of Publisher, Editor, and Managing Editor: Publisher, Richard A. Perez & Karen L. Perez, PO Box 520, Ashland OR 97520; Editor, Joe Schwartz, PO Box 520, Ashland OR 97520; Managing Editor, Claire Anderson, PO Box 520, Ashland OR 97520. 10. Owner: Home Power Inc, Ashland OR 97520; Richard & Karen Perez, Ashland OR 97520; Joe Schwartz, Phoenix OR 97535; Dale & Marilyn Hodges, Medford OR 97501, Scott & Stephanie Sayles, McMinnville OR 97128. 11. Known bondholders, mortgagees, and other security holders owning or holding 1% or more of total amount of bonds, mortgages, or other securities: None. 12. Tax Status: Has not changed during preceding 12 months. 13. Publication Title: HOME POWER. 14. Issue date for circulation data: 9/1/14.

15. Extent and Nature of Circulation:	Avg no. of copies of each issue during preceding 12 months	No. of copies of single issue published nearest to filing date
a. Total No. of Copies	32,876	22,605
b. Paid Circulation		
1) Mailed Outside-County Paid Subscriptions	19,371	18,489
2) Mailed In-County Paid Subscriptions	0	0
3) Paid Distribution Outside the Mail Including Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Non-USPS Paid Distribution	6,481	1,547
4) Paid Distribution by Other Classes of Mail Through the USPS	0	0
c. Total Paid Distribution	25,852	20,036
d. Free or Nominal Rate Distribution		
1) Outside-County	374	364
2) In-County	0	0
3) Other Classes Mailed Through the USPS	0	0
4) Distribution Outside the Mail	1,229	1,231
e. Total Free or Nominal Rate Distribution	1,604	1,595
f. Total Distribution	27,456	21,631
g. Copies Not Distributed	5,420	974
h. Total	32,876	22,605
i. Percent Paid	94.06%	92.63%

17. This statement of ownership will be printed in the November/December 2014 issue of this publication.

18. I certify that the statements made by me above are true and complete. Scott M. Russell, Operations Director, 9/30/14.

Solar Water Heating

PART 3

Troubleshooting Valves

Story & photos by Chuck Marken

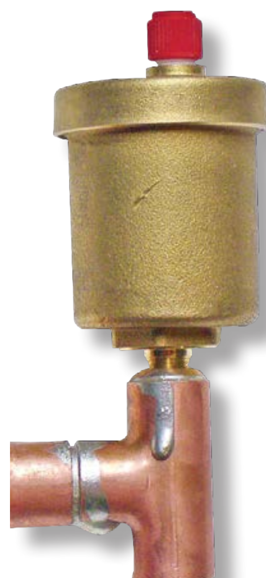
Solar water heating system not working? Check the valves—those simple levers that are ubiquitous in SWH systems.

SYMPTOM
Gurgling at the top of the collector piping.

Cause **Air-relief valves** are used in antifreeze systems to release air from the system. Air in pump impeller housings can stop fluid circulation, possibly causing the pressure-relief valve to open. Small amounts of air will normally gather at the topmost part of the system and air-relief valves are most effective when installed there. Manufacturers' instructions usually specify an automatic air relief that has a Schrader valve, which is similar to a tire valve.

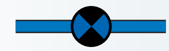
Solution The Schrader valve stem can be pressed to ascertain if air is present in the system—if fluid comes out, the air has been purged. A leaking automatic air-relief valve can be replaced with a less expensive and more failure-resistant manual air-relief called a coin vent.

Coin vents are manually operated using a small flathead screwdriver.



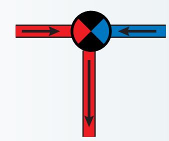
Air-relief valves eliminate air automatically, but have a higher failure rate, especially when installed in places where they are subject to large temperature variations.

Schematic Valve Styles

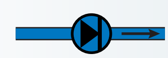


Ball or Gate Valve

Fill & Drain Valve



Antiscald/Mixing Valve



Check Valve

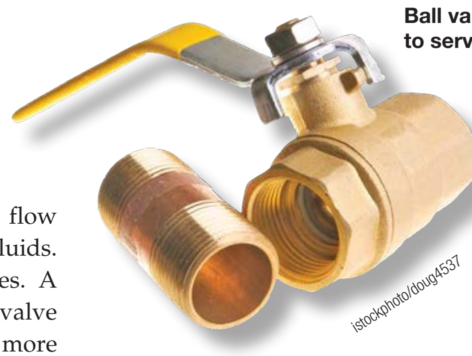
Pressure, Air, and T&P Relief Valves

SYMPTOM
Small leaks

Cause **Gate and ball valves** are used to stop the flow of fluids, isolate parts of the system, or to reroute fluids. Gate valves have higher failure rates than ball valves. A common failure of gate valves is failing to close. When valve replacement is required, use a ball valve, which is more reliable.

Gate and ball valves all have handles and a small "packing" nut, which seals the valve's stem. This nut can loosen and cause a small leak.

Solution Carefully inspect any leaking valve to ensure the packing nut isn't the problem. A quick tightening can often remedy the need to replace an otherwise good valve.



Ball valves are preferred by the pros to serve as shut-off valves.

istockphoto/fcafotodigital

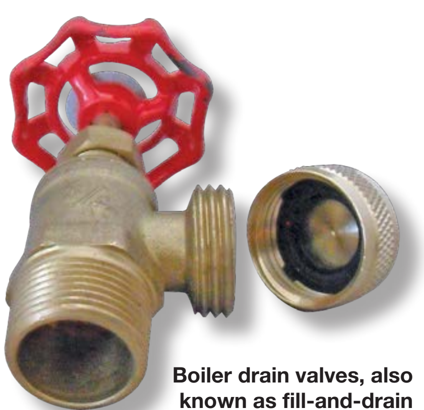
A weak point in gate valves is the stem that connects the valve handle with the round gate, which moves up and down inside the valve. A stem failure results in the valve shutting incompletely or failing to open.

SYMPTOM
Unusually high overnight heat loss from the SWH storage tank, and a difference in temperature between the supply and return pipes when the controller pump is off.

Cause **Check valves** allow fluid to flow in one direction and are used in direct forced-circulation (DFC) and indirect forced-circulation (IFC) antifreeze systems to prevent the thermosyphon of the heat-transfer fluid when the pump is off. They are available as swing or spring models—which describes the mechanism that actuates the valve. Spring valves can fail due to the spring breaking, although this is rare. Most check valves fail due to an obstruction—perhaps a small piece of solder—that keeps it open. In some cases, the night thermosyphon results in the backup element actuating at night, resulting in extra energy use (and expense). If a vacation bypass valve has been accidentally left open, it has the same symptom as a failed check valve.

Solution Valve failure requires a replacement unless an obstruction can be dislodged with what I call the "vigorous tapping procedure (VTP)"—that is, hitting it with a handy wrench.

Check valves only allow flow in one direction and are used in forced-circulation and antifreeze systems to prevent thermosyphon losses at night.



Boiler drain valves, also known as fill-and-drain valves, are common on all types of solar heating systems.

SYMPTOM
Leaky drain valve.

Cause **Fill-and-drain valves** are also known as boiler drain valves. They are manufactured with pipe thread on one end and garden-hose thread on the outlet. Fill-and-drain valves are normally used only a few times in the life of a SWH system and have very low failure rates. The most common problem is an older valve that won't shut off completely.

Solution The easiest solution to stop the leak is to use a bronze hose-thread cap with a hose washer.

Antiscald valves prevent scalding water temperatures by mixing cold water into hot water that's above the valve's setting. Upon cold water failure, such as from an upstream cold water valve being shut off, the valves shut off for safety.

SYMPTOM
Cool or tepid (never hot) water at the tap.

Cause **Tempering or antiscald valves** limit the water temperature to prevent burns. The valves have cold, hot, and mix ports and can be either factory-set to a certain temperature or field-adjustable. When water entering the hot port is above the temperature setting, the cold water port opens to cool the hot water before it exits the mix port. When these valves fail, the symptom is cool or tepid water that never gets hot since the water is constantly being mixed regardless of the water temperature.

Solution Replace failed valves with nickel-plated valves that have Teflon-coated inner components.

Mixing or tempering valves are about half the price of antiscald valves but don't have the safety shut-off feature and are not acceptable replacements for antiscald valves.

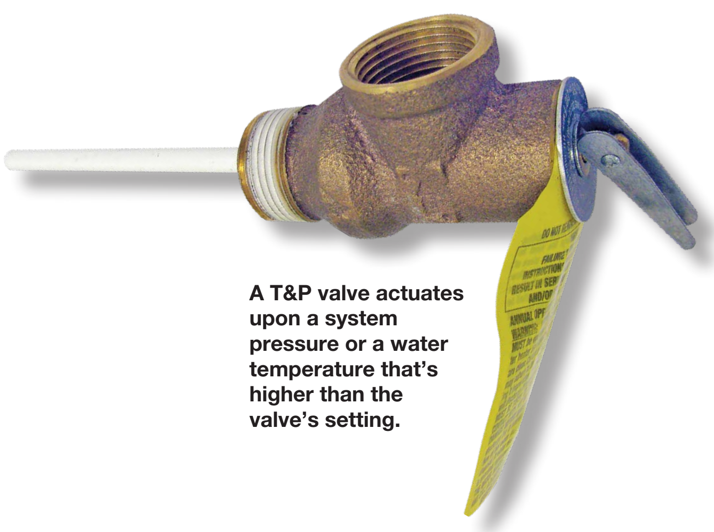
SYMPTOM
Excessive loss of drainback heat-transfer fluid; pump failure.

Cause **Vacuum breakers** were used on early drainback systems to prevent freezing by facilitating the draining of collectors. Placed at the highest point of the system, they introduced air into the piping when a vacuum was produced as the collector-loop pump shut off. In areas where hard water is prevalent, these bronze valves are prone to sticking. Their failure was the cause of freeze-breaks in thousands of collectors, resulting in the poor reputation of drainback systems.

Solution If it isn't possible to alter the piping or system design to eliminate the vacuum breaker, the valve should be removed every year and soaked in vinegar or another mild, acidic solution to neutralize the hard water deposits. Another fix for systems that cannot be modified (for example, piping that cannot be sloped to the drainback tank) is to install two vacuum breakers to provide some redundancy. Even then, they should be descaled annually.


Vacuum breakers are still used in older drainback systems to introduce air into the piping and allow water to drain.

SYMPTOM
Leaks at the relief-valve pipe.


A T&P valve actuates upon a system pressure or a water temperature that's higher than the valve's setting.

Cause **Temperature and pressure (T&P) relief valves** are required by plumbing and solar codes on all water heaters, including SWH storage tanks. The valves are available with different specifications; the most common relieve excessive pressure above 150 psi or at temperatures above 210°F. These can develop small leaks.

Solution T&P relief valves should never be plugged or capped like the leak solution for a drain valve. They all have a manual lever that also actuates the valve. Moving this lever repeatedly while applying the VTP can sometimes fix a leak. But never move the lever unless you are trying to stop a leak—actuating it can often cause the valve to leak. If the leak can't be stopped, the valve needs to be replaced.

SYMPTOM
Excessive pressure causes fluid to be released by the pressure-relief valve.

A pressure-relief valve actuates upon a system pressure that's higher than the valve setting.

Cause **Pressure-relief valves** are actuated as a result of excessive pressure buildup in SWH and hydronic heating systems. Common causes of excessive pressure are pump and control failures and undersized or failed expansion tanks. The pressure gauge on an antifreeze system will read zero if the pressure relief has been actuated. Pressure reliefs should not be mistaken for T&P valves—they lack the white temperature-sensing stem that T&P valves have.

Solution Troubleshoot the pump, expansion tank, or control to find the cause of the excessive pressure, and repair or replace the component as necessary.

SYMPTOM
Burst collector tubing (water running out of collector)

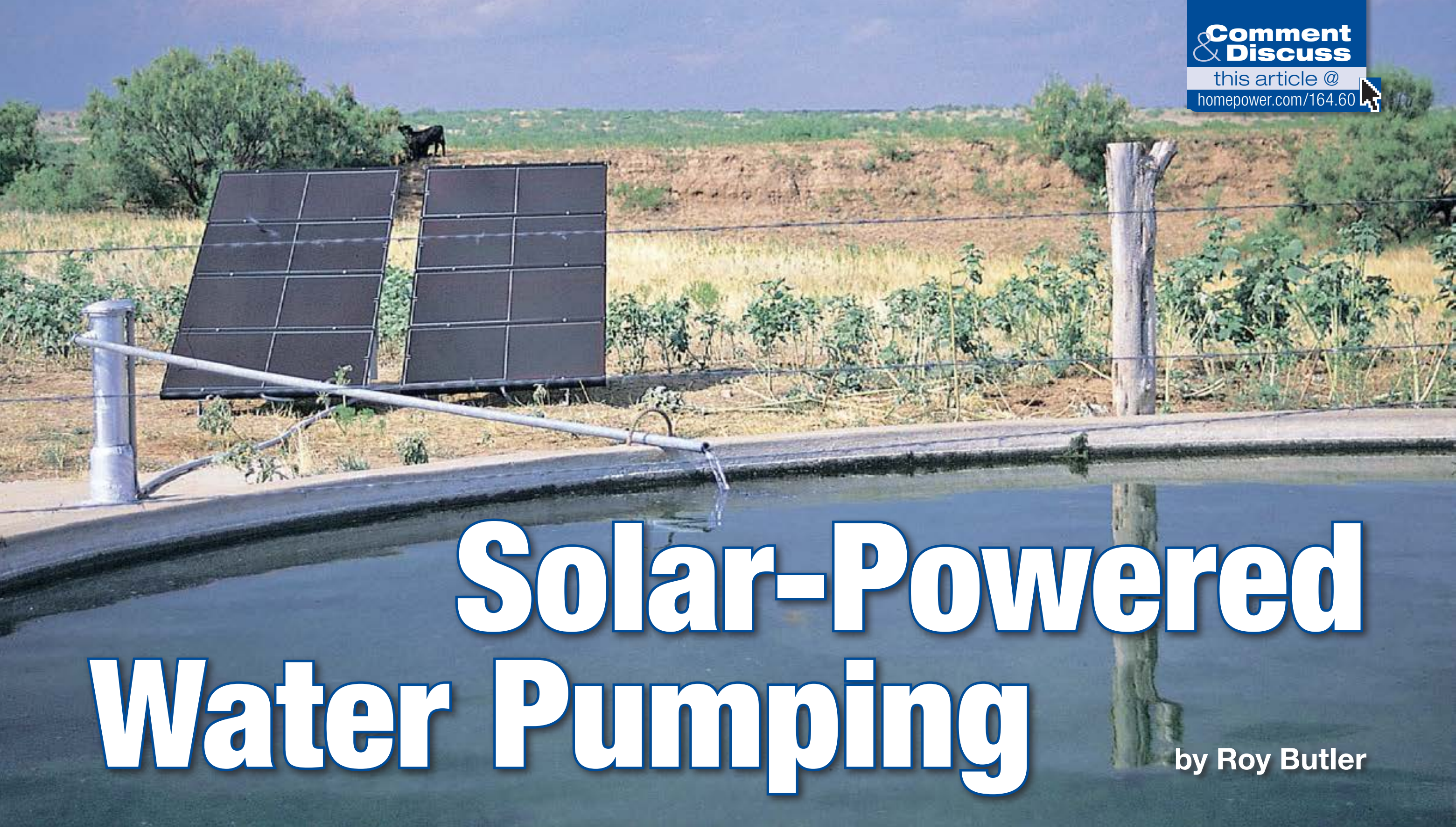
Cause **Freeze-protection (aka dribble) valves** are designed to dribble water out of a collector to prevent the tubes inside from freezing. This strategy is akin to letting a kitchen or bathroom faucet trickle to prevent household pipes from freezing. The most common freeze valve is plastic; more expensive valves are made of brass or stainless steel. Freeze-protection valves are available in two temperature ratings. A 45°F valve is recommended for DFC systems to protect the collector's small riser tubes. A 35°F valve is used for integral collector storage (ICS) systems, which don't have the small tubes. The valves require no energy to actuate. The small flow of water starts at 35°F to 45°F and allows warmer (hopefully) tank or ground water to enter the collector to keep it from freezing.

In DFC systems, the valve is normally between the collector's hot return outlet and a check valve installed below it on the same pipe. This allows the pressurized water to flow through the entire collector prior to dribbling out of the freeze valve, and replaces the about-to-freeze water in the collector with storage-tank water. Freeze valves have high failure rates, so are seldom used outside of southern Florida. Even if a hard freeze occurs only every 10 years or so, a freeze valve failure will cause numerous burst tubes, usually rendering the collector too expensive to repair.

Since the symptom of a clogged freeze-protection valve is its failure to drain at outside temperatures near freezing, they usually are discovered only after they fail—and collectors have already been damaged. Freeze-valve failures have ruined thousands of collectors and some state, municipal, and utility incentive programs exclude systems using them for freeze protection.

Freeze valves are used in otherwise nonfreeze-protected systems, allowing water to dribble out of the valve when near-freezing temperatures are encountered. However, in solar heating systems, relying on valves for freeze protection has resulted in more collector damage than all other causes of failure combined.

Solution Modify the system to a drainback or antifreeze system.



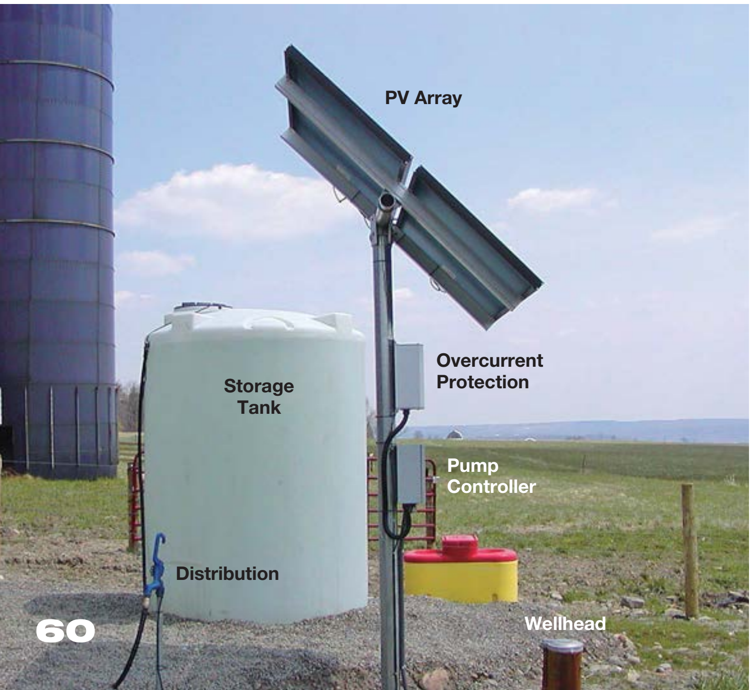
Solar-Powered Water Pumping

by Roy Butler

Courtesy Grundfos

Solar water pumps are a cost-effective and dependable method for providing water in situations where water resources are spread over long distances; power lines are few or non-existent; or fuel and maintenance costs are considerable.

Solar pumps are specifically designed to accept DC power directly from the solar modules and are optimized for operating under less-than-ideal sun conditions. Where conventional AC-powered pumps require a stable voltage and frequency to operate, solar pumps can operate over a wide range of voltage and available current.



Roy Butler

Conventional AC-powered pumps require large amounts of power to move large volumes of water in a short period of time. Solar pumps typically move a smaller volume of water over an extended period of time. This method requires far less power, which minimizes the size and cost of the PV array.

There are several methods for pumping water in remote areas, such as windmills, gas/diesel pumps, and ram pumps. But most of these options are either too expensive to install, or for fuel and maintenance, or require specific site conditions to operate.

Solar pumps can work for most locations and are at full capacity when needed most: during warm, sunny days. In temperate regions, they can be used year-round—which can be particularly helpful for potable water, animal grazing, and other farming operations. For many sites, a solar pump is often the best option for reducing cost and labor.

In areas with a remote well and limited access to the power grid, solar pumps are the best option—particularly where utility interconnection costs more than $5,000, usually about one-quarter to one-third mile from the grid. (In my area—western New York—the cost for utility power is about $10 per foot, so even PV-based water-pumping systems that are one-eighth mile from the nearest power line can be cost-competitive.) Specific applications include:

Domestic water supplies for off-grid homes and cabins. Although solar water pumps are used in this application, usually the home has an existing power system. In that case, it's far more cost-effective to run an efficient DC or AC pump off that system.

Livestock watering for pond and stream protection, rotational or prescribed grazing, and remote pasturing. This is the most popular use for solar pumping systems. They have proven to be cost-effective even without the use of federal or state incentives.

Aquaculture for aeration, circulation, and de-icing. Aquaculture is another application where the need for power coincides with peak solar availability. De-icing applications require oversized arrays due to less-than-optimum sun conditions in winter.

Irrigation for small-scale applications. With the recent reduction in the cost of PV modules, solar irrigation is fast becoming cost-effective. Solar pumps are available that can move the larger volumes of water needed for irrigation.

General System Types

In **PV-direct systems**, the PV array directly powers the water pump. With only three primary components—the array, pump controller, and pump—this can be a very affordable and low-maintenance system. As long as the sun is shining and the system is calling for water, the pump will run. For this type of system, adding water storage and/or oversizing the array for improved low-light operation is critical for most applications. There are three main options for PV-direct systems:

1) **PV-direct with gravity delivery or direct-to-source** (e.g., stock tank).This is the least complex and therefore usually the most cost-effective option. This system is well-suited for hilly terrain due to the ability to gravity-feed individual stock watering troughs from the primary tank.

2) **PV-direct to storage tank, with a booster pump for pressurized delivery.** This option has more complexity and cost due to its booster pump, pump accessories, and the need for extra PV power. Because it's not always possible or advisable to run two loads from one PV array, boosters are usually used on battery-based systems. These systems usually include a pressure tank so the booster pump does not have to run all the time water is being used.

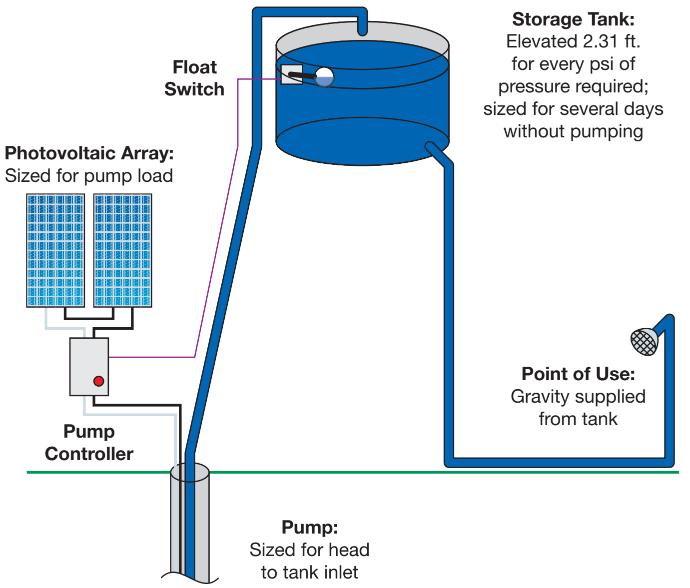
3) **PV-direct to an oversized pressure tank.** Although this system is fairly straightforward in the equipment that's needed, due to the addition of the pressure tank, it requires a pump and array sufficient to handle the additional total dynamic head (TDH; resistance to flow) from the pressure tank.

Battery-based systems (nighttime, pressurized, etc.) are fairly complex and, generally, the most expensive. This type of system is only recommended if full-time pressurized water is necessary.

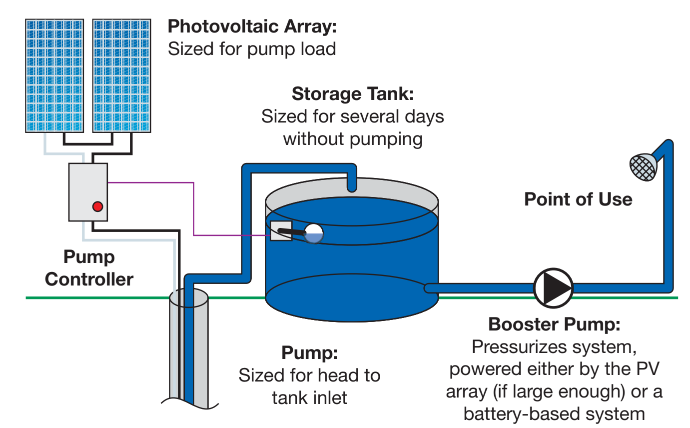
System Sizing

Determine needs. First, determine how much water you will need. If your needs vary during the season, be conservative and use the highest demand you expect (see the "Application & Water Use" table).

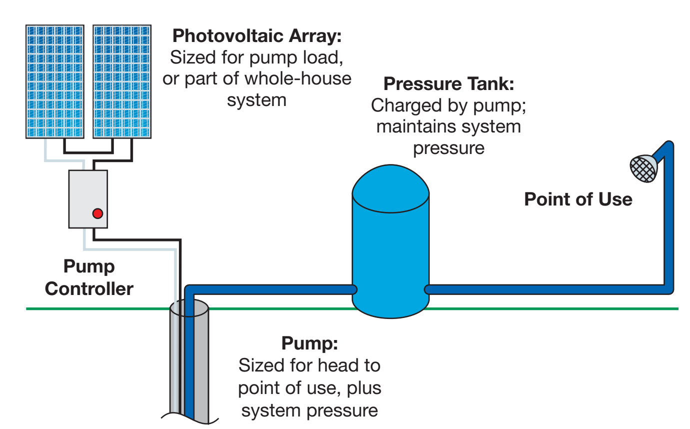
PV-Direct: Pumped to Storage, Gravity Distribution



PV-Direct: Pumped to Storage, Booster Pump Distribution



PV-Direct: Pumped to Pressure Tank for Distribution



Application & Water Use

Application	Approx. Usage (Gal./Day)
Household	50 per person
Cattle & horses	10–15 per head
Dairy cows	20–30 per head
Sheep & goats	2 per head
Small animals	0.25 per 25 lbs. body weight
Poultry	6–12 per 100 birds
Young trees	15 each, in dry weather

A surface pump can move large amounts of water, but because it has a limited draw depth, it is not usually used in drilled wells.

Determine source. The water system's configuration will be determined largely by the type of water source and its location. The source will either be subsurface (well) or surface (pond, stream, or spring). Wells are often preferred because of water quality and consistency—but they're expensive to drill, particularly where water tables are deep. Surface water sources may vary seasonally, often with low flow and quality during summer when higher volumes are usually needed.

For existing wells, the following needs to be determined (for new wells, consult the driller for this information):

- Static water level—the water level in the well under nonpumping conditions
- Seasonal depth variations
- Recovery rate—how quickly the well replenishes after pumping, measured in gpm
- Water quality (if for human consumption)

For surface water sources, the following need to be determined:

- Seasonal variations in water level, etc.
- Water quality, including presence of silt, organic debris, etc.

The water delivery system should be mapped out to show the location of the water source and the points of distribution. Include terrain contours to calculate the height differences. If the system is complex, find a water resource manager to help plan the water distribution system. Your local or county soil and water conservation district (SWCD), a branch of the USDA, is a great resource for this assistance.

Solar Siting

The water source site must then be evaluated for solar suitability. The following must be present for a productive PV system:

- A south-facing location with no significant shading
- Ample surface space for the pump, controllers, storage tank, and any other components
- A site for the solar array as close to the pump as possible to minimize wire size and installation cost
- If batteries are used, they must be in a reasonably dry/temperature-controlled location with proper venting
- If year-round water is required, freeze-proofing must be addressed. In a cold climate, a heated area is preferred for water storage and pressure tanks. (It is not economical to use PV to run a resistance heater in the winter.) In-well pressure tanks are sometimes used for freeze proofing.

PV arrays should maximize their direct exposure to the sun. That usually means in an area clear of shading, facing generally southward, and tilted at an angle about equal to the location's latitude. A tracker may be used to aim the PV array at the sun as it moves across the sky. This increases daily

This submersible pump is suspended from a raft near the center of this pond. Note the PV array that sits close to the pond's edge.

An in-well pressure-tank assembly for freeze protection.

Roy Butler (3)

energy gain by as much as 40%, depending on the latitude of the location (see “Tracking” sidebar). With PV module prices continuing to be some of the lowest in history, compare the cost of using a tracker versus adding additional modules on a fixed-mount system.

Assuming that you can locate the array in full sun, you then need to estimate the solar potential (daily sun-hours) using published data or maps. Multiply the array wattage by the number of expected peak sun-hours to get a rough estimate of daily energy available.

Tracking

A tracker for the PV array may be used to increase the power output by keeping the array pointed at the sun throughout the day. Passive trackers are preferred in remote locations where it is difficult to visually inspect equipment. A passive tracker has canisters of liquid on each end that are connected to each other by a tube. When the sun heats one canister, it turns some of the liquid to vapor and drives part of the liquid to the canister on the other side, and the weight difference causes the rack to tilt. When it faces the sun directly, both sides are equally heated and equilibrium is reached to stop movement.

A tracker can increase power output by 25% to 40%, reducing the number of PV modules required. The cost of the tracker with fewer modules should be compared to the cost of a larger stationary array. An additional benefit of a tracker is a potential reduction in pump stalling due to low-light conditions during late afternoon, low sun angles. This is of particular importance for systems that use a centrifugal pump, where water yield drops markedly with a drop in power. Trackers are favored in the summer months because of the sun’s longer arc of travel across the sky.

But trackers are not for every application. Their large surface area and the “wings” that block side sunlight can catch wind, so they should not be used in high-wind areas. Additionally, because it must be warm enough for the fluid to move from one side to the other, passive trackers may have difficulty tracking in the early morning and in extremely cold weather (below -10°F).

Courtesy SunPumps

Friction Loss in Schedule 40 PVC Pipe

Flow (GPM)	Head Loss in Vertical Ft. per 100 Ft. of Pipe, for Nominal Pipe Sizes (in.)					
	1/2	3/4	1	1 1/4	1 1/2	2
1	1.13	0.14	0.05	0.02		
2	4.16	0.35	0.14	0.05	0.02	
3	8.55	2.19	0.32	0.09	0.05	
4	14.80	3.70	0.53	0.16	0.09	0.02
5	22.18	5.78	0.81	0.25	0.12	0.04
6	31.08	7.85	1.00	0.35	0.18	0.07
7		10.60	1.52	0.46	0.23	0.08
8		13.40	1.94	0.58	0.30	0.09
9		16.90	2.43	0.72	0.37	0.12
10		20.30	2.93	0.88	0.46	0.16
12		28.60	4.11	1.22	0.65	0.21
14			5.47	1.64	0.85	0.28
16			7.02	2.10	1.09	0.37
18			8.73	2.61	1.34	0.46
20			10.60	3.16	1.64	0.55
22			13.30	3.79	1.96	0.67
24			14.90	4.44	2.31	0.79
26				5.15	2.66	0.90
28				5.91	3.05	1.04
30				6.72	3.46	1.18

Note: Shaded values are over 5 ft. per second & should be selected with caution

Source: dankoffsolarpumps.com

Determine Total Dynamic Head (TDH)

Once you know the amount of water needed, the water source’s characteristics, the distances (both vertical and horizontal) that the water will be pumped and the pipe size, you can determine the size of pump and PV array. You first need to calculate the value of TDH, which is the sum of the height from the water level to the storage tank top, plus friction losses. For submersible pumps, TDH is not calculated from the pump depth, but from the static water level less any draw-down that occurs when the pump is running.

Friction losses are the resistance to water flow on the inside surface of the pipe and fittings. The smaller the pipe and the greater the pumping rate, the higher the friction loss, expressed in equivalent height.

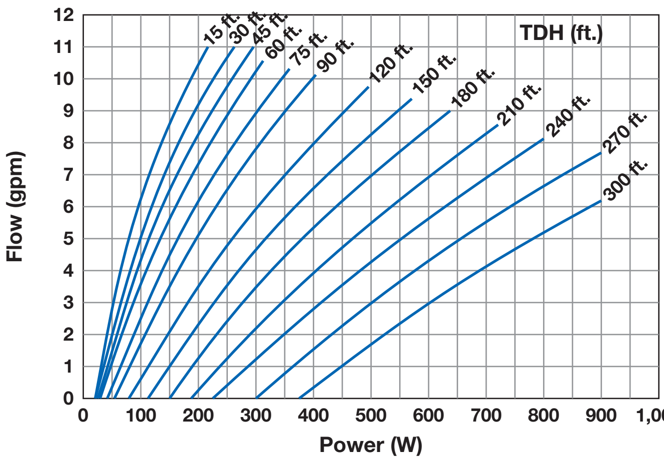
To calculate the required pumping capacity, use the following equation:

Pump capacity = (Gallons/day ÷ daily peak sun-hours) ÷ 60 min./hr. = XX gallons per minute

For example, if your water needs are 1,500 gallons per day and you have determined that the site has 5 peak sun-hours per day during the grazing season, you need a minimum pumping rate of 5 gpm.

A friction-loss table (see above) uses the pumping rate and the pipe’s inside diameter to give friction loss in vertical feet for every 100 feet of pipe. For example, if you are using 300 feet of 3/4-inch pipe at 5 gpm, you would need to add 17.34 feet (5.78 × 3) to the total lift height.

Grundfos 11 SQF-2 Pump Performance



Courtesy Grundfos

This Grundfos controller operates on AC or DC, and in a variety of voltages.

Determine Pump & PV Array Sizes

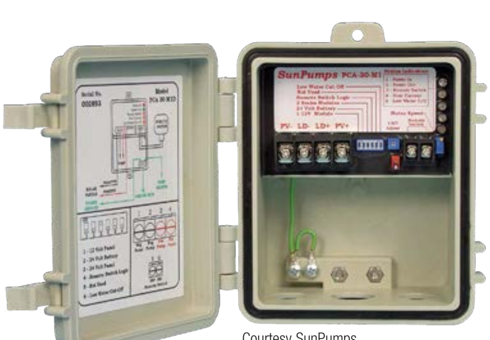
Using the TDH and desired gpm, refer to the pump manufacturers' graphs to determine the pump wattage necessary. To size the PV array, some pump manufacturers require you to increase the specified pump's wattage by 25% (multiply by 1.25) to compensate for array power loss due to high heat, dust, aging, etc. Some solar pump companies, such as Grundfos, offer an online sizing tool that already accounts for PV array losses.

Small 12- and 24-volt DC pumps will require the use of lower-power modules that are typically more expensive than higher-power modules. Larger pump systems that require higher-voltage arrays, and battery-based systems that use MPPT charge controllers can use less expensive, more commonly available modules. For a detailed example of system sizing, see "Methods" in this issue.

Pump Controllers

The pump controller includes an electronic linear current booster that acts similar to a maximum power point tracker controller, optimizing power to the pump despite wide variations in solar power production. It is particularly helpful in starting the pump in low-light conditions. Most manufacturers require the use of their proprietary controllers with their pumps.

Most controllers have the capability to control pump operation via a float switch or pressure switch. System status and diagnostic displays are also common.



Courtesy SunPumps

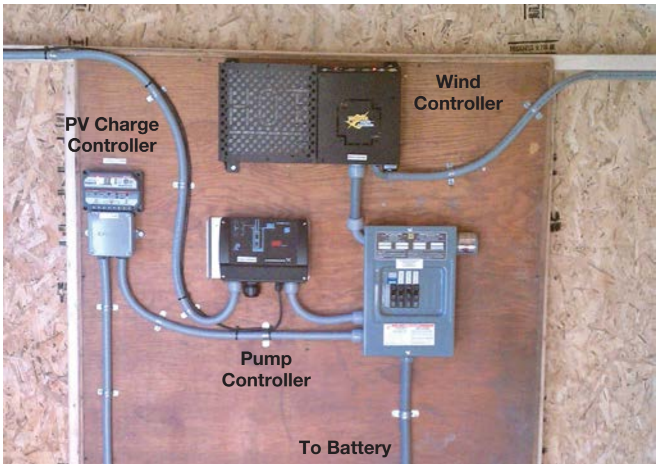
This SunPumps controller can run PV-direct or from batteries, and includes remote switching and a low-water cutoff.

Charge Controllers

When batteries are included, a charge controller is needed to keep the batteries from overcharging or overdischarging. Basic pulse-width modulated (PWM) controllers are typically used for small 12- and 24-volt battery systems. These have a fairly narrow voltage input window, so properly matching the modules to the controller is critical. Maximum power point tracking (MPPT) charge controllers can use higher-voltage module strings, which allows choosing from a wider range of modules. Where long wire runs between the array and pump are required, the higher-voltage strings allow using smaller wire, which reduces system cost and minimizes voltage drop.

Load control is another feature found in many charge controllers. The most common load control is a low-voltage disconnect (LVD), which prevents damage to the batteries by turning off the pump if the battery voltage gets too low due to deep discharge. Another use is to divert the PV power to run another load if the batteries are full, allowing full use of the array's potential.

Battery-based pumping systems provide water when the sun isn't shining, but add cost and complexity.



Roy Butler

Tank Storage

Most solar water-pumping systems use some type of storage. A general rule is to size the tank to hold at least three days' worth of water to balance variable sun conditions. With too much storage or too long, water quality issues such as algae growth may arise. To prevent algae growth, a maximum storage of two days is recommended if the tank is in full sun; if the tank is shaded, a maximum of three days of storage is advised.

Food-grade plastic tanks are most common, and often placed at a high point on the property for gravity-feed to the end use. Although these tanks are usually the most affordable option, sun exposure tends to promote algae growth in them.

A better but more expensive option is a buried cistern. A cistern offers freeze protection, stabilizes water temperature, and minimizes poor water-quality issues. A float switch inside either type of tank controls the pump according to water level. A wire is run alongside the fill pipe from the float switch to the pump controller.

Pressurized Water Systems

In some applications, a pressurized water system may be required. For example, most freezeproof livestock watering stations require a constant water pressure of at least 3 to 5 psi to keep the ground convection loop active. A properly sized solar pump can pressurize a water system much the same as a standard AC-powered pump. If water is needed day and night, the pressure tank can be oversized to provide water through the night. A pressure-operated switch turns the pump controller on and off according to tank pressure.

If more capacity is needed than an oversized pressure tank can provide, batteries can be added to provide energy when solar is not available—the PV array recharges the batteries each day. A charge controller and low-voltage disconnect are needed in this type of system. The complexity and maintenance considerations of this type of system make it one of the more costly solar pumping options.

Roy Butler

A float switch hangs on a weight inside a storage tank.

Courtesy Conergy

A typical pressure switch can control a PV-powered pump.

Roy Butler

Aboveground poly tanks are inexpensive and durable. White ones stay cooler, but allow light to penetrate, which can cause more algae growth.

Solar Pumps

Most conventional AC pumps use a centrifugal impeller that "throws" the water into motion. A multistage centrifugal pump has a series of stacked impellers and chambers. When operating at low power, the output of centrifugal pumps drops dramatically. This makes centrifugal pumps somewhat limited for solar applications, though more-efficient centrifugal pumps are available. Solar centrifugal pumps are capable of high flow rates but are limited in vertical lift capabilities. They also require fairly large PV arrays. These pumps are ideal for low-head irrigation applications.

Positive displacement pumps, which bring water into a chamber and then force it out using a piston, rotating chambers, or a helical screw, are often used as solar pumps. These generally pump more slowly than centrifugal pumps, but have good performance under low-power conditions and can achieve high lift and pressure. These are ideal for small livestock, pond aeration, and small potable water systems.

Even a few feet of height can give a tank enough head for low-pressure gravity distribution.

Roy Butler

Manufacturers

Advanced Power • solarpumps.com
Aquatec • aquatec.com
CAP Solar • capsolar.com
Dankoff Solar Pumps • dankoffsolarpumps.com
Grundfos • us.grundfos.com
In-Well (No Tank) • inwelltech.com
Lorentz • lorentz.de
Mono Pumps • mono-pumps.com
Shurflo (Pentair) • shurflo.com
Sunmotor International • sunmotor.ca
SunPumps • sunpumps.com
SunRotor • sunrotor.com

SunPumps' SCB 10-185 DC surface pump.

Courtesy SunPumps

This Lorentz pump controller converts DC to three-phase, variable-frequency AC. Pictured next to the controller is a three-phase AC submersible pump.

Courtesy Lorentz

Although a submersible pump remains underwater, such as in a well, it can also be used for some surface water applications. A suction-type surface pump is mounted at or just above water level, and is excellent for pushing water long distances. Surface pumps are less expensive, but are not well-suited for suction—they can draw water from only about 10 to 15 vertical feet. They are also not dirt- and debris-tolerant, and typically require filtration.

Solar pumps are available in a wide range of types and sizes. The right pump is determined by carefully calculating your needs. For example, one of the smaller solar DC surface pumps requires a PV array of just under 150 watts and can pump at 1.5 gpm. During 10 sunny summer hours, it can pump up to 900 gallons—if it has full power the entire time. A submersible DC pump, with 300 W of PV modules, might pump more than 1,100 gallons in about 5 hours from a 150-foot-deep well. The equivalent 3/4 hp, 240 VAC pump would require 2,000 W of PV modules, an inverter, and batteries to pump this amount of water in one hour.

Adapted, in part, from the "Guide to Solar-Powered Water Pumping Systems in New York State" by Roy Butler, Christopher Sinton & Richard Winnett.

Comment & Discuss
this article @
homepower.com/164.68

Rapid Shutdown of PV Systems: Part 1

by Brian Mehalic

The 2014 *National Electrical Code's (NEC)* new Section 690.12—Rapid Shutdown of PV Systems on Buildings—is creating buzz in the PV industry. And sometimes it is leading to confusion and controversy, as authorities having jurisdiction (AHJs) and PV professionals attempt to interpret and implement the new requirements. (A subsequent "Code Corner" will cover possible ways of implementing rapid shutdown using currently available equipment.)

Section 690.12 only applies to PV system circuits "on or in buildings." For example, a ground-mounted array with the inverter and utility interconnection not on a building is not required to have rapid shutdown capability. "On" buildings also means you cannot get around this requirement by just running all the PV system circuits on a building's surface.

The goal is to decrease the risk emergency responders—particularly firefighters—face when they work on a fire at a building with a PV system. Ideally, they should be able to shut off the PV system along with the utility service (if present), preferably with a single switch or disconnect; next best is a readily accessible, clearly labeled switch dedicated to this purpose. The risks are due to:

A power source—the PV array—that continues to be energized when the sun is shining on it. The array is often wired for high-voltage DC which increases arcing hazards, and could become re-energized after fire damage occurs, possibly reigniting a fire.

Even those these PV output circuits don't penetrate the building, they are on the building and portions are more than 10 feet from the array, so a means of rapid shutdown is required.

Courtesy EV Solar Products Inc.

Batteries—New battery chemistries are being used, which may require new firefighting training and techniques if involved in a fire—or even if they are just in a building that catches on fire, since the batteries will be energized.

Circuits that may be energized by a PV system even if the AC utility service or meter is pulled, or main disconnect is shut off. And components with "terminals on both the line and load sides" may still be energized in the open position.

Inconsistent labeling—In an emergency, how might a firefighter pick out the most important red label to read when there's a bunch of equipment with red labels? The 2014 *NEC* refers to the National Electrical Manufacturers Association (NEMA) ANSI Standard Z535.4-2011 (Product Safety Signs and Labels), which governs appropriate signage colors, but this is only an Informational Note—and not necessarily being enforced by AHJs.

The complexity of different system types and configurations—stand-alone, grid-tied, supply-side connections, and different architectures even among systems that are the same "type."

A rooftop disconnect may not be enough depending on its location in the circuit. Though now required for rooftop combiners per Section 690.15(C), this switch stops current in the circuit, but the box the switch sits in will still have voltage present on one side of the switch and all the way back to the modules, whenever the sun is shining.

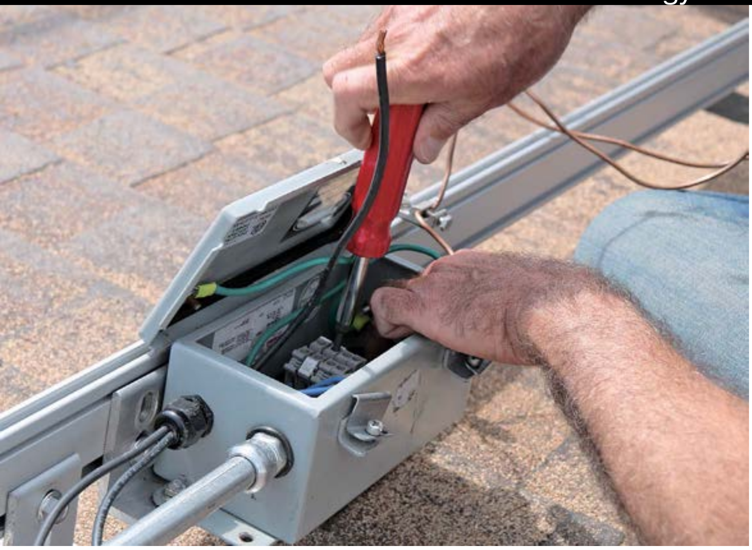
Controlled Conductors

Rapid shutdown requires controlling specific PV system circuits. These circuits include:

- PV source and output
- Inverter input and output
- Charge controller input and output
- Batteries and/or inverter input

Circuits are not subject to rapid shutdown (i.e., are not required to be controlled) if they are:

- On a building and less than 10 feet from the PV array
- Inside a building, with a length less than 5 feet



Because these circuits are within 10 feet of the PV array, they are not subject to rapid shutdown requirements.

This means that the module interconnects and PV source-circuits located behind roof-mounted modules do not have to be controlled by rapid shutdown. Nor do the DC conductors running to and from a roof-mounted junction box or combiner box—both PV source and output circuit conductors—so long as they are within 10 feet of the array.

Conductors that enter a junction box behind a roof-mounted array and then proceed into the building need to be controlled within 5 feet of entering the building. Conductors between a battery bank and an inverter or charge controller could conceivably be less than 5 feet long, and thus not subject to being controlled under 690.12, if that's the case.

Ground- or pole-mounted PV arrays are only subject to 690.12 if system circuits touch or enter a building. For example, a pole-mounted array may be connected to an inverter inside a house. If the DC and/or AC conductors in the building are longer than 5 feet, then 690.12 applies to that portion of conductors in or on the building. (Of course, this may mean that the rapid shutdown feature will shut off DC circuits at the array as a matter of practicality but, in reality, only the section in or on the building would need to be controlled.) The same holds true if an inverter is located on a ground-mounted structure but the AC output conductors in or on the building are more than 5 feet long.

Systems with batteries add complexity. Battery circuits, much like PV circuits, may be energized regardless of utility service. In the case of backup systems, the whole point is for them to continue to operate when the grid goes down. As such, rapid shutdown strategies appropriate for batteryless grid-tied systems may not be suitable.

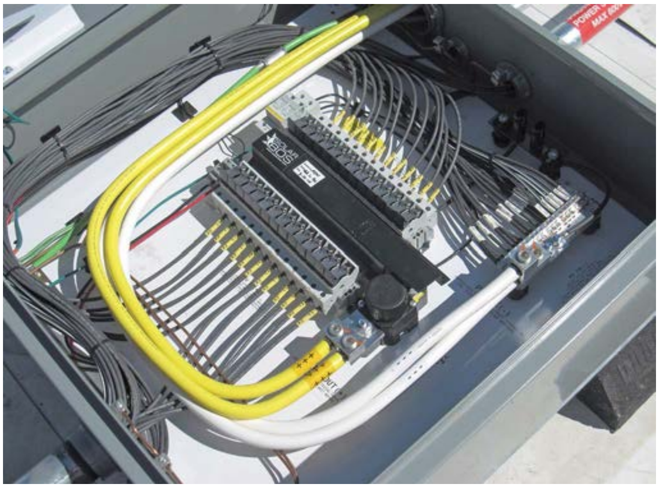
What Needs to Happen

Within 10 seconds of initiation of rapid shutdown, the controlled conductors must be limited to no more than 30 V and 240 VA, as measured between any two conductors and between any conductor and ground. In general, 30 V is considered touch-safe in a wet environment. It is also below the voltage (50 V) at which Sections 110.3(F) and 110.4(A)(1) of the National Fire Protection Association's (NFPA) 70E standard require a "hazard identification and risk assessment procedure" and limit testing and troubleshooting to "qualified persons."

In some cases, particularly on the DC side of the system, implementing 690.12 may require contactors, shunt trip breakers, or other remotely controlled switches to operate automatically, often using 24 VDC or AC. While the control power to these switches may be below the rapid shutdown voltage threshold and could remain energized, it is critical—though not explicitly stated in Section 690.12—that the rapid shutdown system, should it fail, do so in a safe manner (i.e., shut down). This means that relays or contactors used for controlling circuits must be normally open, closing (completing the circuit) only when control power is available (meaning they are closed only during normal operation of

The inverter and interconnection point in this grid-tied PV system is on an exterior wall. PV circuits that are on the building, but less than 5 feet in length, do not require rapid shutdown.

This rooftop combiner box has a contactor that can be activated either with a dedicated switch or by shutting off the AC service to the building. It is within 5 feet of the connected PV array.



Courtesy MidNite Solar

MidNite Solar's Birdhouse is designed specifically for disconnecting a rooftop PV array—as well as other PV system circuits—at ground level.

the system and if the power supply to them fails, they open).

It is important to realize 690.12 does not mandate module-level control. Instead, the section allows for de-energizing PV conductors that are more than 10 feet from the array, even if series connections between modules (or, in the case of a combiner box next to an array, parallel connections between PV source circuits) remain energized. However, as a matter of practicality, rapid shutdown of DC circuits will typically be implemented in combiner boxes.

Also note the DC capacitance on many inverters—if the inverter is in or on a building and is not specifically designed to isolate its internal capacitors upon shutdown, then additional switching will also need to occur within five feet of the inverters' DC input to control those conductors (i.e., isolate them from the capacitance in the inverter).

Since 30 V is greater than the operating voltage of 12 V and 24 V nominal battery banks, these circuits do not need to be controlled, regardless of their length. However, the AC output of the inverter will likely need to be controlled, depending on the conductor length and location. When 48 V battery banks are connected to conductors longer than 5 feet in a building, battery conductors within 5 feet of the bank will need to be automatically switched to isolate the voltage during rapid shutdown. Meeting this requirement can also fulfill the new disconnect requirement for batteries outlined in Section 690.71(H).

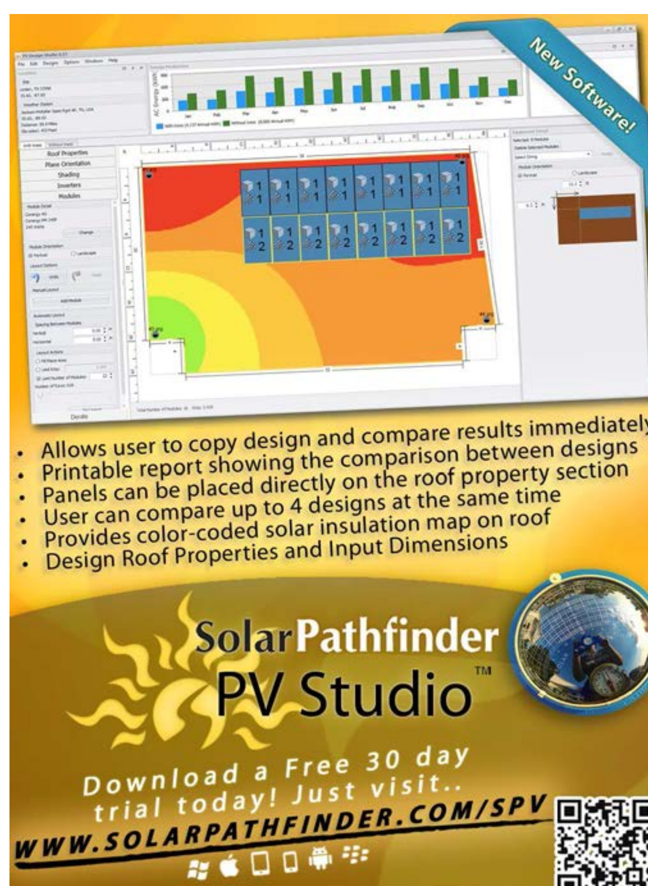
web extras

"A Peek at the *2014 NEC*—Part I" in *HP158* discusses terminal limitations and 75°C lookup • **homepower.com/158.86**

See "More 2014 *Code* Changes" in *HP160* for discussion of sizing overcurrent protection • **homepower.com/160.84**


LIVING OFF GRID DOES NOT MEAN YOU'RE ALONE.
NORTHERN ARIZONA WIND & SUN
YOUR SOURCE FOR:
Solar and renewable system design and support. Call us for free help designing your system.
All components in an easy, online store, including:
▪ Solar panels
▪ Wind generators
▪ Inverters
▪ Batteries
▪ Pumps
▪ Accessories and more
We ship nationally. No sales tax on PV systems/equipment.
800-383-0195 ▪ www.solar-electric.com
ELECTRICITY FROM THE SUN SINCE 1979

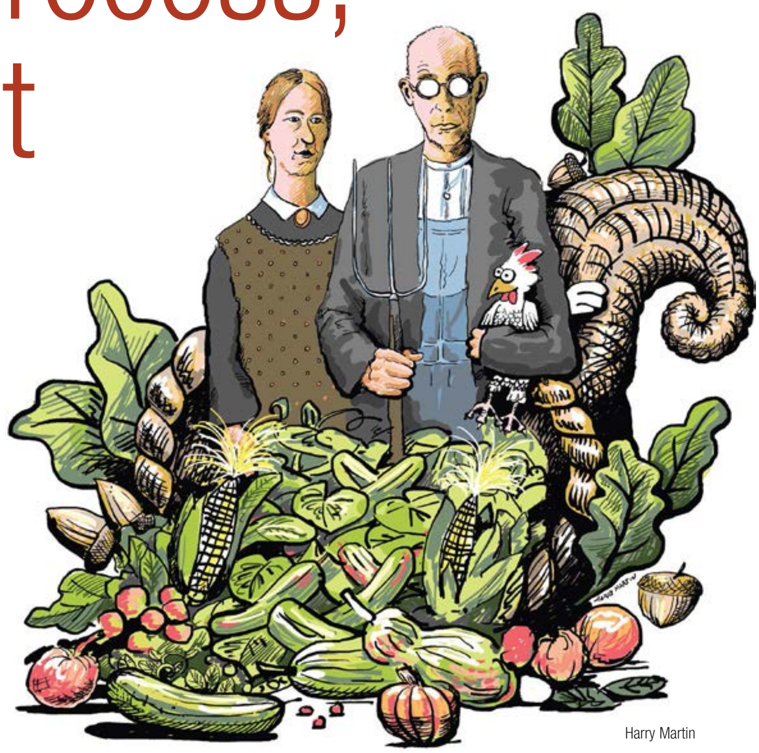

We reinvented the wheel!
Introducing the next generation of microhydropower. Tried and tested technology, now redesigned to bring you more power than ever before.
X-STREAM ENGINE
Energy Systems & Design
With an upgraded rotor, higher powered magnets, and our widest ever operating range, the X-Stream Engine is ready to power your world!
Energy Systems & Design
Microhydropower since 1980
506-433-3151
YouTube channel: ESDhydro
sales@microhydropower.com
www.microhydropower.com


New Software!
• Allows user to copy design and compare results immediately
• Printable report showing the comparison between designs
• Panels can be placed directly on the roof property section
• User can compare up to 4 designs at the same time
• Provides color-coded solar insulation map on roof
• Design Roof Properties and Input Dimensions
SolarPathfinder PV Studio™
Download a Free 30 day trial today! Just visit..
WWW.SOLARPATHFINDER.COM/SPV

Comment & Discuss this article @ homepower.com/164.72

Pick, Rinse, Process, Sleep...Repeat

by Kathleen Jarschke-Schultze



Harry Martin

Our gardens this year are the biggest areas of planted vegetables my husband Bob-O and I have ever attempted. Our recent retirement and our new well contributed to the decision to grow big this year. I had always thought there was a market for my garden's overages by selling the produce at the campgrounds around the nearby reservoir. Turns out, this was not the year for that little dream.

Greenhouse Glut

Bob-O and I were both home all spring, first planning, then prepping and planting all three garden plots. We actually ran out of seedlings to plant before all the prepped and tilled rows could be used. Well, that's not entirely true. I am not a ruthless gardener. If a volunteer vegetable has the gumption to grow on its own, I leave it be or transplant it someplace out of the path. It's this way in my greenhouse, too. I plant a lot of seeds, and I grow all the seeds that sprout, sometimes transplanting them into smaller pots several times while waiting for our frost-free date of June 1.

I did not run out of tomato plants, but I drew the line at planting more than 30. At 20 plants, I stopped planting cukes. You get the picture. I was overplanting at that, still thinking of being able to sell my extra vegetables.

After I had planted all I thought we could handle, I boxed up the leftover seedlings and dropped them off outside our small post office. My homemade sign stated, "Free organic, open-pollinated veggies. Some labeled, some mysteries. Take a few, leave a few. Grow good food; eat well."

On our way back home that evening we stopped by to take any leftover plants home. There were none, only the empty boxes. All summer long, I have imagined people growing and enjoying my tomatoes and other veggies.

Bounty

Our new well and our enhanced watering system has performed just as it should, supplying water to all our gardens and orchard. Our tanks are automatically refilled for fire protection. Of course, Bob-O has ideas on how he wants to tweak it, once the garden and fire season are over, by adding another water tank at the upper site and putting our whole watering system on the higher pressure.

We have been having, as they say, a bumper crop. We were overrun with lettuce, arugula, and snow peas, so I started traveling down to the campground at the end of our road in Evie, our electric golf cart, to sell produce, along with free-range eggs from my chickens and honey from my bees.

What I found was that, when they are headed out to the sticks, most people come prepared with food. I sold a few items a couple of times, which was okay with me. It was fun. I figured business would pick up when the corn, cucumbers, and tomatoes came in.

Mis-Adventures

It wasn't very long before the garden exploded. I had more vegetables than ever. My problem now was that no one was camping because a toxic algae bloom had grown in the lake. Warning signs were posted in every campground: Don't eat the fish; don't swim; don't let your dog drink the water.

To add insult to injury, then the wildfires started. Our usually blue summer skies turned gray and smoky. This year's fires have pretty much surrounded us—but only one was close enough to cause us worry. Luckily for us, the wind pushed that fire away from our homestead.

Stealth Cukes

The cucumbers hit all at once. A daily picking wasn't enough to keep them in check. Bob-O and I would be on our knees, peering through the green leafy veil of scratchy vines, trying to spot a cuke before it got too large. Invariably, one or the other of us would bound to our feet, proclaiming, "I win!" and holding up an enormous orange-rinded monster.

Every time we went to town, we would drop off a box of cucumbers at the post office. On the way home, we would retrieve our empty box. One morning, we were caught in the act by our postmaster, who was out front raising the flag on the pole. “Okay,” Bob-O said, lugging the big box of cukes inside. “Yes, it’s us. We’re busted.” The postmaster said it was fine—people liked the free cukes.

I was vacuuming one morning while Bob-O and the dog were on a morning walk. A couple of minutes later, I was surprised when he burst back through the door with a neighbor in tow. “I found someone who wants cucumbers,” he announced jubilantly.

Payday

I hate to waste food, so I canned, pickled, dried, blanched, and froze some produce every day, trying to keep up with each morning’s harvest. I was on Mother Nature’s clock now. If it was ripe, it got picked; if it was picked, it was dealt with.

Our garden largess has filled our larder, pantry, keep, and freezers. I use just about any preserving method possible, but I do admit to a fascination with food preservation techniques that don’t require using a lot of resources. Each gardening season, I pick up a few new favorite preserving recipes. Each winter, I find out what we really use from the shelves. After three years on the shelf, that chow chow went to the chickens.

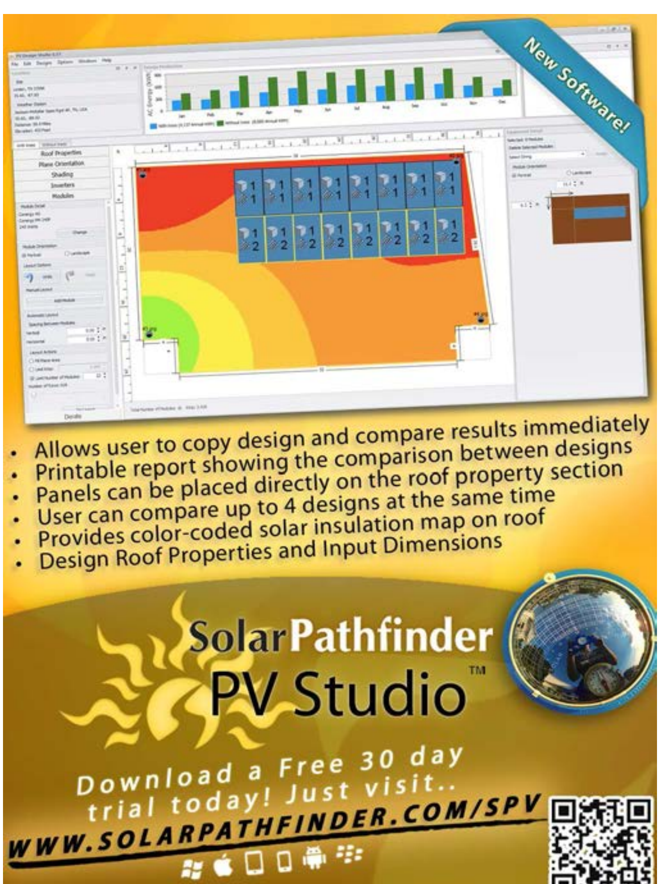
Harvest Zen

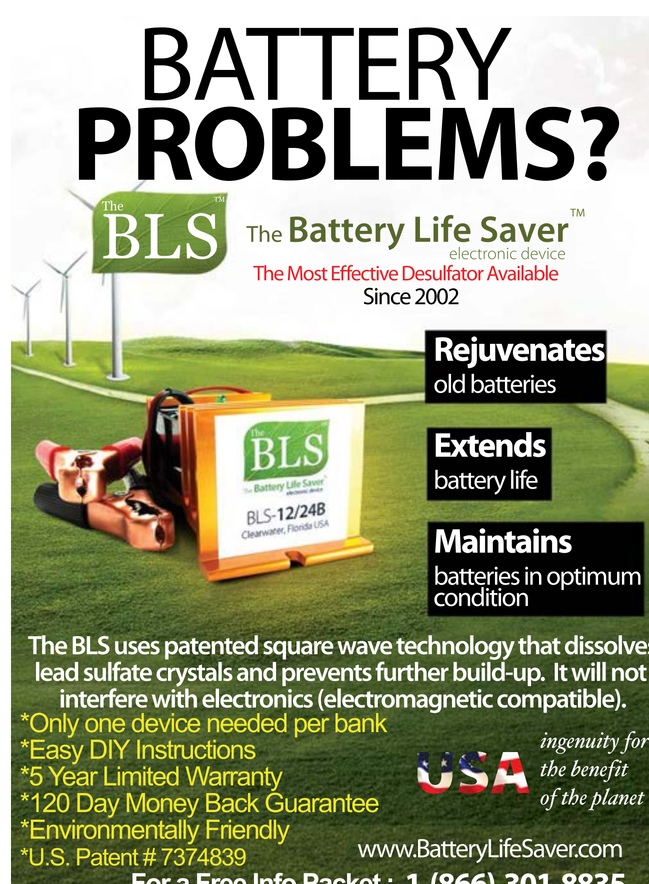
One of the things that all of this bounty has taught me about harvesting is to take a second look. When you are harvesting cucumbers, tomatoes, peppers, beans, sprouting broccoli, okra, eggplant, and more, you have to view that plant from several angles to see all the ripe fruit. We have thought we picked a plant clean, only to glance back and spot two or three more fruits we missed.

And it’s okay if you can’t use all of your produce. Share it—someone else will be glad for it. And I hope by identifying my donated plants and vegetables as organic and open-pollinated I can educate and change a few minds about gardens, chemicals, and genetically engineered organisms.

Garden Diva

I feel really good about providing all of this good food for our family and friends—and people I’ll never meet. At every meal, we identify which ingredients of the meal were grown and/or processed by us. It is a wonderful, powerful feeling and probably the big reason I garden. Well, that and I like to play in the dirt.


New Software!
• Allows user to copy design and compare results immediately
• Printable report showing the comparison between designs
• Panels can be placed directly on the roof property section
• User can compare up to 4 designs at the same time
• Provides color-coded solar insulation map on roof
• Design Roof Properties and Input Dimensions
Solar Pathfinder
PV Studio™
Download a Free 30 day trial today! Just visit..
WWW.SOLARPATHFINDER.COM/SPV


BATTERY PROBLEMS?
The BLS™
The Battery Life Saver™
electronic device
The Most Effective Desulfator Available
Since 2002
Rejuvenates old batteries
Extends battery life
Maintains batteries in optimum condition
BLS-12/24B
The BLS uses patented square wave technology that dissolves lead sulfate crystals and prevents further build-up. It will not interfere with electronics (electromagnetic compatible).
*Only one device needed per bank
*Easy DIY Instructions
*5 Year Limited Warranty
*120 Day Money Back Guarantee
*Environmentally Friendly
*U.S. Patent # 7374839
USA ingenuity for the benefit of the planet
www.BatteryLifeSaver.com
For a Free Info Packet : 1-(866)-301-8835

Comment & Discuss this article @ homepower.com/164.76

Thermal Bridging

Thermal bridges might seem small, but they can be a source of significant energy loss. A superinsulated home is only as good as its resistance to heat flow, and that means addressing thermal bridging during the home's design and construction. You can pack your home's walls with insulation, but thermal bridging—places in which the insulation is thinner or nonexistent, such as across a sill or through a wood or steel stud—will cut into your home's energy efficiency. As the *2013 California Energy Code* states, "R-value is used to describe insulation effectiveness, but R-value does not describe the overall performance of the complete assembly," i.e., the complete wall.

These thermal "short-circuits" primarily occur at the wall framing, where materials with low insulative value, such as wood or metal, help heat escape through the envelope. In conventional stick-frame construction, up to 25% of the wall area can be made up of framing members. The result? Suddenly, the R-value of your "well-insulated" stud-framed wall starts to slide. Add in details like windows and doors, and the whole-wall R-value commonly takes a nose-dive. (You can estimate a building assembly's whole-wall R-value through Oak Ridge National Laboratory's interactive calculator at http://web.ornl.gov/sci/roofs+walls/AWT/home.htm.)

The result is reduced energy efficiency, decreased comfort, and, on cold surfaces, the potential for condensate to develop. So how can you reduce thermal bridges in a home you're building or one you'd like to retrofit?

- Use advanced framing techniques, which reduce the amount of wood by increasing the spacing between framing members. For example, 16 inches on center becomes 24 inches on center for a stud-framed wall. A thermally broken double-stud wall can also be used with advanced framing.
- Consider adding a continuous layer of exterior insulation, such as rigid foam or rock-wool (mineral fiber) board, over the wall before sheathing it.
- Use an alternative wall system. For example, the wood I-joist splines in structural insulated panels are thinner than most studs, and panels are usually 48 inches on center (or more), which further reduces thermal bridging.
- Implement proper insulation and thermal breaks around the foundation/slab. A well-insulated slab may mean two pours: one for the foundation wall and one for the slab, so you can provide a layer of rigid foam between the two components.
- "Appendix JA4—U-factor, C-factor, and Thermal Mass"—of the *2013 California Energy Code* provides detailed data and other ways to reduce thermal bridging for a variety of building-assembly types.

—Claire Anderson

Thermal bridging can readily occur through this 2-by-6 window framing.

Courtesy What's Working

Double-stud 2-by-4 advanced framing reduces thermal bridging with little increase in lumber.

Courtesy NREL