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On the Cover

Homeowners Brad Hagen and Linda Niehaus live large in their 1,000-square-foot home with a variety of solar energy technologies (see page 38).

Photo by Mark Arinsberg

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Photos, left to right: Mark Arinsberg; Lena Wilensky; Courtesy General Electric, Fiat, Tenshon, Nexus EnergyHomes

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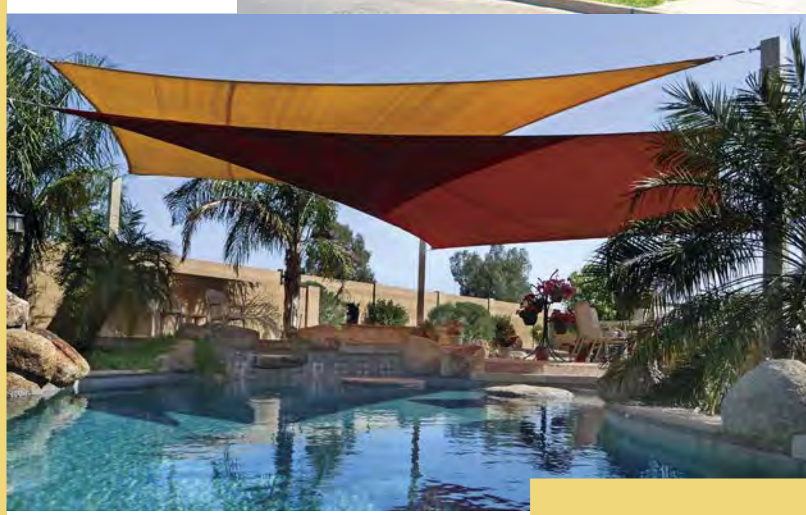

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In Back

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Time for a Utility Overhaul?

Rooftop solar is again under attack by some utilities, who claim that net-metered solar-electric systems (among other energy-efficiency measures) are impinging on their profit margins.

As more rooftop renewable systems tie into the grid, some utilities—especially the investor-owned utilities (IOUs) that provide electricity to about 70% of the U.S. population—are loath to let go of their lucrative earning position. Last year, IOUs' total revenues topped $200 billion.

There's a disconnect when it comes to pairing solar and the grid, and that's because the utility business model doesn't match up. Of course IOUs want to protect their interests—they have a pretty cushy setup. As monopolies, they have guaranteed profits from a captive market. Beholden to their investors, they also have long-term investments on which they demand a "reasonable rate of return."

David Roberts of Grist sums it up most succinctly: "Utilities do not own that distributed generation; it's an investment upon which they receive no returns. And it represents a reduction in demand for what they are selling, a reduction in use of their grid infrastructure, and a reduction in the need for future power infrastructure."

Under net-metering programs, utility customers who have solar-electric systems earn credits at the utility's retail electricity rate for the energy their systems produce. Homeowners with systems that produce as much energy as the home consumes annually can zero out their bill. Good for the consumer; bad, say the utilities, for them. They cry foul, claiming that these grid-tied PV system owners are having their cake and eating it, too—using the utility grid and services without contributing to offset the utility's fixed costs. As more people take advantage of net billing, many utilities say that someone—customers who don't have PV systems, specifically—will have to pick up the tab.

As a homeowner with a grid-tied PV system that zeroes out my household's annual electricity use, I don't have a problem paying a *fair* amount to the utility for using their services and infrastructure. After all, my household relies on the grid at night and to fill in the energy gaps on cloudy days. And some IOUs are doing just this—implementing a small monthly service fee. However, others are proposing the development of a more stringent tariff that essentially values distributed energy production at a wholesale, not retail, rate. In other words: Sayonara, net metering.

Not so fast, says a January 2013 report by energy consulting firm Crossborder Energy. The study's authors examined claims by California IOUs that "the state's net energy metering (NEM) policy causes substantial cost shifts between energy customers with solar photovoltaic (PV) systems and other nonsolar customers, particularly in the residential market." And what did they find?

"Recent changes in residential rate design," says the report, "and updated models of the costs that the utilities avoid when they accept NEM power exported to their grids show that NEM does *not* [emphasis added] produce a cost shift to nonparticipating ratepayers; instead it creates a small net benefit on average across the IOUs' residential markets." The report goes on to say that "NEM is even more cost-effective for nonparticipants in the commercial, industrial and institutional (C&I) market."

The paper points out that rooftop solar's economic benefits—an estimated $92.2 million—far outstrip the utilities' costs of managing net-metering programs and lowered revenues. The study points out that rooftop solar systems also:

- Save on expensive fossil-fuel-based electricity
- Reduce the need for new transmission and distribution infrastructure
- Reduce electricity line losses, since the solar electricity generated is first used at the source
- Save on the cost of managing power delivery
- Save on the cost of meeting carbon and RE requirements.

So how can we solar users and consumers protect our net-metering agreements? It's ultimately the lawmakers who will decide this, so contact your state legislators and ask them to support net billing and other clean energy incentives. Let them know that it's important to keep rooftop solar moving forward—and unacceptable for the utilities to take even a small step backward.

—Claire Anderson, for the *Home Power* crew, with special thanks to David Roberts at Grist.com for his illuminating series on utility electricity. You can read his three-part series at http://bit.ly/RobertsOnEnergy.

Think About It...

"Just as fossil fuels from conventional sources are finite and are becoming depleted, those from difficult sources will also run out. If we put all our energy and resources into continued fossil fuel extraction, we will have lost an opportunity to have invested in renewable energy."

—David Suzuki, scientist

contact us

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The State of PV Module Manufacturing

By the end of 2012, installed prices for PV systems had fallen to $5.04 per watt in the residential market, $4.27 per watt in the non-residential market, and $2.27 per watt in the utility market. And while the price drops have prompted record numbers of installations, the sharp decline, due in large part to a global oversupply, has put a financial strain on PV module manufacturers worldwide.

Multiple factors—including overproduction by Chinese manufacturers and waning solar subsidies in Europe—drove the oversupply. Shrinking profit margins have caused solar companies across the globe to exit the market, either by closure, bankruptcy, or restructuring/acquisition.

Between the beginning of 2010 and early June of 2013, approximately 900 megawatts of module-manufacturing capacity in the United States has gone offline, according to Shyam Mehta, senior analyst with GTM Research, a solar market analysis firm based in Boston.

However, with some exceptions, most of the now-defunct solar companies are small- or medium-sized startups, such as Abound Solar, Evergreen Solar, and Solyndra, that focused on unique or specialized technologies, according to John Smirnow, vice president of trade and competitiveness for the Solar Energy Industries Association (SEIA).

"Because the global oversupply has driven profit margins down, it's been hard for young companies to grow and take flight. These startup firms need time to get their costs down by scaling up manufacturing—and this competitive environment does not allow for that," says Smirnow. "Solar companies, big and small, are having to sell below cost to survive, and most young companies simply can't afford to do that."

An ongoing trade war with China—the country that accounts for more than half of the world's solar-module production, with the majority exported to the United States and Europe—has exacerbated the decline in stateside manufacturing. In the United States, the Coalition for American Solar Manufacturing (CASM)—a group of manufacturers led by SolarWorld Industries America—filed an antidumping complaint citing unfair competition from Chinese companies. Last year, a federal investigation concluded that the Chinese government provided unfair subsidies to its domestic producers and then flooded the market with low-cost modules to undercut U.S. competitors.

Thin film PV manufacturer FirstSolar is headquartered in Tempe, Arizona, and has manufacturing facilities in Perrysburg, Ohio, and Kulim, Malaysia.

Courtesy FirstSolar

As a penalty, the Department of Commerce's International Trade Administration created duties on solar imports of crystalline silicon solar products made in China. The tariffs were retroactively applied to all Chinese PV cell and module imports that entered the United States beginning December 3, 2011. However, a loophole in the tariff decision excludes Chinese modules made from cells manufactured in a third country. In February, CASM, led by SolarWorld, filed an appeal with the U.S. Court of International Trade in New York to compel the Commerce Department to close the loophole.

Whether the penalties continue to help stabilize PV pricing will largely depend on the accuracy of customs reporting and whether companies take advantage of the loophole. Meanwhile, global trade tensions continue to escalate

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Born in the U.S.A.?

Only a handful of companies still manufacture PV modules in U.S. factories. Although some companies advertise that their products satisfy the "Buy American" requirements, be sure to read the fine print: The products may not be manufactured wholly in the United States as you might assume. The BA requirements also offer loopholes that allow for modules to be classified as "domestically manufactured" even though their cells are made overseas.

Only products that qualify for the "Made in U.S.A." standard through the Federal Trade Commission are "all or virtually all" made in the United States from U.S. materials. However, the FTC does not pre-approve advertising or labeling claims, and although a company that makes false statements can be fined by the FTC, few are investigated.

If you want to support U.S. jobs and U.S.-based companies, here are a few module manufacturers with a U.S. presence.

- **FirstSolar** is headquartered in Tempe, Arizona, with manufacturing facilities in Perrysburg, Ohio (and Malaysia).
- **Kyocera**, a Japanese company, opened its San Diego plant in 2010, where some of its modules are assembled.
- German PV module manufacturer **Mage Solar** opened its U.S. assembly plant in Dublin, Georgia, in 2011. PV cells and other materials are sourced from domestic and foreign vendors, and then assembled into modules at that location.
- Since 2003, Japanese **Sharp** assembles PV modules at its Memphis, Tennessee, plant.
- **SolarWorld** produces silicon solar crystals, wafers, cells, and modules in the United States from U.S.-sourced materials. Every step of manufacturing the crystalline silicon PV modules—from growing silicon crystals to assembling panels—happens at the company's Hillsboro, Oregon, plant.
- **Suniva**, a U.S. manufacturer of crystalline silicon PV cells and modules, is expanding its module assembly operations at its Norcross, Georgia, headquarters, increasing its capacity for Buy America Act-compliant modules. The company's modules have 85% U.S. content, which includes solar cells produced at its U.S. plant. Some assembly of those components into the actual finished modules, however, happens in Asia.
- In 2011, **SunPower** partnered with Flextronics to build a plant in Milpitas, California, that is capable of producing 75 megawatts of PV modules per year.

For the complete manufacturing story in the United States, says Smirnow, you must look beyond just module assembly. "There are lots of other components that go into a solar energy system," he says. "Many of which are increasingly made in the United States. We'd like to see our domestic solar supply chain grow."

Smirnow says that there are several facilities across 28 states and the District of Columbia that produce the primary components of PV systems, including solar-grade polysilicon, ingots, wafers, cells, and inverters. U.S. glass and steel manufacturers also provide essential components for utility-scale solar power plants, including concentrating solar power projects (CSP). DuPont operates a plant in Circleville, Ohio, that produces Tedlar, a white film material used as back sheet for solar cells. Hemlock Semiconductor produces polycrystalline silicon for PV cells at its plant in Midland, Michigan. Global Solar Energy operates a Tucson, Arizona, facility that supplies the CIGS cells to Dow Solar, which then assembles them into flexible solar shingles at its Michigan factory. Unirac manufactures some of its rack products in Albuquerque, New Mexico. Genmounts manufactures its racking system at plants in Texas, New Jersey, New Hampshire, Pennsylvania, and California. Several inverter companies—Exeltech, SMA America, and Power One, to name a few—have U.S. manufacturing facilities as well.

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elsewhere, with Chinese manufacturers facing antidumping investigations in Europe and India that may result in new tariffs on Chinese-made goods. In early June, Europe imposed provisional tariffs on imported Chinese solar products of 11.8% from June to August 2013. After August 6, the average import duty increases to 47.6%. The decision whether or not to make these charges permanent will be made in December. Additionally, Chinese manufacturers have filed complaints, prompting the Chinese government to launch its own antidumping and antisubsidy investigations into solar-grade polysilicon imported from the United States, European Union, and South Korea.

Since the tariffs went into effect, SEIA reports that Chinese module imports into the United States have decreased by 86.8%, but the effect on U.S. manufacturing and jobs is not clear. The Solar Foundation reports that U.S. solar companies lost about 8,200 manufacturing jobs last year (about 22% of the total) and are expected to regain about 2,600 this year. According to Solar Foundation stats, nearly half of the 119,000 U.S. solar workers are installing PV modules, while only a quarter are employed manufacturing them.

Predicting the Future

In the short term, there may be little relief for PV module manufacturers everywhere. GTM Research predicted that average crystalline silicon PV module wholesale prices were likely to drop to $0.61 per watt by 2015, and that, globally, as much as 21 gigawatts of PV module manufacturing capacity will go offline by 2015 as the market continues to reconcile the supply/demand imbalance.

Despite the declining number of U.S.-based PV module manufacturers, the United States accounted for 11% of all global PV installations in 2012—its highest market share in at least 15 years. According to the market data compiled by SEIA and GTM Research, PV installations grew 76% over 2011, to total 3,313 MW in 2012. This was driven in large part by utility-scale projects and the growing popularity of residential solar leases. SEIA and GTM Research forecast that 2.3 GW of PV will be installed in 2013, growing to nearly 9.2 GW in 2016.

—Kelly Davidson

Courtesy SMA

SMA TL-US Inverters with Standby Power Supply

SMA America (sma-america.com) released its new line of Sunny Boy batteryless inverters. Built for the North American PV market, the transformerless inverters are available in 3, 4, and 5 kW models. The inverters include a "secure power supply" dedicated AC outlet, delivering up to 1,500 watts in daylight during a grid outage—*without* needing a backup battery bank.

Features include an extended operating temperature range (-40°F to 140°F), which is helpful for systems requiring outdoor inverter mounting, and two maximum power point (MPP) trackers for combining arrays mounted in two different orientations. With a DC input operating range from 125 to 600 V, these inverters offer a wider input voltage range than their predecessors. An integrated arc-fault circuit interrupter (AFCI) meets the 2011 *National Electrical Code* section 690.11. Inverter CEC efficiency is listed at 96.0% to 96.5%.

—Justine Sanchez

Thomas & Betts

Ty-Rap PV Array Wire Management Clips

Courtesy Thomas & Betts

Thomas & Betts' (tnb.com) new weather- and UV-resistant nylon cable clip can accommodate up to four 10 AWG conductors running at a right angle to the module frame, which can be helpful for organizing PV interconnect and home run wiring. They can be slid up or down the frame, creating tension to eliminate sagging cables. Ty-Rap clips fit module frames ranging from 0.060 to 0.120 inches thick, and are rated to operate in temperatures from -40°F to 220°F.

—Justine Sanchez

Energizing Education

Even when school is out for the summer, there are still countless organizations hard at work developing unique opportunities to engage students with solar energy. Whether you're a teacher, student, parent, or solar energy advocate interested in bringing solar energy education to your area schools, here are a few programs helping solar shine in classrooms nationwide.

We Share Solar • wecaresolar.org

Since 2008, the nonprofit We Care Solar has sent approximately 300 of its signature yellow "solar suitcases" to rural health clinics and medical facilities in 25 countries. Cofounders Dr. Laura Stachel and Hal Aronson developed the suitcase-sized solar-electric systems to power LED medical task lighting, charge cell phones and batteries, and provide electricity to 12 VDC devices. The turnkey PV system fits in a watertight, protective hard case.

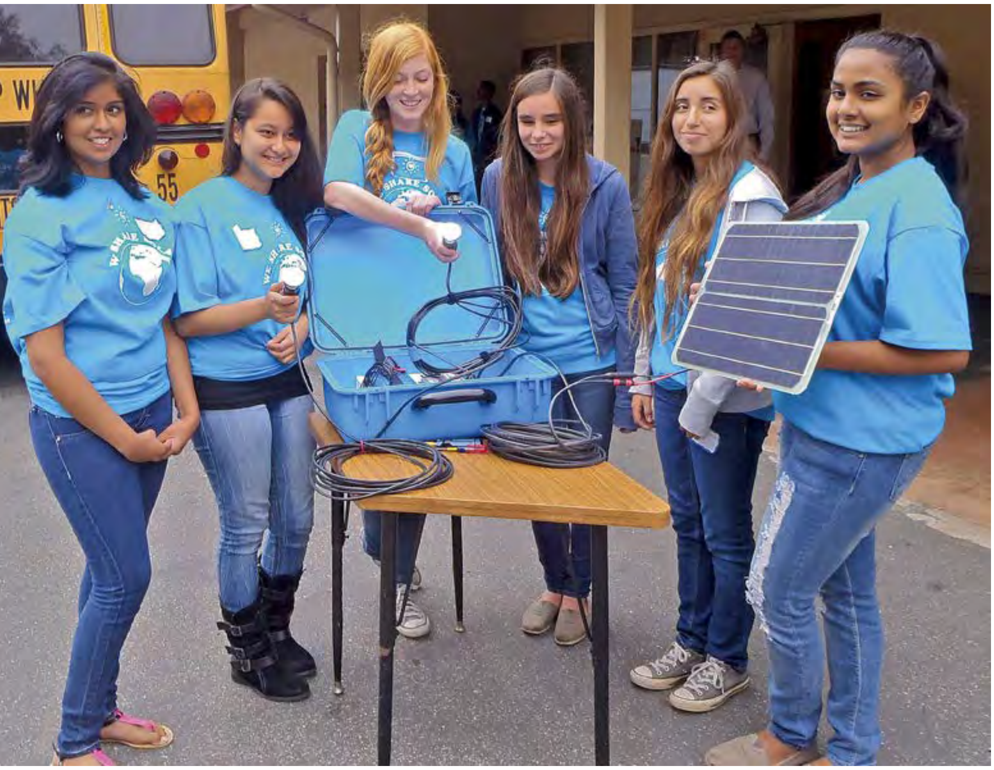
As word of the solar suitcases spread, WCS began receiving more and more requests from orphanages and schools without electricity. To serve this growing need, WCS launched a new program called We Share Solar (WSS), which empowers U.S. students to build small, portable PV systems for schools and orphanages in developing countries. The project teaches students about solar electricity and energy efficiency, as well as selfless giving. Aronson, a solar energy designer and educator in California, adapted the design of the WCS medical solar suitcase to be used as a teaching tool in classrooms. Key modifications included using crimp-on connectors to eliminate wire stripping, as well as separating the wires so students can make the individual connections themselves and better understand the circuits.

Students, teachers, or schools in the United States raise the money to buy the suitcase assembly kit (about $1,200). Prior to the suitcase's assembly, students learn how circuits and electricity work. As a class, the students work with their teacher to assemble the components into an operating 200-watt PV system. Once it has been assembled, the students select a destination for the suitcase—typically a school, orphanage, or organization operating in a developing country. Through the selection process, the students learn about energy poverty and sustainable development in other countries.

A WSS partner trains the recipients in the suitcase's use. The recipients are often asked to contribute toward the shipping costs, or give back to WSS or its partner in some way. "When the recipients contribute to the suitcase, in whatever way they can, we've found they value it more and take better care of it," Aronson says. As part of the project, the U.S. students are encouraged to write notes to the recipient students abroad and follow how the suitcase is used.

Since the program's start last year, U.S. students have built 45 *blue* solar suitcases as class projects or special workshops in middle schools, high schools, or community colleges across the country—from Valencia College in Orlando, Florida, to Montgomery High School in Santa Rosa, California. The suitcases now provide light and electricity to thousands of children and students living in Haiti, Guatemala, Kenya, Costa Rica, and a host of other countries. The solar suitcase can charge up 10 to 20 high-efficiency e-readers in one day, and several organizations are working to distribute the readers to needy schools. In cooperation with Pennies for Posho, some suitcases have been installed at a girls' dormitory at New Hope Orphanage in Bugiri, Uganda, providing a safer environment where the girls can study and play.

Students proudly displaying their We Share Solar suitcase project, slated for a school or orphanage in a developing nation.



Courtesy We Share Solar

Schools For Salone helped deploy the suitcases to two schools in Sierra Leone—including the Children in Crisis Primary School, which serves 470 students in Upper Allentown.

Courtesy Solar 4R Schools

The 2.8 kW demonstration Solar 4R Schools project at Hosford Middle School in Portland, Oregon.

Solar 4R Schools • solar4rschools.org

Developed and managed by the nonprofit Bonneville Environmental Foundation (BEF) in Oregon, Solar 4R Schools (S4RS) provides hands-on kits and lesson plans for K-12 schools interested in teaching solar, wind, and other renewable energy technologies. Grade-appropriate activities range from teaching the basic principles of solar thermal and passive solar heating to teaching solar energy basics through sun-made art with sunlight-sensitive paper. Perhaps most importantly, the program acts as an integrator, partnering schools with grants, sponsors, and donors to cover the installation costs of grid-tied PV systems, typically 2 to 5 kilowatts in size. In other cases, the program assists schools in creating lesson plans to complement an existing PV system.

"Our bull's-eye is middle school. During those years, the science curriculum is focused on energy transformation and circuits. Solar energy is a natural fit," says Craig Collins, S4RS program manager. "Having a PV system on campus, close and visible, demystifies the technology. Students can monitor the power production with data displays in the classroom and engage with the technology. Just like recycling containers are in most schools, we hope PV arrays will one day be on every school." The key to the program's success, Collins says, is a strong teacher champion who applies to the program and engages key stakeholders, from administrators and parents to custodians. To receive a solar-electric system, schools agree to own and maintain the system after installation. In turn, the school receives an exciting learning tool and all of the clean, renewable electricity produced.

Since its 2005 launch, the program has worked with more than 200 schools nationwide. In April, 2013, the program worked with Continental Tire and MLS WORKS to fund a 2.8 kW solar demonstration project, RE education materials, and live data monitoring to Hosford Middle School in Portland, Oregon. The system is prominently displayed in the schoolyard, providing a real-world example of solar energy technology for students and visitors. In Vermont, Champlain Valley Union High School received a 1 kW PV system and an RE education package funded by snow sport manufacturer Rossignol and Protect our Winters, a nonprofit dedicated to reversing global warming. In Seattle, Washington, the cafeteria roof at Dimmitt Middle School is home to a 2.6 kW solar installation, primarily funded through a grant from Seattle City Light.

Solar Energy International • solarenergy.org

Solar Energy International (SEI) has been providing online and on-site solar training and renewable energy education from Colorado for more than 20 years. In 2002, SEI launched its Solar In the Schools (SIS) program to help educators teach about energy—both how it is used and where it is sourced. Educators come from across the country to participate in K-12 professional development courses—including Teaching Solar Energy to Kids workshops that provide an overview of lesson plans and hands-on elements that can be employed in the classroom. Activities include understanding how much energy can be generated with pedal power, using simple solar ovens, wiring solar cells, measuring solar electrical output, and powering DC toys and water pumps with photovoltaic cells.

"These teachers return to their schools as energy champions, armed with hands-on techniques and materials that can effectively convey renewable energy concepts to students of all ages," says Noah Davis, SEI's SIS program manager. "Children inherit what we give them. Our goal is to give them the knowledge, skills, and inspiration they need to overcome current and future energy challenges."

With its SIS van packed with hands-on teaching equipment and displays, the program also delivers presentations to primary and secondary schools operating in the Colorado region. These presentations reach more than 2,000 students annually, one classroom at a time. SIS also offers RE Science Kits to regional teachers through its lending library.

This year, the program launched the "Solar Rollers" race series—a solar-powered radio-controlled car race geared toward high school students interested in electronics, mechanical systems, and renewable energy. Students from several Roaring Fork Valley schools in Colorado used math

Courtesy SEI

The Solar Energy International educational crew, along with students and staff, show off their 2013 solar rollers.

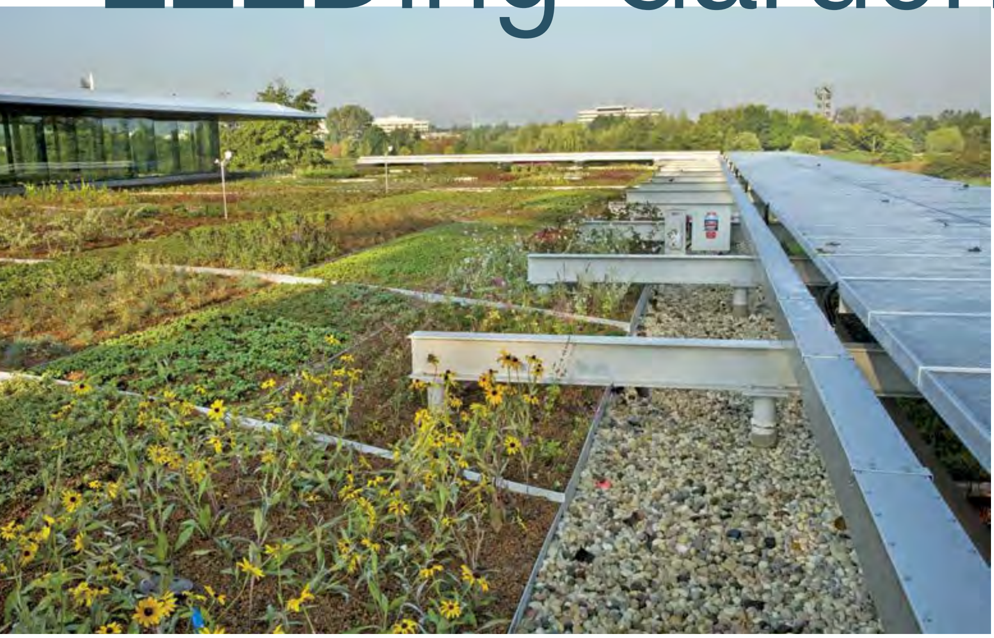
and science skills to research, design, and build custom RC cars powered solely by the sun. While simpler solar car races are nothing new in solar education, SIS aims to create a national "Solar Rollers" car race—the first race of its kind. The high school competition aims to fill the gap between the National Renewable Energy Laboratory's Junior Solar Sprint event (in which middle school students race simple solar dragsters along guide strings) and the American Solar Challenge (in which teams of university engineering students race complex solar vehicles in hopes qualifying for the World Solar Challenge race across Australia).

This year's prototype "solar rollers" are energy-efficient and lightweight, featuring custom components fabricated from carbon fiber, with roughly 40-watt hand-built arrays soldered together by students. Per the guidelines, cars started with "empty" batteries 30 minutes before the race, when they were placed at the starting line to begin charging in the sun. Cars reached speeds greater than 20 miles per hour, following a winding tennis-court-sized racecourse.

In May, the teams traveled to the National Renewable Energy Lab in Golden, Colorado, to demonstrate and race their cars against each other on a small track, in the first-ever, official Solar Roller demo. In the future, the race will bring teams from across the country to compete. Students work together building cars with guidance from a parent, teacher, or coach to compete in race and design categories. Each Solar Roller will cost the team about $1,000 in parts and tools—a challenging but achievable fundraising level for a high school, Davis says.

—Kelly Davidson

LEEDing Gardens to the Sun



The building's green roof and PV modules.

When the Chicago Botanic Garden decided to build a state-of-the-art plant science center, one of their goals was to achieve Leadership in Energy and Environmental Design (LEED) Gold certification. In 2010, one year after the building opened, they did just that. The Daniel F. and Ada L. Rice Plant Conservation and Science Center, which houses laboratories devoted to the study of plants and soil, received points in six categories, including sustainable sites, water efficiency, and energy.

To qualify for LEED Gold, the design team, from Booth Hansen Chicago, hired consultants from the nonprofit energy-efficiency think tank Rocky Mountain Institute (RMI). The construction documents were already complete by the time RMI joined the team, and they made numerous suggestions that resulted in rethinking the entire project. "The biggest energy consumption is the mechanical systems," says Jean O'Brien Gibbons of Grumman/Butkus Associates, the project's engineering consultants. "We really had to stop and re-evaluate all the systems."

"They initially figured, 'Oh, we've missed all our opportunities,'" says Cara Carmichael, a senior consultant for RMI. "But that wasn't at all the case."

One of the key design upgrades RMI made was to add more energy-efficient clerestory windows—reducing lighting energy consumption in the atrium by 79%. These low-e windows, along with the building's sloped roof, bring light into the building's inner offices. Light sensors were added to automatically extinguish artificial lighting when natural light reaches a threshold level.

Other suggestions by RMI included the use of recycled materials, such as flooring that incorporates rubber from shredded tires, metal shavings mixed with epoxy for bathroom countertops, and a wall from a black walnut tree that previously stood on the site. Twenty percent of the building's construction consists of recycled materials (half post-consumer and half pre-consumer). Fifty percent of wood used on the project was Forest Stewardship Council-certified.

Water efficiency is maximized through a rainwater catchment system that surrounds the building—including the parking lots. The runoff flows into a bioswale where native plants naturally cool and clean it. This water flows into a lake and is used on site to irrigate plants. Another water-saving strategy included the planting of native plants for landscaping, which reduces the need for irrigation by 50%. In addition, the building uses 30% less water by using low-flow plumbing fixtures and valves.

One of the building's most notable features is its green roof. While the advantages of green roofs are becoming well-known, such as reducing heat gain in the warmer months, this one has an important difference. The 16,000-foot garden serves as an outdoor laboratory, as many new varieties of plants are tested to see which are best suited for rooftop planting in the Midwest.

Daniel F. & Ada L. Rice Plant Conservation and Science Center.

Courtesy Chicago Botanic Garden (2)

The roof also features a 54.7 kW batteryless grid-tied PV system, which offsets about 5% of the building's electricity use, saving the Garden more than $10,000 per year. The Sanyo bifacial modules produce power from both sides of the module, and may produce up to 130% of its STC rating, depending on the albedo (reflectance) at a site. The modules installed at the Plant and Science Center get approximately 5% to 10% of their energy from reflected light.

The HIT Double Bifacial modules were chosen because they had the highest efficiency rating at the time. They were also considered aesthetically appealing, since you can see through them from below. The decision to use a zero-degree tilt was also an aesthetic one—though this necessitates cleaning at least twice a year, as recommended by their installer, Habi-Tek. Another factor that went into the choice of this PV system was the ability of installers to complete their work entirely from above. The subarrays are cantilevered over the edges of the building, helping provide shade to windows and plantings around the building's perimeter.

—Kathy Kelley

Overview

Project name: Daniel F. & Ada L. Rice Plant Conservation Science Center

System type: Grid-tied PV

Installer: Habi-Tek

Date commissioned: June 2008

City: Glencoe, Illinois

Latitude: 42.1°N

Average daily sun-hours: 3.9

PV system capacity: 54.7 kW STC

Annual production: the sum of production from each inverter equals 63,310 kWh (2012).

Predicted annual production according to PV Watts: 59,573 kWh

Utility electricity offset: 5%

PV Equipment Specifications

PV modules: 288 Sanyo HIT Double, 190 W

Inverters: Four Solectria Renewables 15 kW PVI

Array installation: Custom roof-mount on aluminum frame

Tilt: 0°

Solar on SIPs

A structural insulated panel (SIP) roof has no embedded lumber in the structure, and therefore nothing substantial for attaching PV array and solar hot water mounts. Single or double lumber splines could be put into the panels, or I-joists at 4-foot intervals could be added. However, the thermal bridging that they would create are at odds with the goal of an energy-efficient building. As buildings get tighter and more insulated, thermal bridging plays a relatively larger role in energy loss.

One solution for mounting solar equipment to a SIP roof is to drill completely through the roof, passing a threaded rod through to the bottom skin and placing a large washer under the nut. Since most SIP roofs are vaulted on the inside, though, few homeowners would be OK with seeing the nuts and washers on their ceilings.

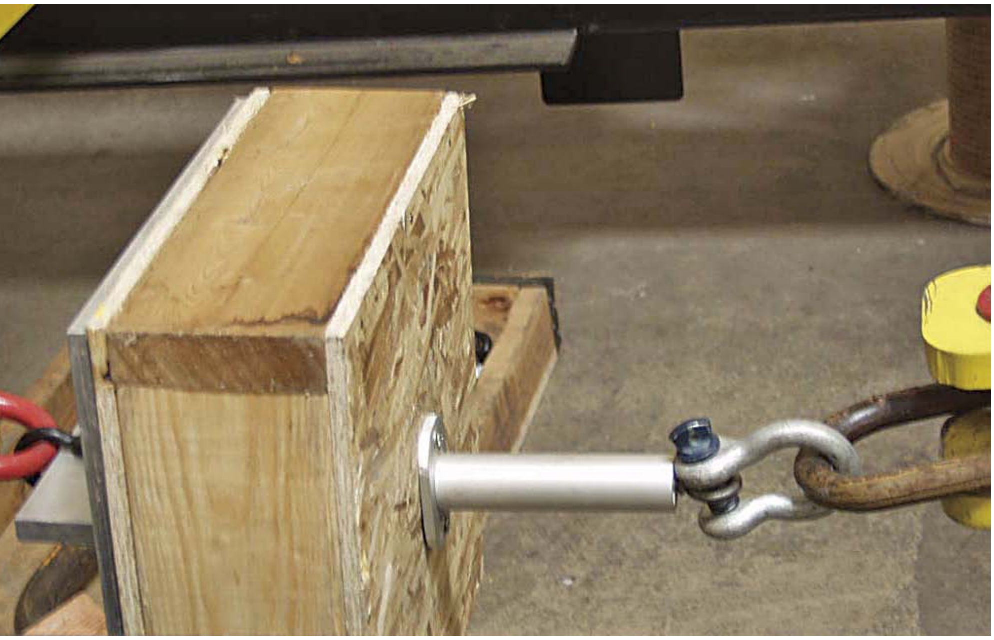
On a recent SIP project in Hood River, Oregon, the PV contractor asked for test results for fastener pull-out so he could design an appropriate rack system. An independent test at Rigging Products in Portland, Oregon, provided the figures he needed. The first test, using hollow-wall anchors, gave a result of 405 pounds to failure. Dividing by three (which accounts for the industry standard safety factor) gives a working load of 135 pounds. Failure occurred as the hollow-wall anchor folded up and pulled through the anchor holes. In an area with 100 mph wind gusts, we did not think a hollow-wall anchor would hold up.

A Toggler Snaptoggle anchor is similar to a toggle bolt but with a stronger cross piece. (Note: Plastic straps are used only for initial placement.) Once in place, the anchor accepts a cap screw inserted from the opposite side of the SIP.

Courtesy Patrick Sughrue (2)

In the second test, two 3/8-inch, high-performance toggle bolts were used. Toggler brand bolts were used with cap screws instead of the original machine screws since the holes in the standoff were 3/8 inch. In hindsight, I would have used 5/16-inch bolts to give a little wiggle room for alignment. In this test, the failure of the SIP—when the OSB skin cracked—occurred at 1,105 pounds, or a working load of 368 pounds.

—Patrick Sughrue



The sample section of SIP, with the solar rack standoff mounted and ready to be tested for pull-through strength.

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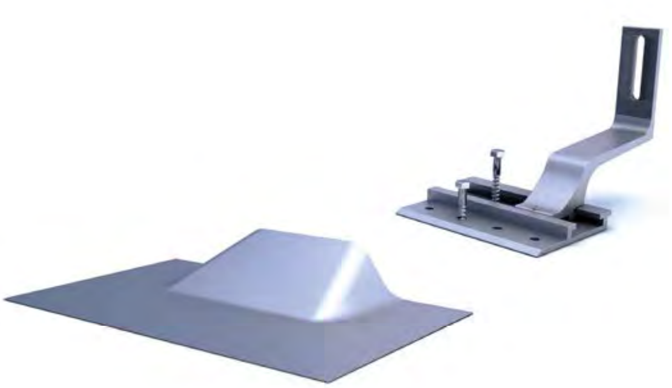

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Skunk Solutions

Kathleen's tale of skunk eviction from her hens' laying boxes ("Home & Heart: Surprise, Surprise, Surprise" in *HP155*) is all too familiar to us. Though we have little more than an acre of land, it is an island of biodiversity surrounded by farms. Consequently, every year finds us trying to evict families of badgers and raccoons while there is still something left of our gardens. Like Kathleen, we make use of live traps for critter abatement, and while we never try to trap skunks, invariably, at least one blunders into a trap each year.

I like her forethought (pre-bagging the trap) when trying to trap a skunk. In our case, since we are not trying to catch the little stinkpots, it is already too late to bag the trap. Instead, my husband holds up a large, black plastic sheet so that he can't be seen by the skunk, then inches toward the trap until he can very slowly drape the plastic over the entire trap. Then, he can grip the handle through the plastic sheet and load the wrapped trap very gently into the back of a pickup truck.

The solution to getting a skunk to leave a space is simple, and could have been used to evict Kathleen's from the hens' nesting boxes instead of using a live trap. Get an inexpensive radio with really good volume and an on-off switch separate from the volume knob. Tune the radio to the most obnoxiously loud music station you can find and crank up the volume, then switch it off. Place the radio as close as possible to the location of the skunk's head and turn it on, then get out of the skunk's path. You don't even have to put the radio in the space with the skunk, unless it is surrounded by acoustical insulation like straw bales.

In the case of the wooden hen boxes, leaning it against the wood box helps by transmitting the vibrations through the whole box structure like a drum. If the critter is in a comfy, dark space, you can give additional incentive by dropping a very bright flashlight into the space before you turn on the radio. The skunk should be gone within a few minutes of this treatment, but be sure that you see where he exits so that you can close up his entry hole immediately. Here's to "Whew!", not "Pe-yew!"

Christina Snyder • Manchester, Michigan

Sometimes I feel like trapping is my first profession. When any of the myriad of varmints in our little bit of paradise shows up at the hen house, we trap them. The attraction of such an easy source of protein is enough to keep any varmint coming back for more. We could not just scare the skunk away. Everybody likes chicken and eggs and laying mash and a comfy, warm, dry place to sleep. I like the idea of a concealing shield of plastic and have tucked away that nugget of good sense for when I may need it.

I once came upon a skunk in a garbage can of cat chow when feeding a neighbor's cats. I put the garbage can lid back on and got Bob-O. We loaded the closed garbage can into the back of my old Subaru wagon. We hadn't gone a half-mile before the skunk sprayed inside the can. We came to a screeching halt. We both jumped out, opened the hatch, grabbed the can and holding our breath, ran it out into a field. Bob-O whipped off the lid and kicked the can over. Again, we ran. I came back the next day to get the empty garbage can. Lots of Pepé Le Pew jokes after that.

Kathleen Jarschke-Schultze •
"Home & Heart" columnist

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Schneider Electric

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America's Real Problem with Solar Energy

Each day, our solar industry sits down and whittles the unsightly knots off the tree we call solar energy. We, as a group, spend more time than we should pointing to one of a growing number of reasons why solar energy isn't taking hold in America: that perhaps our government incentives were cut too quickly, that our state's SREC program is broken, that the net-metering requirements aren't strong enough.

Not that those things wouldn't further bolster our industry, but go out and ask your friends and family about solar energy. The problem with solar energy in America isn't a result of the deficiencies of the incentives (although improved incentives would set this industry on fire), it's with the astounding lack of knowledge about a technology that can transform the lives of everyone in our nation and around the world.

Do you know how much of a return on your investment you would receive if you installed solar on your home or business right now? Do you know enough to even estimate the amount of money you'd save over 25 or 30 years? Would you guess that solar energy is actually a financial investment with returns more solid than stocks and bonds? Do you know that solar energy works in colder climates and on cloudy days? Did you know that nearly any solar installation company will gladly provide you these numbers for free? Not many Americans can begin to answer these questions.

A PV-powered community—in Germany.

Courtesy ASES

Our industry is still young. We're not the like the big corporations with seemingly unlimited budgets to pay for lobbying and well-placed television commercials. We reach out to a media who has no idea what solar energy really is. We have so much passion to help our country, and yet many nights feel like we are strangers to all. You can't explain the entirety of the benefits of solar energy in 140 characters. It's both a great and terrible feeling to know what you can give people if only they knew what you could give. It's unrequited love in the form of a solar panel, and we have thousands upon thousands of them waiting to find good homes.

We're not at war with the other energy companies, either. People will still need oil for a very long time. No energy employee from fossil-fuel plants will end up on skid row because of solar anytime soon. What about utility companies? Utilities are actually required by the state governments to purchase renewable energy, and most of them have employees that are themselves dedicated to the renewable energy sector. They are not our enemies, either. Banks? Banks are in the business of lending—they would love for solar modules to be included in home appraisals. The real estate market? Solar panels on a home sells that home much easier and the real estate market is not our enemy.

What we do face is a nation who just doesn't understand us. We're right here, and there's not been a better time to go solar than today. The systems pay for themselves typically about halfway through their life cycle, and the rest is yours to keep. There is a 30% federal tax credit for installing a solar energy system on a home or business. Many states have similar tax incentives to add. In many states, you can get paid to send your excess energy back to the grid—or at least use it to offset future energy use. You can also sell solar credits to utility companies. And if you own a business, there's a good chance you can depreciate the entire installation in one year. Did you know you'll see, on average, a more steady return from "going solar" than folks have seen on stocks and bonds? Most people don't know that.

So here we are: an industry with such a powerful solution for our country and citizens. We are, as a nation, being passed up by other countries. Look at countries like Germany and what they are doing with solar energy—it's amazing. But we in the United States can't afford to tell everyone what they need to know. We, instead, have to rely on people finding us. We try to reach out, but we just don't have the financial size

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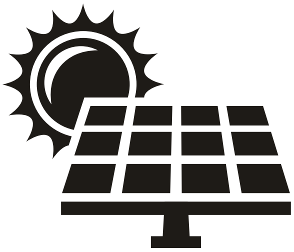

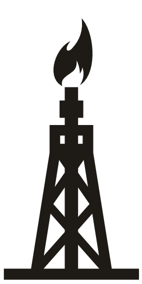

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and subsequent influence to achieve the success solar energy deserves. The solar industry is young, lacking the means to get the word out in the way that giants of other industries are able to do.

We can see what is ahead, and we'll still be here waiting. And when you say "Oh man, I wish I knew about this sooner," we won't judge. We'll love and support you just the same. It was Marty McFly in *Back to the Future* who said: "I guess you guys aren't ready for that yet. But your kids are gonna love it." See you soon, America.

Terrill Dines • Honeycomb Solar

Nothing is Free

Reading the articles "Cruising with Renewables" (*HP152*) and "EVs Don't Cost Much to Run" (*HP153*) brings me to some reflections about this difficult matter of energy and its associated costs. And it's true: The math is tricky—quite tricky.

Any form of energy has its price, but both articles suggest that these particular end users pay little or even nothing. From the natural way of seeing life, how can we be entitled to something for nothing? Let's look at some more details.

- Coal: According to the U.S. Department of Energy and a report published in the *Annals of the New York Academy of Sciences*, the levelized cost of coal is $0.28 per kWh. This includes fuel cost, operation and maintenance costs, and externalities such as subsidies, environmental cleanup, and air and water pollution. What we pay on our utility bill is just a fraction of this.

- Nuclear: This technology has hit taxpayers for more than $150 billion (more than the Vietnam War and the U.S. space program combined).

- Gas: It burns cleaner that coal and we're discovering new ways to extract and burn it, but to an extent, we'll end up with the same social consequences as we have from extracting coal.

- Solar: For big solar plants, land disturbance is a reality, since large arrays interfere with the flora and fauna's life cycles, and change erosion and drainage. Something that is not really taken seriously—the reflection of the sun from the system—can harm the aerial traffic. Reflecting the sun's light back into the atmosphere has unknown consequences. We also are just beginning to recycle old solar panels responsibly.

- Wind: This seems to be the technology with the fewest side effects of all, and brings no health consequences, national security, nor environmental effects that nonrenewables so abundantly present.

- Subsidies: One study showed that, from 1989 to 2009, oil and gas industries received almost $5 billion per year. Nuclear energy received about $3.5 billion per year; biofuels, $1 billion; and renewables, about $300 million ("What Would Jefferson Do? The Historical Role of Federal Subsidies in Shaping America's Energy Future;" bit.ly/HistSubsidies).

The final question still remains: How much does a kWh really cost? If it is free for me, someone is surely paying for it in many forms and ways.

Uwe Frischknecht • via email

Solar is Da Bomb

I read the letter ("Mailbox" in *HP154*) from a Joey Dobbins that concerned a "jaded" non-conservative slant on an article in *HP152*. The following morning (March 12, 2013), National Public Radio interviewed another Dobbins—a James Dobbins of The Rand Corp. This Mr. Dobbins explained in no uncertain terms how the U.S. military must strike the Syrian air force with stealth bombers and drones: Catch 'em on the ground, wipe 'em out, and, at that point, the opposition can fight 'em on the ground. Mr. James Dobbins also quipped that we abandoned Afghanistan in the 1990s, which resulted in our current problems there.

I think we should ignore both Mr. Dobbins, and drop massive amounts of solar ovens, PV water pumps, PV light plants, and other high-tech renewables on any country that we don't agree with. It's probably less expensive.

Arthur deVitalis • via email

write to:

mailbox@homepower.com

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

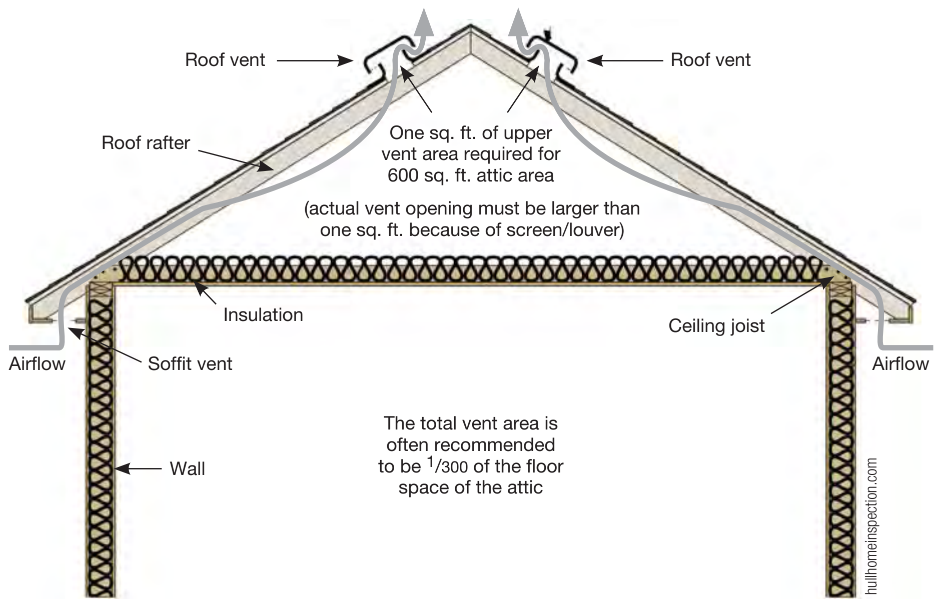
Published letters are edited for content and length. Due to mail volume, we regret that unpublished letters may not receive a reply.

Powered Attic Ventilation

According to a paper by John J. Tooley Jr., Natural Florida Retrofit and others, powered attic ventilation is counterproductive and, in some cases, dangerous. Is this paper wrong, or are proponents of powered attic ventilation unaware of the problems?

Barry Elkin • via email

Recommended Attic Ventilation



The purpose of powered attic ventilation is to remove heat from an attic so cooling loads are reduced. The ventilators exhaust hot attic air while drawing in lower-temperature ambient air. This reduces heat conduction through the ceiling to living quarters below. A typical control strategy is to use a simple thermostat that turns on the attic fan once a certain temperature is reached, and turns off the fan once the attic is sufficiently cooled.

The authors of the paper you mention discovered many instances of attic ventilators causing depressurization of the attic. Although they do not address the root cause, it would seem that either the ventilators are oversized or the intakes are undersized. Whatever the cause, a depressurized attic could cause air to flow from the living space to the attic. This could, according to the authors, cause energy loss, indoor air quality issues, and decreased thermal comfort. They do briefly address some possible remedies to the main problem—proper sizing of fans and intakes. And airflow can be minimized by proper sealing, though the vast majority of houses are quite leaky. However, they do question the basic effectiveness of powered attic ventilation—does the strategy really save energy?

Unfortunately, the energy savings rarely exceed the energy costs of running a powered attic ventilator. This is because most attic ventilators use a fair bit of energy— a typical 250-watt fan would use 180 kWh per month if run continuously (60 kWh per month if used 8 hours per day). To put this electricity use in perspective, the average U.S. home uses about 950 kWh per month.

Heat flow from the attic to the living space comes in several forms. Besides conduction (direct heat transfer from material to material), there is also considerable radiation heat transfer. Solar radiation is absorbed by the roof, which in turn radiates heat in all directions, including toward the ceiling insulation. Ceilings should be well-insulated to significantly reduce heat flow to the living space, even with very high attic temperatures.

In my opinion, using electricity to ventilate an attic for reducing cooling loads is rarely justified. Instead, there are techniques that have better results. Air-seal the attic floor/interior room ceiling, and maximize the insulation there. This is usually much more effective in reducing heat transfer than attic ventilation. A well-designed *passive* attic ventilation system, with adequate ventilation openings, can be implemented. Half of the ventilation openings should be as low as possible on the roof, and the remainder as high as possible. The hotter, less-dense air rises through the high openings, while replacement air comes in through the lower openings.

Solar-powered attic fans can help, as long as there is adequate and low intake vents. Powered attic ventilators should only be used if the other options have been implemented and extreme temperatures persist in the attic, possibly causing premature failure of building materials.

Note that people often confuse attic fans and whole-house fans. A whole-house fan cools a house by pulling air from the house; cool air is allowed to enter through open doors and windows. Most whole-house fans are mounted in the ceiling and push air into the attic. This air then exits the attic through attic vents.

Neil Smith • AirScape Fans

Efficient Lighting

My 80-by-55-foot shop, which has an 18-foot-tall ceiling, is lit with 18 eight-foot-long, high-output T12 fluorescent lamp (FL) fixtures. Although I have a 15 kW solar-electric system to offset my electricity use, I'd like to reduce my lighting load. But when I've compared lumen output of other "efficient" lamps, they still draw nearly the same power. Is my lighting as efficient as it gets?

Dave Zabokrtsky • via email

At this time, it's difficult to improve on the efficiency of straight-tube FLs. They still are the most efficient technology for illuminating large spaces. But you do have a few energy-saving options to consider.

If your fixtures are mounted directly on your 18-foot-high ceiling, the least expensive option might be to lower the fixtures so they can be closer to your work. Then you can simply remove lamps from each fixture as needed to save energy. If your lighting is not zoned, another inexpensive option might be to zone your lighting onto

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LED lighting can often replace traditional fluorescent bulbs, although they are more expensive and not available in all sizes.

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separate switches so you can illuminate only the areas you are using at any given time.

If those options aren't possible or don't save enough energy for you, your choices start to get more expensive. You can upgrade your current T12 lighting to more modern T8 or T5 fixtures and lamps, but the energy savings could take years to offset your investment. (The 12, 8, and 5 numbers refer to the diameter of the tubes, in eighth-inch multiples).

LED options with improved efficiency are now available to replace 4-foot and 8-foot FL fixtures, but they are also expensive and not usually available at your local big box store.

Will it be cost-effective for you to switch your 18 FL fixtures for new, more energy-efficient replacements? For that decision, you'll have to weigh your energy needs against the cost of lighting retrofit options.

Dan Fink • Buckville Energy Consulting

Power, Energy & Power Factor

I am concerned about universal energy measurement standards that are used for certain consumer devices, residential service meters, and appliance rating guides.

Typical energy consumption measurements use watt-hours (Wh) or kilowatt-hours (kWh). Although the units are accurate for 100% linear (resistive) loads, accurate measurements need to calculate the total flow of electrons (amperage) through both the resistive and reactive portions of loads.

The reactive portion of inductive loads (most electronics, microwaves, fluorescent lights, refrigerators/freezers, pumps, etc.) increases the amperage to the load based on the load's power factor (electrical efficiency). Adding a capacitive load (such as a capacitor) can offset the increased current by improving the power factor. There is no "free lunch" when using the wattage of a load and not accounting for any extra energy consumed by its inefficiency.

I've used a watt-hour meter to read the energy consumption of a static-load appliance. This device takes the measured wattage and multiplies it by the cumulative time recorded in the device. Although this same device can measure current, voltage, and power factor, it isn't using these values for energy consumption calculations. I believe this results in very inaccurate readings and misleading information for the consumer.

Our typical service meters are billed using Wh or kWh units, but they are actually measuring volt-ampere-hours (VAh) or kilovolt-ampere-hours (kVAh), because they use the current in the meter. Using VA or kVA should be the true standard for electrical measurement, especially in today's world, where nonlinear loads are far exceeding linear loads. A watt-hours measurement is antiquated and mostly inaccurate.

Rick Simpson • via email

The central issue is that power factor (PF) is *not* electrical efficiency. The two are distantly related, but they're entirely different concepts. Because of power factor effects, any volt-amp measurements will often be wrong. Contrary to what you seem to be suggesting, volt-amps gives an incorrect overestimation of the actual energy consumption.

What's PF? It's the ratio of what is sometimes called "apparent" power to actual power. A PF of 1.0 means that the two are the same. A PF of 0.5 tells us that a 100 W load actually needs a 200 VA source to power it. But it does not mean that it *uses* 200 W, since some of the energy sent out by the source is returned to the source.

PF comes into play in non-resistive—inductive and capacitive—circuits. Ideal inductors consume zero energy, yet plugging inductors into AC outlets draws significant current. It's the same with capacitors. If we multiply their voltage and current measurements,

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Bill Beaty

A standard residential kilowatt-hour meter.

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we'll see major watts of energy flow. But this wattage is wrong, and the actual energy consumption is zero.

Inductors do draw energy from the utility grid—but then they give back every bit! During each cycle of AC, the electrical energy ends up "sloshing" back and forth between the distant generator and the inductor. Resistors don't do this. Their current and voltage alternate at the same time, so the energy flows in just one direction.

While I appreciate your investigative zeal, the present energy meters we use are doing it right. When connected to an inductor, it ignores the volt-amperes and the reversing energy flow. We don't want to measure the "sloshing energy" created by an inductor or capacitor. We only care about the total energy that moves, on average, from generator to appliance. In some specialized applications, having equipment that can measure VA and PF is helpful. But for almost everyone, focusing on watts and watt-hours is the best approach, since this is what we generate, move, and use.

Bill Beaty • amasci.com

12-Volt Power

How much savings result from converting your house from 120-volt AC power to 12-volt DC power?

Lenny Grissom • via email

Shifting to a low-voltage (12 VDC) system might sound more energy-efficient, but unless you have a strictly conservationist lifestyle, it will more likely be complicated, unconventional, and expensive. And 12-volt loads are not inherently more efficient; in fact, line losses at this low voltage require larger (read "more expensive") wire to carry the same amount of energy. Low-voltage systems can make sense in boats, RVs, and small cabins where the wire runs are short, but not in conventional homes.

A better question might be, "How much savings could you attain by switching to energy-efficient loads?" And the answer could be, "25% to 75% of your present energy usage." Energy savings come from reducing energy (kilowatt-hour) usage, which means doing less, or doing the same job using less energy. A typically wasteful North American home uses 25 to 30 kWh per day for nonheating loads. After an energy-efficiency upgrade—including installing efficient appliances and lighting, eliminating phantom loads (appliances that are on even while not operating, like a TV or microwave oven), and possibly some load shifting to solar or other sources—you may be able to get to as low as 6 to 10 kWh per day. That's real savings!

It is sometimes suggested that DC is inherently "more efficient," but for conventional homes, this is rarely the case. On-grid homes are supplied with high-voltage alternating current (AC) from the utility, and converting to low-voltage DC incurs a loss, plus a cost for the conversion equipment. Sometimes, kitchen and other lighting is low-voltage DC, but that requires a step-down converter. If you feel that little black box, it will be warm—wasted energy.

If your energy supply is DC—from solar-electric modules and batteries—you might make a case for having your loads DC as well. I made this case to myself more than 30 years ago, and have lived with some DC loads since. But the reality of modern life is that most available appliances are AC, and very few people (including me) are happy to live with *only* DC. So even if you can run some loads on DC, you still need conversion equipment and/or wiring infrastructure for some AC loads. DC appliances are less available—they are made mostly for RVs and boats—so manufacturers are less likely to strive for high-efficiency standards. And the DC appliances, since they are designed for part-time use, may not be as robust as AC appliances that are used daily in homes.

Overall, higher *voltage* systems will actually be more efficient and more cost-effective, whether DC or AC. Losses in electrical circuits are based on the amperage (electron flow). You can move more energy (kWh) with lower amperage by running it at higher voltage. This is why utility transmission lines run in the thousands of volts, and homes at 120/240 volts. Higher voltage means lower losses with the same size wire, or the same losses with much smaller wire. Copper wire is costly, so higher voltage saves you dollars up front, as well as energy losses throughout the life of the system.

The real savings—in dollars and kWh—is in reducing *energy* usage. Figure out what you actually *need* in lights, appliances, and other loads. Then find the highest-efficiency (lowest kWh) equipment to do the job.

Ian Woofenden • *Home Power* senior editor

Brian Teitelbaum

Wasps like to make their nests in shaded, secluded spaces like those found on the back of PV modules.

Hornets on a PV Array

I have a client who has developed quite a problem with wasps nesting behind her solar-electric array. Does anyone have experience getting rid of them? I'm afraid of the possibility of insecticide sprays or detergents damaging the modules' back-sheets. Is that a legitimate concern?

Dana Brandt • Ecotech Energy Systems

While I've heard it recommended, I'd be wary of using dish or laundry detergents on PV modules because they can contain petroleum surfactants that may damage the back-sheet. (That's why the agents are so effective at stripping oil off bird feathers after an oil spill.) Safer brand insecticidal soap, which uses potassium salts of fatty acids, will kill wasps, and is nontoxic and petroleum-free.

I deal with wasps nesting on my ground-mounted system with a high-pressure sprayer on a garden hose. I have to go out there a few times in the spring to knock down the nests, but the wasps eventually get the idea that they aren't wanted. Two years ago, I had a nest of white-faced hornets build one of their marvelous cone-shaped nests on the back of the array, and it was pretty large by the time I saw it, so I left them alone. I like hornets because they kill and eat yellow jackets. Unlike yellow jackets, if you don't bother the hornets, they won't bother you.

For outdoor-mounted solar-electric equipment, such as inverters and other outdoor equipment enclosures, make sure that you seal or screen any openings that could be potential entryways for insects, birds, or rodents. You still need to ensure that the equipment has proper ventilation, but prevention can sometimes be a great cure.

Brian Teitelbaum • AEE Solar

write to:

asktheexperts@homepower.com

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Green, Greener,

by Patrick Sughrue

Comment & Discuss this article @ homepower.com/156.38

Mark Arinsberg (2)

Active and passive solar pair up to offset this home's energy needs.

The house's narrow footprint makes the best use of the small lot.

Building "green" means lots of different things for homeowners as well as homebuilders. This isn't surprising considering the array of green building certification programs in the United States today, such as Energy Star, LEED, ICC-700 National Green Building Standard, Earth Advantage, and Passive House (see "Green Home Certifications" sidebar).

Despite the differences, the most important element of any green building strategy is maximizing energy efficiency. And the biggest impact you can have on energy use is by building smaller. According to the Oregon Department of Environmental Quality, in the 70-year life of a U.S. home, the largest use of energy is in occupancy use—not the embodied energy or end-of-life deconstruction costs. And smaller homes typically require less energy for their operation. Of course, water conservation, maintaining good indoor air quality, using resources efficiently, embodied energy, and site impact also come into play.

Passive Energy Measures

As a green designer eager to start a new project, I was happy to hear from builder Gary Dorris when he called me in June 2012 to talk about an interesting one. We had worked together on an Earth Advantage Platinum-certified home a couple of years ago—the beginning of a great working relationship.

Gary wanted me to meet Brad Hagen and Linda Niehaus, who were moving to southern Oregon from central Washington. Gary told me they wanted to build an energy-efficient home, but needed help with the design. From the beginning, Brad and Linda knew they wanted their new home to be energy-efficient and oriented for passive solar gain as well as for active solar systems.

Beyond the thermal performance of their home, Brad and Linda had simple design requirements: a single-story, two-bedroom modern home. They also wanted to keep it around 1,000 square feet, which I'm delighted to say is being requested

Greenest!

Mark Arinsberg (2)

Well-placed windows on a south wall let in sunlight for warmth. Honeycombed shades slow heat loss through the windows at night.

Energy Star appliances are part of the whole-house approach to efficiency.

more often these days—the philosophy of living simply is resonating with a broader segment of the population. Much of what I know about smaller living spaces I have learned from architect and author of the "Not-So-Big" books, Sarah Susanka: Quality is better than quantity, define spaces without walls, light is good, and details in the finish can make your home unique and personal.

The first lot Brad and Linda looked at failed to work because of the neighborhood covenants, conditions, and restrictions, which did not allow a modern design. But Linda knew what she was looking for and it did not take too long to find an alternate site: a narrow lot, 45 feet wide by 120 feet long, with a good solar window. Only 10 blocks from the center of town, it was good location for easy access to services.

Envelope Efficiency

I attempted to simplify the decision-making process by offering three different design levels for the building envelope. Gary had worked with several homes constructed with structural insulated panels (SIPs), and appreciated the ease and speed with which the envelope could be assembled, so I specified SIPs for the entire envelope.

Level one was the "green" package, which exceeds the existing Oregon building energy codes for R-values. This design includes R-24 SIP walls, an R-40 SIP roof, and 2 ACH50 (air changes per hour at a pressure of 50 pascals—see "Build It Tight, Ventilate It Right" sidebar). "Greener" is a good step up, with R-32 SIP walls, an R-48 SIP roof, and 1 to 2 ACH50. Both levels one and two were estimated to cut thermal bridging by about 40% compared to standard stud

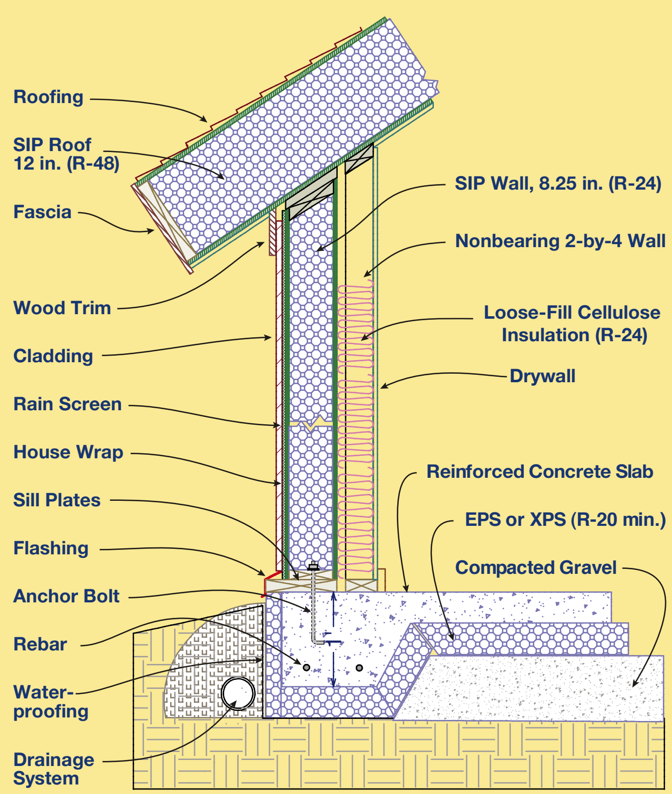
Building Efficiency: 3 Essential Elements

More insulation than code requires. Building codes specify only the minimum standards required by law. In most cases and in most climates, it is easy and cost-effective to increase the insulation R-value over code by 50%. We used to hear that you would be wasting your money to put in more insulation. That statement is relative to the cost of energy, and the severity of your climate.

Relatively airtight. Although an Energy Star home in the Northwest is allowed to have an air exchange rate of four ACH50; many homes built just a few years ago have an ACH50 between 10 and 15. Brad and Linda's home was tested by the City of Ashland to have an ACH50 of 1.2.

Minimal thermal bridging. A thermal bridge occurs wherever a building material connects from the inside to the outside of the thermal envelope. Primary examples include framing studs, top and bottom sill plates, and window bucks, all of which interrupt the effectiveness of insulation.

Insulation that exceeds the minimum code requirements, minimal thermal bridging, and an airtight envelope add up to create a high-performance, energy-saving home.



Custom-cut structural insulated panels go up fast, and insulate well with little air leakage or thermal bridging.

Build Tight, Ventilate Right!

People need fresh air and buildings need to stay dry. Depending on the climate, there are many ways to properly ventilate a home, including using an energy recovery ventilator (ERV) or a heat recovery ventilator (HRV). Like an exhaust fan, an ERV ventilates indoor air to the outside but also brings in an equal amount of fresh outdoor air. When the two airstreams pass each other, most of the heat in the indoor air is transferred to the incoming cooler air. ERVs also transfer moisture in the air, helping maintain appropriate humidity levels within the home. HRVs just assist in fresh air exchange, and don't exchange moisture.

The standard set by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers is 0.30 air changes per hour. This means that, about every three hours, almost all of the home's indoor air is exchanged with fresh air. Along with the fresh air, the indoor relative humidity should be kept below 60% to inhibit mold growth.

construction. This improvement can result in heating and cooling energy savings of 15% to 20%.

Brad and Linda selected level three—the "greenest" option, which is closer to Passive House standards or for clients who are contemplating a net-zero annual energy use home. This design uses an insulated nonbearing stud wall constructed with 2 by 4s along with an 8.25-inch SIP, resulting in a 12-inch-thick wall. Separated from and on the interior side of a SIP, this construction method eliminates almost all thermal bridging. The space created by the inner wall provided easy access for plumbing and wiring runs. After the mechanicals were installed, it was packed with cellulose insulation. We used a 12-inch SIP roof and placed the structure on an insulated slab with R-20 around and under the slab, which was double the code requirement.

When building with R-48 walls, it is always disappointing to install R-2 or even R-3 windows, since that draws down the envelope's overall thermal performance. Brad and Linda specified Andersen E-Series/Eagle double-hung, double-pane, low-e windows with R-values ranging from 3.33 to 3.7. We "tuned" the windows for passive solar gain, specifying a higher solar heat gain coefficient (SHGC = 0.39 to 0.44) for the south-facing glazing.

A nonloadbearing 2-by-4 wall inside the SIP wall provides room for additional insulation.

Courtesy Structures NW (3)

The 12-inch-thick SIP roof is placed by crane.

Conservation + Solar Solutions

It is great when clients come to the table knowing they want to use the sun to help maintain the thermal comfort of their home. We often have clients who say they want to design a passive solar home, but then prioritize orienting the home for the view rather than solar access. For this project, Brad and Linda had actively sought out a property that was in alignment with their solar goals.

It is fairly easy to get sunlight and solar gain into a building; the challenge is to keep it in the building once the sun sets. This is where the structure's insulation and thermal mass (in this home's case, a concrete slab floor) come into play. Another vital element of a passive solar structure is involving the occupants in the home's management. In the winter, this might include closing thermal shades at night and opening them in the morning. In the summer, it might be opening windows at night and shutting them in the morning.

Beyond passive solar, this home's narrow, long design made daylighting much easier to accomplish. To minimize the energy used for artificial lighting, Brad and Linda installed LED bulbs in almost every fixture.

Mark Arinsberg (2)

An efficient washer and dryer help save water and energy, and Linda and Brad routinely use the drying rack (above) for even greater energy savings.

Green Home Certifications

There are many avenues available to assist in determining just how "green" a new home can be, where the emphasis is on energy savings, enhanced comfort, and healthier indoor air quality. In all cases, true certification comes with the services of a disinterested third-party verifier. Most programs are based on the number of points earned in each of several categories, including energy, air quality, materials, environment, and water. Below are the programs readily available in the Pacific Northwest.

The Northwest Energy Star Homes program is a regional initiative of the Environmental Protection Agency (EPA) where the emphasis is on energy efficiency. Homes with the Energy Star label are projected to be at least 15% more efficient than homes built to current state building codes. This is accomplished by limiting the windows-to-floor area to 21%, and requiring high-performance HVAC equipment (e.g., a 94% vs. 90% efficient furnace), mastic sealer on all heating ducts, all Energy Star appliances, and 80% of lighting must be compact fluorescent or LED. A blower door test is required following construction to assure a maximum of 4 ACH50 (air changes per hour at 50 pascals). Ducts are also tested with a maximum acceptable leakage rate of 6%. The EPA also has complementary certification programs available for water conservation and indoor air quality.

The Earth Advantage New Homes program allows for different levels of certification (i.e., Earth Advantage Silver, Gold, or Platinum) depending on the number of points earned in each of five categories: energy efficiency, indoor air quality, resource efficiency, environmental responsibility, and water conservation. In addition to the score sheet, Earth Advantage requires two verification visits: the first during construction, to test for maximum moisture content in studs (where applicable) and assure proper installation of insulation and mastic application (among other things); and the second following construction, to conduct the blower door and duct leakage tests.

Leadership in Energy and Environmental Design (LEED) is a program of the U.S. Green Building Council. LEED for Homes 2008 is also a points-based program with four performance levels: Certified, Silver, Gold, and Platinum. There are 18 prerequisites (mandatory measures), certain minimum requirements, and a total of 136 points available in eight categories, including sustainable sites, location and linkages (such as proximity to services), and education and awareness. LEED for Homes adjusts point requirements depending on the home's size, rewarding builders for smaller structures.

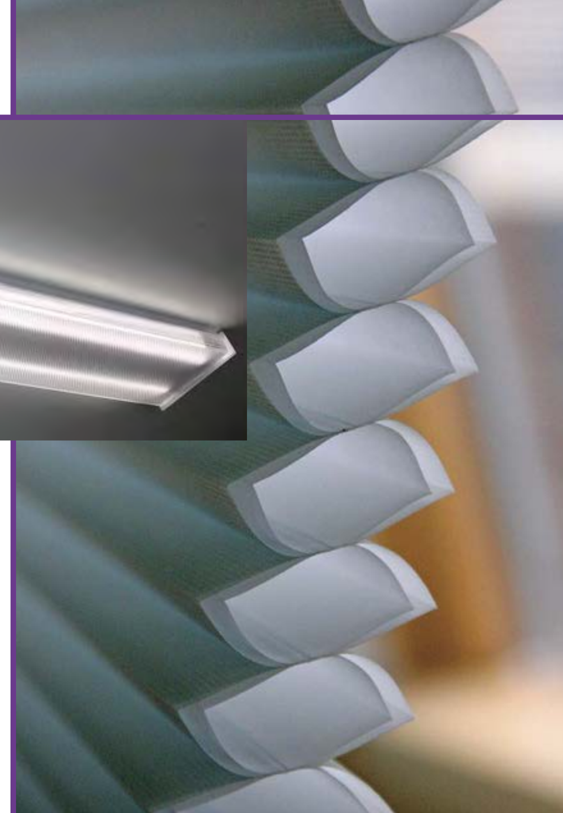
The 2012 ICC-700 National Green Building Standard (NGBS) is a program developed through a partnership between the National Association of Home Builders (NAHB) and the International Code Council (ICC). Certification under the NGBS can be achieved at four levels: Bronze, Silver, Gold, and Emerald. Points are earned in six categories: energy efficiency, water conservation, resource conservation, indoor environmental quality, site design, and homeowner education. The latest version of the NGBS requires energy-efficient performance to be 15% higher than the 2009 International Energy Conservation Code and includes new scoring opportunities for choosing lots in green communities, and for existing building projects, including a protocol for common renovations (e.g., kitchen, bathroom, or basement) or an addition under 400 square feet.

In contrast to other green-building certification programs, **Passive House Institute US (PHIUS)** has developed an ultralow energy building standard with the goal of a 90% reduction in energy consumption. It requires building design with a Passive House consultant and a PHIUS+ rater, who consider how to make the operational elements (e.g., cooking, lighting, bathing, etc.) of the home abide with the standards. At the end of a full year of occupancy, calculations are made to determine if the energy usage goals were met.

—Jill Sughrue

Above: LEDs are used throughout the house, including in these T8 fixtures in the utility spaces.

Left: Space-saving is part of energy savings. Linda and Brad have matching fold-down desks in one bedroom, which also functions as an office.



Above: Even the most efficient windows lose heat. Thermal blinds help keep it in.

An efficient, well-insulated envelope is much easier to heat and cool, requiring minimal energy inputs. When supplemental heating or cooling is required, Brad and Linda rely on a small minisplit heat pump. Because they are ductless, minisplits avoid the energy losses inherent in conventional ducted central heating systems. And because each interior unit has its own thermostat, homeowners can choose to heat or cool only when rooms are occupied.

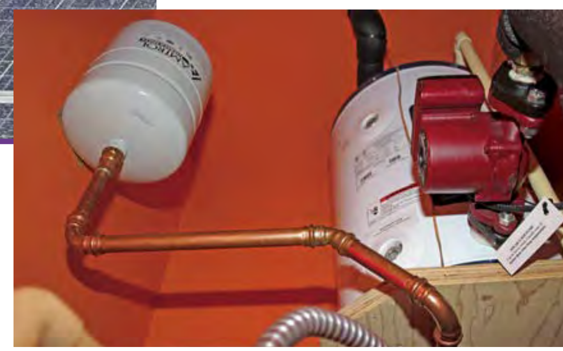
Mark Arinsberg (6)

A minisplit heat pump that helps heat and cool the home with minimal energy input.

Right: The wall-mounted minisplit air handler in the guest bedroom is unobtrusive.

Left: Two 4- by 8-foot Aurora solar thermal collectors provide as much as 85% of the homeowners' hot water needs.

Below: Peeking up into the thermal closet at the expansion tank, drainback tank, and Grundfos circulator pump.



Mark Arinsberg (3)

Solar Hot Water

Brad and Linda were interested in using the sun's energy as much as possible, and turned to active solar systems once they had maximized its passive aspects. They had met solar water heating (SWH) system installer Luke Frazer on a solar home tour and had decided, early on, that they wanted an SWH system for their home. With the relatively mild climate in Ashland, Frazer specified a drainback system for the couple. It was sized for an "average" household and designed for the amount of space available for the equipment. Because the system was planned before the home's construction, Frazer was able to work closely with the contractors to keep pipe runs short and properly sloped. He also worked closely with their photovoltaic (PV) installer, coordinating the placement of the collectors with the rooftop PV array.

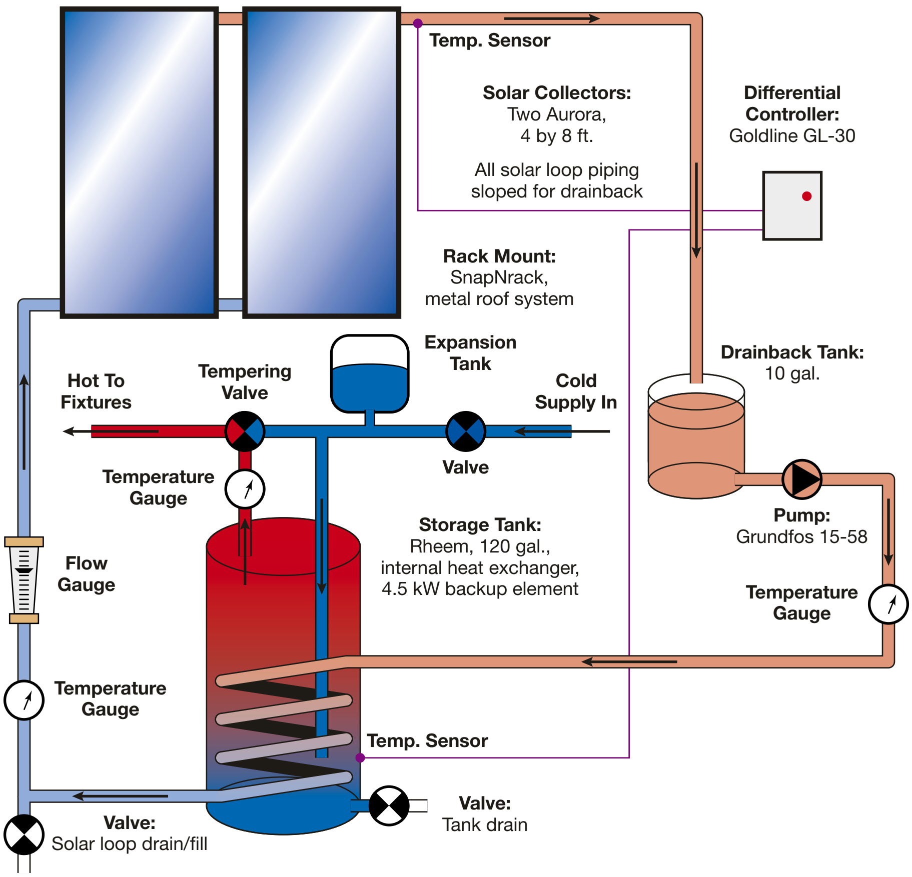
With the house's small footprint, tank size was a consideration from the beginning. Frazer paired the 50-gallon electric single-tank system with two 4- by 8-foot flat-plate collectors. The circulating pump is powered by 120 VAC. With an average of 4.9 daily peak sun-hours, Brad and Linda wanted to produce as much of their hot water as possible with this system. In the summer, the system easily provides 100% of their water heating. Annually, it will likely offset between 75% and 85% of their household hot water usage. At a net cost of $3,660, the system is anticipated to have a fairly quick payback.

SHW System Costs

Item	Cost ($)
SWH system, installed	$8,800
Oregon state tax credit	-1,500
Federal tax credit	-2,340
City of Ashland rebate	-1,000
Net Cost	$3,960

Right: A single-tank drainback system is ideal for small spaces. This utility closet was sized specifically for the system.

Drainback Solar Thermal System



SHW Tech Specs

System type: Active drainback

Location: Ashland, Oregon

Solar resource: 4.9 daily peak sun-hours

Annual production: 2,630 kWh (estimated)

Percent of hot water offset: 75% to 85%

Equipment

Collectors: 2 Solene Aurora, 4 ft. x 8 ft.

Collector installation: Roof-mounted at 10° tilt

Heat-transfer fluid: Water, with corrosion inhibitor

Circulation pump: Grundfos 15-58

Pump controller: Goldline GL-30

Storage

Storage & backup tank: Rheem 82V120HE-1, 120 gal.

Heat exchanger: Integrated into tank

System Performance Metering

Thermometer: 3 Pasco

Flow meter: Letro 5 gpm

Photovoltaics

Brad and Linda didn't want to stop with just solar water heating—they wanted the sun to produce all of the energy for their all-electric house. With the City of Ashland buying back all the surplus solar energy the home could produce at 125% of the residential block rate for the first 1,000 kWh (and wholesale rates beyond that), they decided to install a 12 kW system. While they didn't complete a comprehensive load analysis, their installer, Seaira Safady, felt that a system of this size would meet—and exceed—their needs. It was also about as much room as was available on the roof, minus the solar thermal collectors and fire access clearances.

Safady specified microinverters for the system, which offer module-level monitoring, with monthly energy reports and email notification if an error is detected. Among other things, he says, the microinverters offer increased safety by eliminating the high-voltage DC circuitry and redundancy, since an inverter failure doesn't compromise the entire system compared to a string inverter-based system. The Enphase microinverters used in this project also carry a 25-year warranty, the same as the modules.

So far, Brad and Linda's monthly electricity bills have been very minimal, and they are expecting to produce more electricity than they consume, especially during Ashland's long sunny summer days.

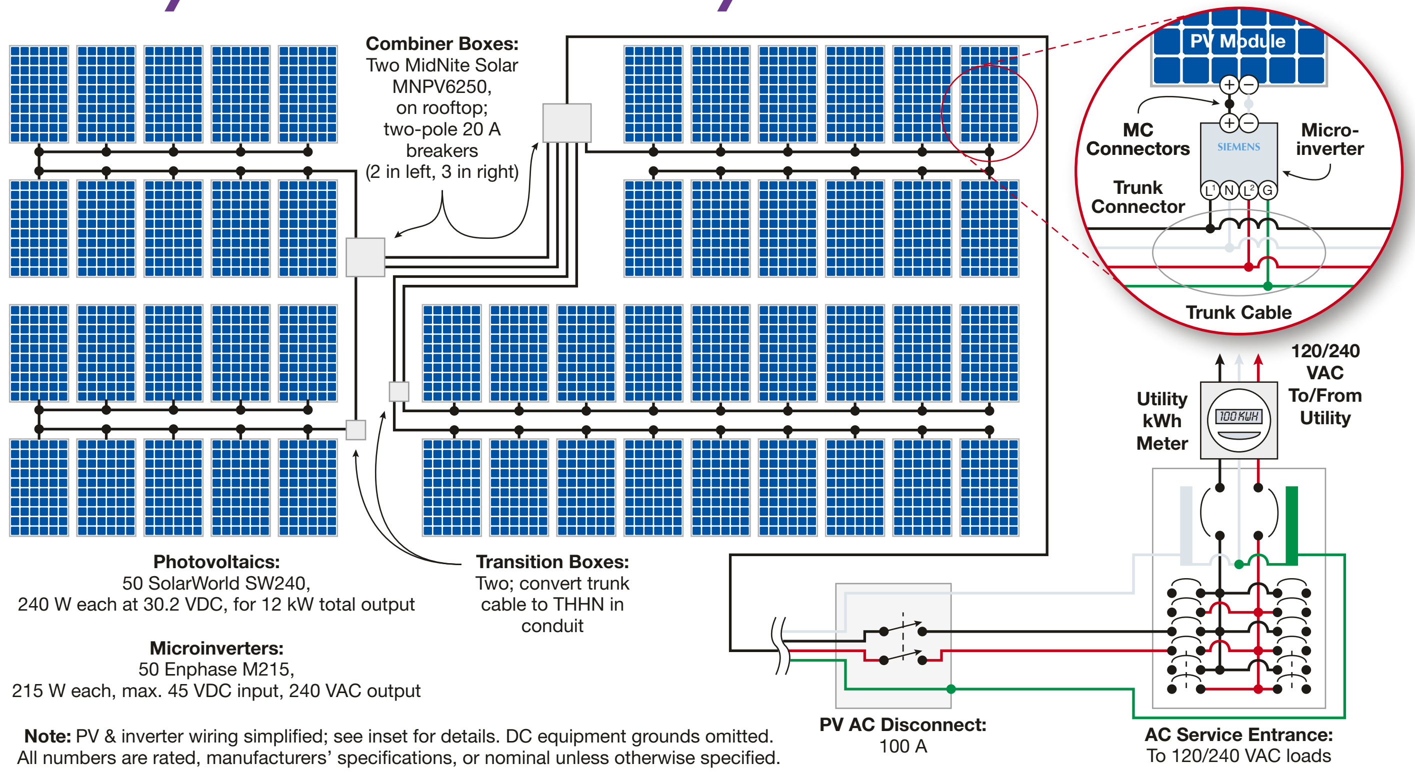
Mark Arinsberg

Part of the 12 kW PV array.

PV System Costs

Item	Cost ($)
Batteryless grid-tied PV system, installed	$43,795
Oregon state tax credit	-6,000
Federal tax credit	-10,889
City of Ashland rebate	-7,500
Net Cost	$19,406

Batteryless Grid-Tied PV System



Mark Arinsberg (2)

Right: At ground level, the PV AC disconnect is the only evidence of the system.

Left: The well-labeled utility kWh meter.

PV Tech Specs

Overview

System type: Batteryless, grid-tied solar-electric

Installer: Alternative Energy Systems

Date commissioned: March 6, 2013

Location: Ashland, Oregon

Latitude: 42.1947°

Solar resource: 4.9 average daily peak sun-hours

ASHRAE lowest expected ambient temperature: 17.6°F

Average high temperature: 96.8°F

Average monthly production: ~1,360 AC kWh

Utility electricity offset annually: Greater than 100% expected

System Components

Modules: 50 SolarWorld SW240 polycrystalline, 240 W STC, 30.2 Vmp, 7.96 Imp, 37.2 Voc, 8.44 Isc

Array: 50 modules with individual microinverters, 12,000 W STC total

Array combiner boxes: Two MidNite Solar MNPV6250-Disco combiner with five, two-pole 20 A breakers

Array installation: SnapNrack Series 100 mounts at 195° azimuth, 10° tilt

Inverters: 50 Enphase M215-60 microinverters, 215 W rated output, 45 VDC maximum input, 22–36 VDC MPPT operating range, 240 VAC output

System performance metering: Enphase Envoy communications Gateway with Enlighten monitoring service

Mark Arinsburg

Water conservation is a key design element: Low-flow fixtures reduce usage. A greywater system distributes the used water in the landscape.

Solar Access

It's not surprising that progressive Ashland, Oregon, has a solar access ordinance, which maintains a landowner or homeowner's right to access sunlight and "preserve the economic value of solar radiation falling on structures, investments in solar energy systems, and the options for future uses of solar energy."

Although the house and lot to the north of Brad and Linda's site was populated by tall trees and the homeowner had no plans to install any solar systems, we still needed to protect their right to solar access. The home's one-story low-pitched roof met the city's criteria and did not impede the neighboring property's solar access. A two-story home with a high gable roof would have obstructed that neighbor's access.

Wiser Water Use

Brad and Linda are both avid gardeners and they wanted to make sure they had plenty of water available—without using the municipal water supplied by the city. They installed two systems to help irrigate their gardens—a greywater system and a rainwater catchment system.

Greywater is collected from the showers, laundry, and bathroom sinks to the filtration unit and then to a subsurface drip irrigation system (see Access), which waters plantings in the front and side yards.

Brad and Linda's rainwater catchment system is a unique underground solution consisting of a custom rubber liner filled with core-tube bundles. These large perforated plastic pipes give the storage unit its shape and allows uses above the system. In Brad and Linda's case, their vegetable garden sits on top of the storage, which can hold 11,220 gallons of water. When water is needed for the garden, a small pump pressurizes the stored water for delivery. The chambers, made of recycled food-grade, high-density polyethylene, flex, bend, and roll with the movement of the earth.

In many municipalities, sewer bills are linked to the amount of water used—whether the water goes into the sewer or into your garden makes no difference. Offsetting the water and the sewer fees can make rainwater catchment systems pay off, depending on how heavy your landscape's water use is.

Gutters feed directly into the cistern.

Perforated black poly pipe is the inner supporting structure for an underground 11,000-gallon rainwater cistern.

Courtesy RainTech

The garden is planted in topsoil that sits above the rainwater storage tank.

Mark Arinsberg (2)

Mark Arinsberg

Linda and Brad cozy up in their high-performance home.

Form & Function

While the couple has only been living in the house for a couple of months, they are pleased with the home's comfort and their solar energy systems' performance.

"Working with Dorris Construction and their foreman Lance was a joy," says Linda.

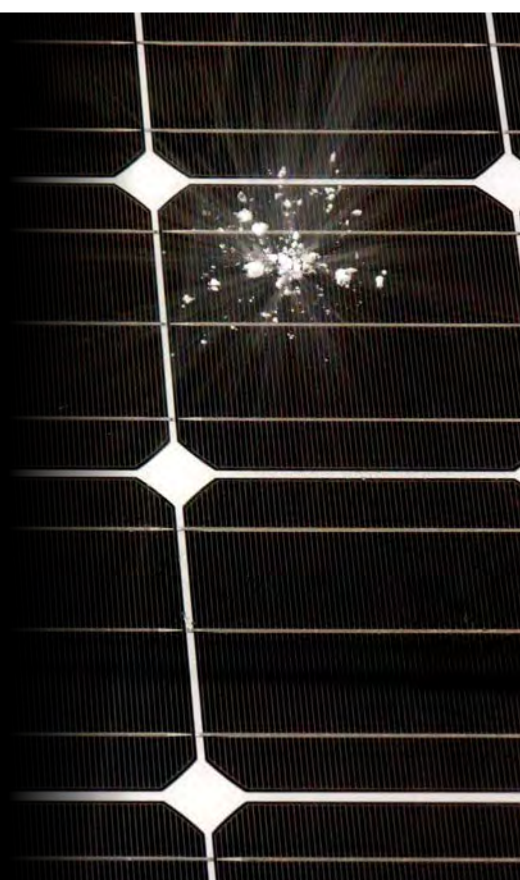
"The collaboration with Patrick at Structures NW in a true team effort is what made the project so much fun," says Brad.

Access

Patrick Sughrue is a sustainable building advisor who started Structures NW in 2003 to assist clients with affordable, energy-efficient building enclosures for their construction projects. In addition to designing projects from one of their building templates, his company also supplies structural insulated panel (SIP) packages.

House Systems:

Alternative Energy Systems • aesinc.us • PV system
Dorris Construction • dorrisconstruction.com • Builder
RainTech • raintechh2o.com • Rainwater catchment
Structures NW • structuresnw.com • Design & SIPs enclosure
The Solar Collection • solarcollection.net • Solar hot water system
Water Wise Group • waterwisegroup.com • Greywater system

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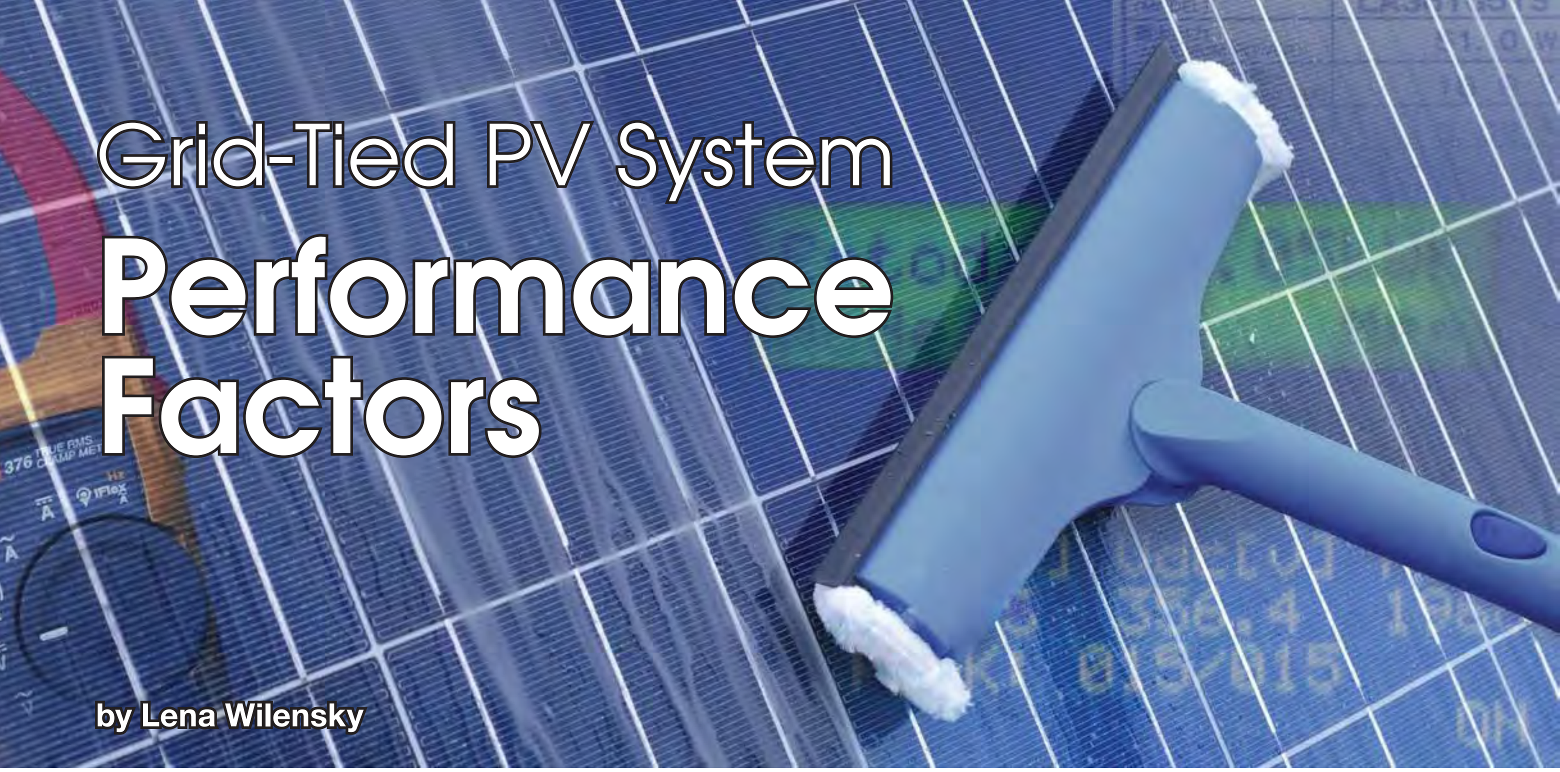
PARTS

Grid-Tied PV System Performance Factors



by Lena Wilensky

The number of PV systems is increasing all over the United States. By the end of 2012, PV capacity was more than 7,700 megawatts (MW), with more than 3,300 MW of PV installed during 2012 alone. But are all of these systems performing at the highest possible level, even after five, 10, or more years of operation? Here are some of the common signs and symptoms of underperforming PV arrays—and their remedies.

Assessing Your System

Figuring out if your PV system is working properly can often be difficult, especially for owners of smaller residential PV systems who have never been given proper instruction on system monitoring. Many folks keep tabs on their grid-tied PV systems just by examining their monthly electric bills. They know roughly what the bills have been since their PV system was installed, and assume everything is fine if their payments stay about the same.

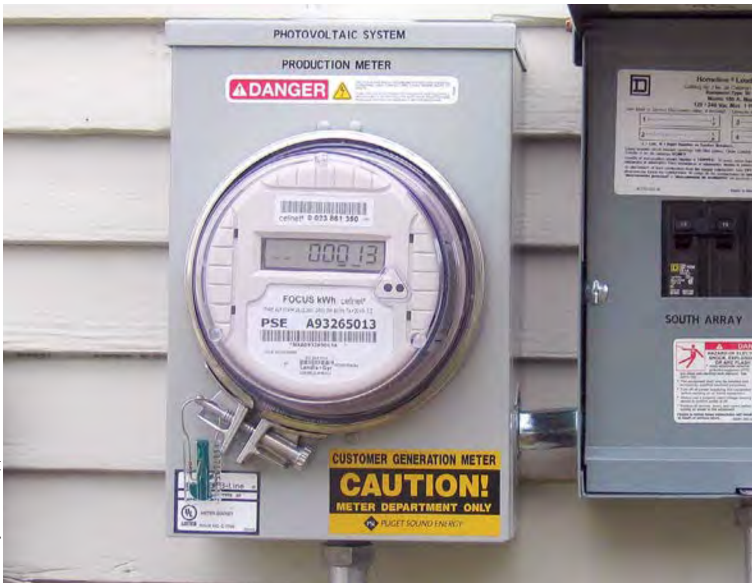
In areas with production-based incentives, a separate meter records PV system generation. This can make monthly comparisons of PV performance more straightforward from year to year. Any significant drops in production for a particular month from one year to the next should raise a red flag—while it could mean only that there was less sun than the previous year, it is a good idea to check the system for problems.

Net-metered PV systems can be difficult to pin down since the utility's meter only shows *excess* PV energy produced after all of the home's electrical usage. If the loads change from year to year, then the net production (if there is any) will change as well, even if the PV system is performing as in the past. Most grid-tied inverters display instantaneous power and energy production totals, but someone needs to check them regularly, record the readings, and compare them from year to year to really know if the system is performing to specifications. And what happens if the system was not installed properly in the first place and has never worked properly? We need a way to know if a system is doing what it is supposed to do.

A remote meter can help you keep track of how well your array is performing.

Courtesy Ben Root (2)

Taking readings from the PV system production meter can help you identify system problems, but only if you have previous records to compare to.



System Spot-Check: Power Output

Let's use a 3 kW net-metered PV system as an example. The system owners notice that their monthly electric bills are a lot higher than the previous year. Nothing looks amiss—the modules are still on the roof, and the inverter has a little green LED lit up when the sun shines. The inverter's screen shows the array is producing 925 watts at about 3 p.m. Should this 3 kW array be producing more?

With a little math and a couple of measurements, we can get a pretty good idea of what an array should be producing any time there is full sun. Here are the parameters you can use to calculate PV system power output:

STC ratings. PV modules are factory-tested to determine their power output. When we talk about the size of a PV system or module, we are using the "STC ratings"—the numbers detailed on the back of the module and on its data sheet. STC, or "standard test conditions," is a solar irradiance of 1,000 W per square meter and a module cell temperature of 25°C (77°F). Although both of these values impact a PV module's output, its rating at STC rarely reflects real-world conditions. The result is that a PV module rated at 250 W STC will only produce 250 W *under those specific conditions*. In full sun and up on a rooftop, the actual conditions are usually much different. For instance, during the winter in an area with no snow and a slight haze, the irradiance will be lower (perhaps 700 W per square meter) and module cell temperature might be close to 25°C (77°F). In the summer, irradiance might be closer to 1,000 W per square meter, but module cell temperatures may be 60°C (140°F).

When calculating the power output, we'll start with the STC rating of the PV array—in this case, 3,000 watts. Then we will include several derate factors, which will lead us to the array's *expected* power output.

Module temperature. The higher its cell temperature, the lower the PV module's voltage will be. With lower voltage comes less output (power). Even if it's 25°C (77°F) outside, in direct sun modules will heat up much higher than the ambient temperature. Systems utilizing ground- and pole-mounted systems, and ones on elevated racks on low-slope roofs benefit from air circulation; in full sun, they tend to be 20°C to 25°C above the ambient air temperature. Systems that are flush-mounted on pitched rooftops have much less air flowing under the modules and can be 35°C to 40°C above ambient air temperature.

Placed against the back of a module, a sensor (attached to a meter) can be used to measure cell temperature. Be sure to take readings on several spots and average the results.

We could measure the air temperature with a thermometer and estimate the module cell temperature from the temperature adders above, but this would not be very accurate. A much better way is to use an infrared thermometer on the back of the module, if possible, since the glass front can cause skewed readings (see "Tools of the Trade" sidebar). It's a good idea to take the temperature in a couple of places throughout the array and average the results. If the array is easily accessible, temperature sensors will provide the most accurate readings. Just be sure the sensors are measuring the *module cell* temperature, and not the ambient air or module frame temperature.

In our example, even though the air temperature is a moderate 18°C (65°F), we measure the module cell temperature at 53°C (127°F). Next, we need to convert this value into a temperature factor to use in our final calculation. First, find the difference between the module cell temperature and STC (25°C), converting Fahrenheit to Celsius:

Temperature difference = 53°C - 25°C = 28°C

Next, calculate the derate factor for the power we expect to lose from the increased temperature (it is preferable to use the specific module's temperature coefficient of power instead of the estimated -0.5% per °C, which is quite conservative):

Temperature derate factor =
1 + (-0.5% per °C difference × 28°C) = 0.86

Our module cell temperature is higher than at STC, and the temperature factor should be less than one since the overall array power will be lower than at STC. If the module cell temperature is less than 25°C, then we should expect a temperature factor greater than one.

Lena Wilensky (2)

A temperature gun checks infrared radiation to give quick readings of cell temperature.

Irradiance. The more sunlight (irradiance) hitting the modules, the more current they will produce. Irradiance is measured with a handheld pyranometer. It needs to be placed at the exact same tilt angle and orientation as the PV array, ideally lined up adjacent to a module.

Many things affect the irradiance levels at the PV array, including time of day, season, elevation, cloud cover, and sometimes even reflection from snow. Unlike module cell temperature, irradiance levels can change very rapidly. A cloud passing by the sun can cause levels to spike, drop, and then return to normal (edge-of-cloud effect) in less than a minute! It's important to look for a window of time, on a clear sunny day, when you can take a couple of readings that you expect to be similar, and record the inverter's output power between the irradiance readings. Even better, have a friend assist, with one person recording irradiance and another recording inverter output simultaneously.

Lena Wilensky (2)

To accurately determine the irradiance striking your PV array, be sure the pyranometer sensor is on the same plane as the modules.

For our example, an irradiance reading of 875 W per square meter is recorded at 3 p.m. Although the sky is clear, there is a slight haze in the air. This was taken at the same time as the inverter output reading of 925 W (noted above). Since 875 W per square meter is less than the 1,000 W per square meter rating at STC, we should be seeing less power than the STC ratings, and an irradiance factor of less than one. To calculate, we simply divide our reading by 1,000:

Irradiance Factor = 875 ÷ 1,000 = 0.875

While irradiance levels of less than 1,000 W per square meter are common in most of the United States, at higher elevations, and with snow on the ground, higher irradiance levels are possible, yielding an irradiance factor greater than one.

"Other Losses" Factor

Depending on the PV system, other factors may affect PV system output. Here are some common ones used in NREL's PVWatts calculator:

PV module nameplate DC rating: Testing has shown that module nameplate power ratings tend to be a bit optimistic, but by how much? A good place to start is the manufacturer's power tolerance specification. For example, you might see "Pmax = 250 W, -5%/+10%" on the module data sheet, which means this module is warranted to produce between 237.5 and 275 W at STC. It's generally best to use the lowest rating. In this example, we will use the -5% tolerance, for a nameplate rating factor of 0.95.

Inverter: We also need to account for the power it takes to convert the DC electricity from the PV array to AC, and we can do so by factoring in the inverter efficiency. While inverter specification sheets will list "maximum efficiency," a more useful value is the "weighted efficiency," which accounts for the percentage of time the inverter commonly spends at various power levels. This gives a better indication of the inverter's real-world efficiency. Most grid-direct inverters have weighted efficiencies greater than 90%. You can find inverter weighted efficiency ratings on the Go Solar California website: (bit.ly/CAeligInv). In this example, we use 0.96 for our inverter efficiency factor.

While this label does not show the PV module's power tolerance, it does give the minimum figure, which computes to be 91% of the rated power (154.7 ÷ 170.0).

Tools of the Trade

Two tools—an infrared thermometer and a pyranometer—are indispensable for accurately predicting a PV array's production. An infrared thermometer (from $50) can take the array's temperature with fairly accurate results. Its laser pointer helps to aim for measuring an object's infrared (IR) energy, which is translated into a corresponding temperature and displayed on the thermometer. Infrared thermometers are also called IR thermometers, laser thermometers, noncontact thermometers, or temperature guns. The reflection from a module's glass surface may interfere with an IR thermometer's accuracy since it has a relatively low emissivity. When possible, take the measurement on the back of the module, which has an emissivity approaching 1, closer to the default settings on most basic IR thermometers.

A pyranometer (about $135 for a simple handheld unit) measures how much sunlight is hitting the site. Most use the electricity generated by a small, internal, and calibrated PV cell to measure the sun's irradiance. Although this tool is costly, it's a worthy troubleshooting tool for the pro, as it can be very difficult to predict PV performance without one.

IV curve tracers are becoming more widely available, and used for troubleshooting and commissioning. They analyze the voltage, power, and current characteristics of PV modules in real-world conditions. They can find and verify underperforming modules and series strings relatively quickly and easily. However, with a nearly $3,000 price tag, they are mostly used by larger PV companies and other professionals.

Infrared cameras (also known as IR cameras and thermal imaging cameras) can be helpful in finding and verifying trouble spots within PV arrays, wiring, and modules. Like IR thermometers, they read infrared energy to show the temperature of different objects in the field of view, and then display the heat differences as a colored image. High-resistance areas will heat up (in wire connections, within modules, etc.) and can show up as "hot spots," making locating trouble areas fairly straightforward. But IR cameras require training to use effectively and with basic models starting at $1,000, they are also mostly for professional use.

Module mismatch: Include this factor unless the PV system has maximum power point tracking (MPPT) capability at the module level, using microinverters or DC optimizers. Due to slight differences in modules' IV curves, or power output profiles, the one MPP used for an entire array or series string will not be a perfect fit for each individual module. A small power loss will result. If there are different makes and models of modules in the array, the power loss will be even greater. If individual series strings of modules have their own MPPT, the loss will be less. Most PV arrays with one kind of module and a single MPPT for the entire array will experience a 2% loss due to module mismatch, so we will use a 0.98 mismatch factor.

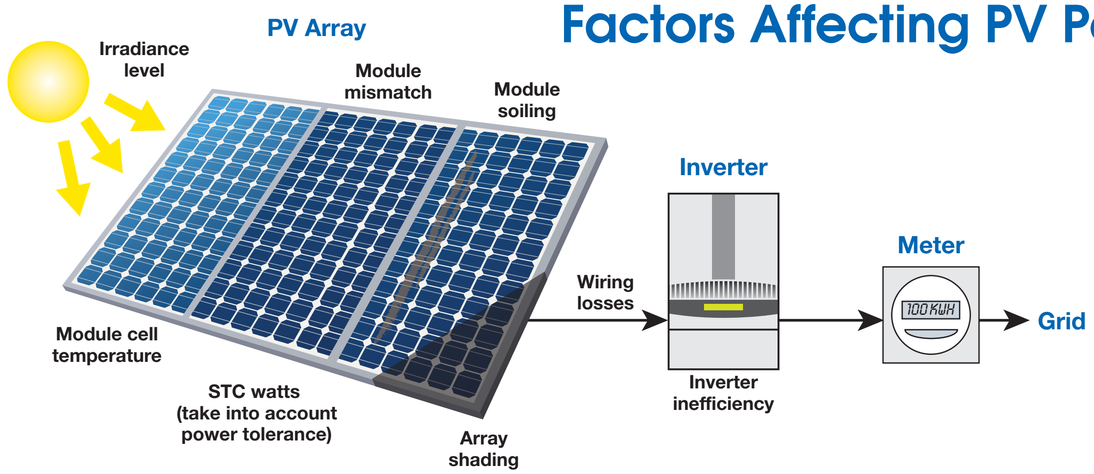
Wiring losses: Wire connections and the DC wire runs introduce losses due to resistance. Since we are measuring inverter output at the inverter, we should not include AC wire losses. Most well-designed systems will have about a 0.5% loss due to connections, and about a 2% loss in the DC wiring. If system designers did not account for voltage drop on a long wire run, or there are poor wire connections, these losses might be greater. We'll assume our system fits the numbers stated above, for a total DC wiring loss of 2.5%, for a 0.975 wiring loss factor.

Soiling: Modules get dirty. In places with lots of dust, few significant rain storms, and buildup of other small debris, this factor can be significant. Modules set at a lower tilt tend to have more soiling. Let's assume we're in an area with "normal" dust, and our array is tilted to about 40° (steep enough to shed most gunk). The modules don't look dirty from the ground, but it hasn't rained in a while. We will use 0.97 for our soiling factor.

Lena Wilensky (2)

Dirty PV modules can significantly reduce output. Clean 'em!

Factors Affecting PV Performance



Age: On average, crystalline silicon modules lose about 0.5% of their output power capacity per year. A new installation would have no age-related losses. The array in our example was installed six years ago, so we'll assume a 0.97 age factor. (Note that degradation rates may vary due to climate effects and may not be linear over time.)

Shading: Quantifying the effects of shading on annual production is fairly easy with site analysis tools. But accurately determining the effects of partial shade on an array at any one time is very difficult. Therefore, you need to choose a time when the array is not shaded to make your measurements.

Now that we have determined all of the other losses, we find the total by multiplying them together. This number will be our final factor:

Other losses factor =
0.95 × 0.96 × 0.98 × 0.975 × 0.97 × 0.97 = 0.82

Putting it All Together

Now we have enough information to calculate what our PV array *should* be producing by multiplying the STC watts by the three main loss factors:

Expected inverter output (W) = STC watts × Module temperature factor × Irradiance factor × Other losses factor = 3,000 W × 0.86 × 0.875 × 0.82 = 1,851 W

Recall that the output was 925 W as shown on the inverter display. According to calculations, this PV array should be producing about twice what the inverter was showing. This is not even close to the expected output. We need to find out what is wrong, but where do we start?

Troubleshooting

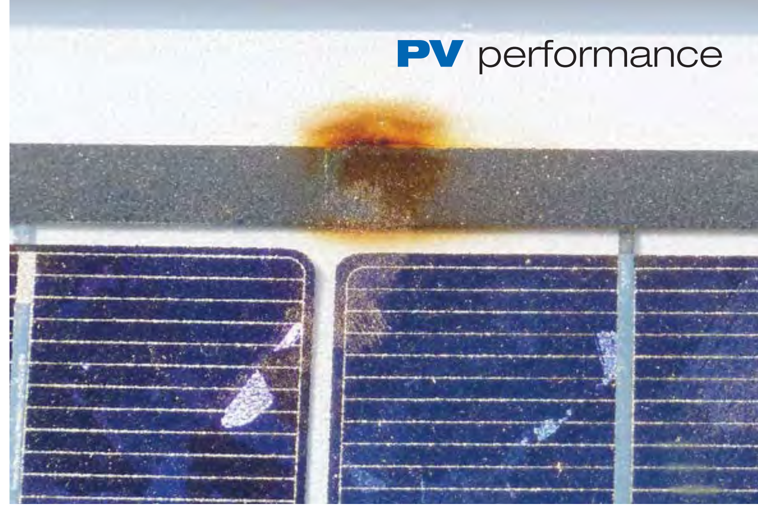
With troubleshooting, anything is possible. Although these procedures are a good place to start, don't limit yourself to them. Common sense, experience, and keen observation can help find solutions.

Error codes on your inverter or remote monitor. This could be an LED light, a specific code flashing on the display, or a ground-fault indicator. Consult your installer or the inverter's manual, or call technical support to determine what the code means. If there is indication of a ground fault, immediately contact your PV installer or other qualified person, as there could be danger of electric shock on parts that are not normally energized (such as metal conduit, module frames, ground wires, metal enclosures, etc.). Do *not* continue investigating the system by yourself if there is a ground fault!


Courtesy Justine Sanchez

Shading can negatively affect your PV system's output. For testing purposes, be sure your array is in full sun.

Lena Wilensky (2)



Warped, misshapen boxes or insulation (left) or burn marks (right) indicate electromechanical problems with one or more PV modules.

Inspect your PV array. Is any of the glass cracked? Do you notice any missing parts? Make sure the modules are aligned and no corners are sticking up or down—heating and cooling cause expansion and contraction, which can lead to mechanical failure within the rack and modules. Look for loose bolts, bent frames, and cracked glass. Snow load can also damage an array.

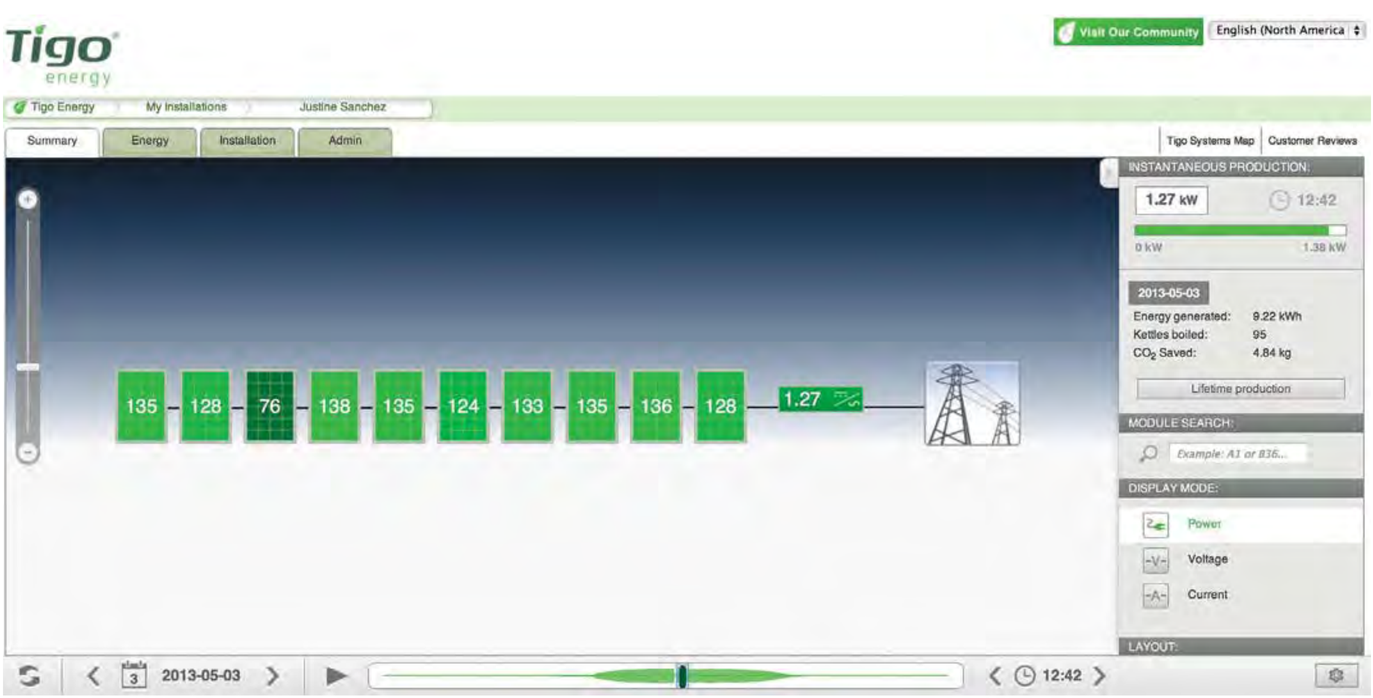
Look for yellow or brown burn marks on both the front and the back of the modules. If you can't easily access the array, you can do this inspection from the ground with binoculars. Diodes and solder connections within the module and its junction box can fail, causing areas to heat up and burn or melt.

Check underneath the array. Are there any loose, dangling wires? Expansion and contraction can also cause taut wires to pull loose from their connectors, or cause the connectors to partially open. Poor connections will create heat from increased resistance and can melt the connectors, junction boxes, or leave burn marks on the white back-sheet.

Is any of the wire insulation missing or damaged? Small animals will often build nests underneath arrays and seem to have an appetite for wire insulation. Has debris accumulated? Leaf litter buildup can create a place for moisture to collect, and loose connections contacting moisture can then cause intermittent faults (especially when the insulation is missing) and, eventually, corrosion.

Try to find problem strings or modules. If you have module-level monitoring, such as with microinverters or DC optimizers, it should be easy to see if one or more modules are underperforming. If your PV system doesn't use this technology, each series string's open-circuit voltage and operating voltage should be tested and recorded, as well as

Finding individual underperforming PV modules is possible with module-level tracking technologies, such as microinverters or DC optimizers.



Courtesy Justine Sanchez

Lena Wilensky (2)

Measuring the array's operating voltage at the positive and negative terminals, with the array connected to the inverter.

A clamp-on meter is used to measure the current while the array is connected to the inverter.

its operating current (using a clamp-on meter). You can then compare string or module measurements with each other or against calculated expectations to find any poor performers. Note that *any* work or measurements on exposed energized parts should be done only by trained individuals. These are often high-voltage systems, which can kill or injure.

Using an infrared camera can also help spot problems within modules, but only if you can get your hands on one and know how to use it! (For more information, see the "Tools of the Trade" sidebar and "Potential PV Problems & New Tools for Troubleshooting" in *HP143*.)

Check production history. Examining past electric bills, and inverter and system monitoring data can help you pin down when the array started underperforming. Is the problem intermittent? This might be due to loose connections or wet debris facilitating a short. Was there a sudden drop in production, or did it seem to happen gradually? Has it always been this way? Perhaps a wire was pinched during the installation and the array has never been producing full power. Finding out the time of year or coordinating the loss of production with other events (storms, grid outages, roof repairs, etc.) can also provide clues about the underlying issue.

Take the problem area apart. If the array's voltage and current meet specifications at the array output, but not at the inverter input, then the problem lies between these points. Check junction and combiner boxes for loose connections, compromised wiring, or blown fuses. Thermal cycling can cause wire connections to loosen; even properly installed wires can come loose over time. Check the inverter and disconnects for the same. If the inverter input meets specs, but its output does not, then it's likely there is an issue within the inverter itself, and the manufacturer will need to be consulted.

If you've narrowed down the problem to the array, sometimes it's necessary to inspect the array wiring and rack up close, as well as isolate and test modules. Check all of the module frames, junction boxes, connectors, glass, and backsheets. An IV curve tracer can be helpful in finding underperforming series strings (see "Tools of the Trade" sidebar) so the entire array does not need to be disassembled. Note: *Only* qualified individuals should work on the array, move modules, or expose or take apart any of the wiring.

Wrapping It Up

Our example system was producing about half of its rated power. What could have gone wrong in this situation? Let's say no shading or error codes were observed, and, from the ground, no damage was visible on the face of the array. However, a rooftop inspection revealed a loose connection between two modules where a connector had come undone, and testing showed one series string with open-circuit voltage close to our expected value and the other one at close to zero. Not surprisingly, the modules with the loose connector were on the low-voltage series string. Perhaps the connector was not completely closed to begin with, and the module wiring was pretty taut underneath the array. Expansion and contraction within the rack and modules might have been enough to pull this connector loose over time. The connector will need to be carefully inspected and, probably, replaced, since there's likely to be heat damage from the long-term loose connection.

Access

Lena Wilensky (lena@nunatakenergy.com) is co-owner of Nunatak Alternative Energy Solutions, a small Colorado RE company. She is a Solar Energy International instructor and a NABCEP-certified PV installer, and is certified by ISPQ as a PV Affiliated Master Trainer. She is also the proud mother of a future solar sister.

Resources:

"Photovoltaic Degradation Rates" • bit.ly/PVdegrade
"Pump up the Power" by Jeremy Taylor in *HP127*
"PV System Commissioning" by Blake Gleason in *SolarPro* 2.6
"Seeking Peak Performance" by Brian Mehalic in *HP133*

Heat-Pump Water Heaters

In the right situation and location, heat-pump water heaters offer improved efficiency and increased energy savings compared to standard tank-style units. Here's how to tell if your household would benefit from this technology.

by Tom Gocze

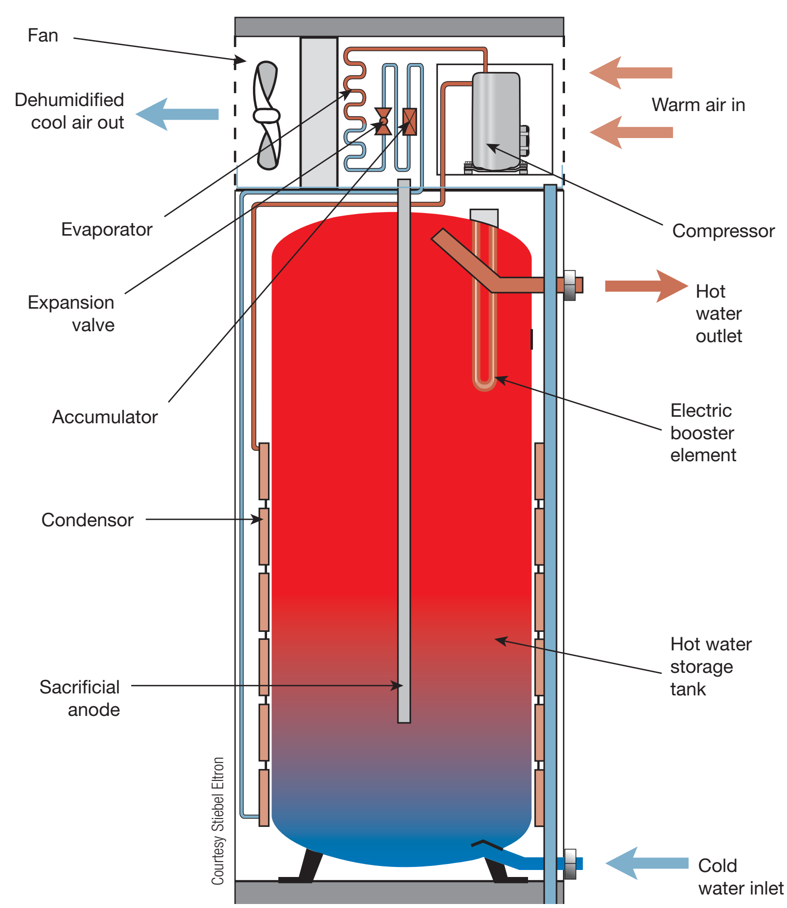
Comment & Discuss this article @ homepower.com/156.58

Using electricity to run a compressor, a heat-pump water heater (HPWH) extracts heat from air, often in the basement, and transfers that energy to heat water in a tank. It's like a refrigerator, only running backward: A refrigerator moves heat from its interior to the room it's located in. An HPWH transfers heat from the room to a storage tank, and does it with remarkable efficiency. In fact, an HPWH is able to transfer more energy (up to 2.5 times) than the electricity it consumes. Today's HPWHs are much less expensive and more efficient than their predecessors.

Inside an HPWH

A heat pump has three basic components: an evaporator, a compressor, and a condenser. Liquid refrigerant is exposed to room-temperature air in the heat pump's evaporator coil. As it picks up energy from the room air, the refrigerant changes from a liquid to a gas within the evaporator coil. The refrigerant passes into the compressor pump, which compresses the gas, increasing its temperature. The heated refrigerant then runs through a condenser, which is either a coil that is wrapped around the integral tank, or a pumped heat

Typical Heat-Pump Water Heater



exchanger that feeds a separate water storage tank. As the hot refrigerant gives up its heat to the colder water, the refrigerant cools and condenses back into a liquid and passes through an expansion valve, where its pressure is reduced and the cycle starts over.

By taking advantage of the unique characteristics of the refrigerant, the heat pump can extract energy from the surrounding room air (slightly chilling that air). How much energy is extracted depends on the ambient air temperature and the tank temperature.

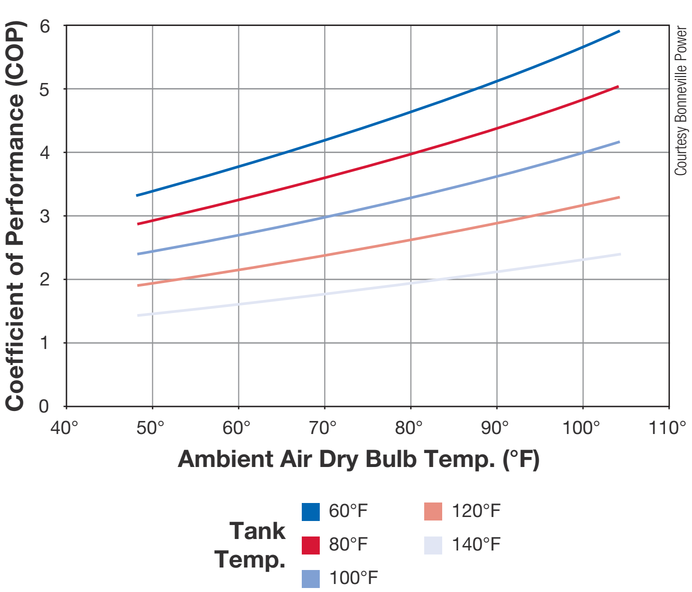
This transformation of one unit of electrical energy into three units of heat is the heating advantage that is unique to HPWHs. This increase in the heating effect is known as the coefficient of performance (COP). Most HPWHs have COPs between 2 and 4, depending on room temperature and humidity, and water temperature. By comparison, a conventional electric water heater is considered to have a COP of 1.

Courtesy GE

Heat-pump water heaters may have a slightly different footprint than conventional water heaters. Since they draw heat from the surrounding air, it is important to consider their location. With its louvered door, this closet essentially shares the same airspace with the living room.

The U.S. Department of Energy considers the COP of HPWHs to be about 2, which accounts for storage losses as heat is lost through the walls of the storage tank. The temperature of the room in which the HPWH is housed, the insulation of the storage tank, and hot water usage frequency all impact the HPWH's COP. For our purposes, we are only considering the actual heating performance. However, it is critical that, with any heat source, the heat storage tank be well-insulated to minimize heat loss.

HPWH COP vs. Ambient Air Temperature



Courtesy Bonneville Power

The energy to feed the heat pump can come from passive solar gain, heat from a conventional heating system, the warming effect of soil surrounding a basement wall, or any other heat source. The resulting cooling of the room by the HPWH is advantageous in the summer, but a disadvantage in the winter. If the unit is installed in a basement, the larger the basement, the less impact it will have on the living area. Additionally, in basement installations in humid regions, a significant benefit of an HPWH is that it also removes some moisture from the air, reducing and usually eliminating the need for a separate dehumidifier. Since HPWHs operate as dehumidifiers, a condensate drain must be provided.

General Installation

HPWHs should be installed in an indoor space—a garage, utility room, or basement—of at least 1,000 cubic feet (equivalent to a 10- by 12.5-foot room with an 8-foot ceiling). Since the HPWH is extracting heat energy from that space, the room will get cooler. The larger the space, the less impact the HPWH will have on the room's temperature. The warmer the space (up to about 120°F), the better the HPWH's performance will be. HPWHs are great at scavenging waste heat from washing machines and dryers, furnaces and boilers, and/or wood stoves.

However, if the space is too small, the HPWH will cool a room too much and the unit will operate at a reduced COP. Forced-air circulation can make it possible to use an HPWH in a smaller space, but if you are operating a blower to feed the HPWH, that energy use will reduce the overall energy savings of the HPWH. Circulating cooled air from an HPWH to cool the rest of your home in the summer can be a beneficial strategy. Some manufacturers will offer ducting hardware that allows you to install a small amount of ducting to move the heat-pump air around. If the ducting runs are too long,

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All-in-One Heat Pumps

In an all-in-one HPWH, the heated refrigerant is usually conveyed through a heat exchanger that's wrapped around the outside of the tank, under the insulation. The refrigerant heats the tank by conduction, transferring heat from the condenser coil through the tank shell, to the water inside.

Similar in appearance to a typical tank-style water heater, these HPWHs are convenient to install. They have a small footprint, since the heat pump is located on top of the tank. All-in-ones typically range in price from about $900 for a 40-gallon unit available at home improvement stores to more than $2,500 for an 80-gallon higher-quality unit, which has more insulation and a more durable tank. If installed by a professional, an HPWH installation should cost no more than a conventional electric water heater installation. If a homeowner feels comfortable installing an electric water heater, they should be able to install this type of system.

To meet increased demands for hot water, an all-in-one HPWH has an electric backup heater, using 240 VAC at 20 to 30 amps. The unit is hard-wired. It has hot- and cold-water plumbing connections. Maintenance is simple, with an air filter to be cleaned when it's dirty, perhaps once or twice a year, and by regularly replacing the tank's anode rod (see "Longer-Lived Tanks" sidebar).

AirGenerate AirTap

Courtesy AirGenerate

A.O. Smith

Courtesy A.O. Smith

Stiebel Eltron

Courtesy Stiebel Eltron

Longer-Lived Tanks

Like a conventional water heater, the longevity of an all-in-one system can be maintained by the simple and regular replacement of the anode rod, a sacrificial piece of metal that is suspended in the steel water-heater tank. Although the inside of the tank is glass-lined, microscopic cracks can develop, leading to rusting of the steel shell without an anode rod. An electrochemical reaction corrodes the anode rod instead of the steel tank, helping to extend its life. Corrosion will eat away at the anode rod over time, necessitating its replacement. Replacing the anode rod every three to five years can extend the tank's life. Magnesium anode rods cost about $20 and are very simple to replace.

Some tanks have electric anodes, which use a small DC current to prevent corrosion. This technology is usually found in commercial hot water tanks, where high usage can accelerate corrosion.

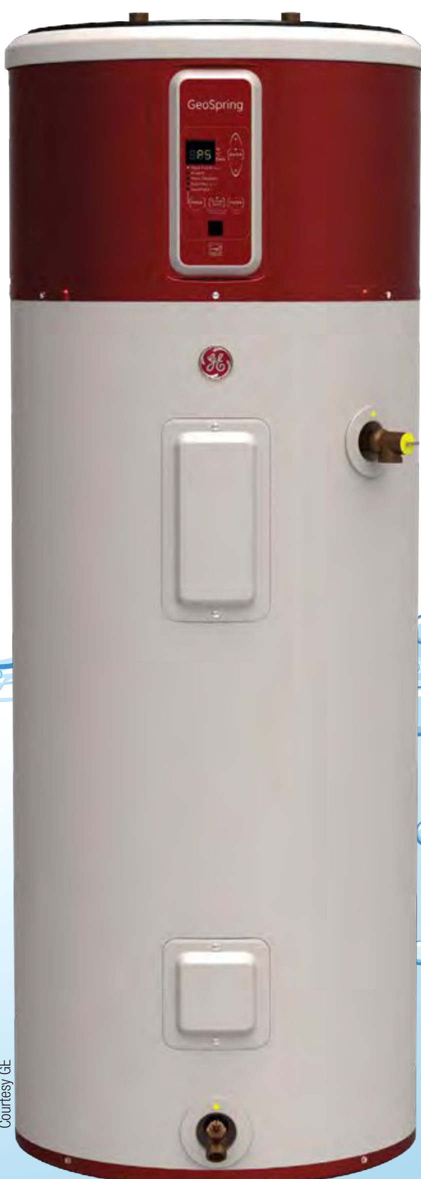
Rheem

Courtesy Rheem

American Water Heater

Courtesy American Water Heater

GE GeoSpring



Courtesy GE

continued from page 59

however, an additional blower would be needed to avoid overwhelming the unit's blower. (The Geyser —see below— offers a ducting takeoff.)

An HPWH's lowest operational temperature varies depending on the room's relative humidity and temperature. HPWHs can operate in unconditioned spaces, like garages and back porches, with some caveats. The coils of the HPWH can become frosted depending on the air temperature and humidity. This energizes a defrost cycle, as in most modern refrigerators, but will compromise the HPWH's efficiency.

Since the heat pump also dehumidifies the air, it needs a drain for the condensate produced. You can run it into a floor drain or save the condensate, which is basically distilled water.

HPWHs are factory-sealed units and are similar in complexity to room air conditioners. Most lower-cost units carry a one-year full warranty. Beyond that, warranties vary by model and manufacturer. HPWHs are complex mechanical devices that need to be serviced by an experienced professional, and most limited warranties do not cover labor expenses.

HPWH Suitability

HPWHs can be larger than typical electric water heaters. Before you buy, make sure the unit will fit in the space where you plan to install it. Stand-alone HPWHs, with their separate storage tanks, require more floor space than all-in-one units.

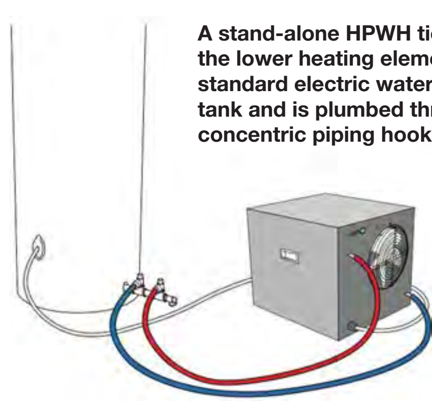
Stand-Alone Heat Pumps

These units move the heat out of the heat pump into a separate tank. This requires a circulator pump and a heat exchanger to transfer the heat to the tank. This additional hardware makes a stand-alone heat pump as expensive as an all-in-one unit, even though no tank is included.

The unit that has been on the market the longest is Nyle Systems' Geyser. The Geyser R (about $900) is made to connect to a standard electric water-heater tank. It ties into the lower heating element of the electric water heater and uses that control to turn the heat pump on and off. The Geyser plumbing interface is usually accomplished by removing the tank drain at the bottom of the electric water heater tank and installing a unique concentric piping hookup. The drain is reinstalled in the end of this interface and the tank operates as before, but is primarily heated by the heat pump.

After installing the Geyser, the thermostat setting that regulates the upper electric element in a standard electric tank can be turned all the way down. This allows the heat pump to deliver all the hot water. The lower control is usually set to maintain the tank water at 120°F. If lots of hot water is required at once, the upper electric element can be left on for quicker recovery heating.

Nyle Systems also offers the Geyser RO. This unit is for indirect oil- or gas-fired DHW tanks. These DHW systems usually derive their hot water from a central heating system boiler. The Geyser RO is a much more efficient way to create DHW during nonheating times of the year. A thermostat built into the Geyser RO has a temperature sensor that installs on the tank to control the tank temperature. This unit has the same plumbing hookup as the Geyser R. The original heat source can still be used for quick recovery during times of extremely high demand.



A stand-alone HPWH ties into the lower heating element of a standard electric water heater tank and is plumbed through a concentric piping hookup.

Nyle Systems Geyser RO stand-alone heat pump.

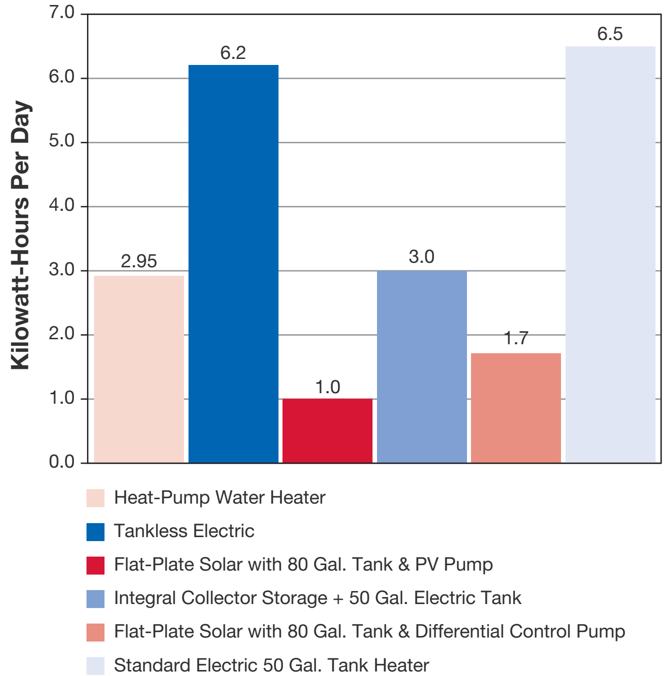
Courtesy Nyle Systems (2)

All commonly available residential HPWHs deliver less heat per hour than a conventional electric DHW tank. This can be a disadvantage for high-volume hot water users. However, having a larger storage tank can minimize this problem. The amount of hot water from any tank-style water heater is limited to the tank's volume and the heater's recovery time. Once the storage is used up, expect a longer recovery time for an HPWH compared to a conventional tank-style water heater. Most HPWHs can deliver 6,000 to 8,000 Btu per hour. Recovery time is contingent on tank size and temperature settings. In general, HPWHs take twice as long to recover as a tank-style electric water heater. If you want to supply hot water to a washing machine and a dishwasher at the same time you're taking a half-hour shower, an on-demand gas- or oil-fired system will likely be necessary—or you'll need to have a very large storage tank.

Some companies, such as Nyle Systems, offer higher-output commercial HPWHs, which extract more heat from the room. This works well for commercial laundry rooms or laundromats that have rather high room temperatures and humidity for the HPWH to extract heat from.

HPWHs are not silent operators. They emit up to the same sound levels as a room air conditioner or dehumidifier. If you have an HPWH installed in a small house, expect to hear it running.

Daily Average Electricity Use for Water Heating



Return on Investment

My experience in replacing electric tank heaters with HPWHs is that customers typically save about 50% on their water-heating costs. Those who have switched from cold-start oil-fired DHW tanks usually experience greater savings.

In Maine, where I live, the average cost of domestic water heating with a conventional tank-style electric water heater is about $50 per month for a household of two or three "moderate" hot water users. Most HPWH users of the same household size end up paying about $20 per month—a 60% savings. Households that switch to HPWHs typically recoup the additional expense within three to five years. If you had also previously operated a dehumidifier, the payback time will be shortened, since the HPWH will also be serving this purpose. Sweetening the payback is a federal tax credit of $300. Some states and utilities also offer rebate and incentive programs for installing an HPWH.

Courtesy Whirlpool

With their high COPs, HPWHs can significantly reduce the costs and energy needed for water heating.

A Match Made for Renewable Energy

In a two- to three-person household, an HPWH may use 3 to 4 kWh per day, drawing about 700 watts per hour when heating. Paired with large storage tanks that are used for solar (or a wood-fired boiler), an HPWH can serve as effective backup.

The key to affordable operation is a well-insulated storage tank. I use a 350-gallon storage tank (insulated with 4.5 inches of polyiso foam) with my Nyletherm HPWH (an earlier version of the Geyser). During the heating season, this tank is fed by a wood boiler. During the nonheating times of year, the heat pump runs about four hours a day to maintain our hot water at 120°F, avoiding the use of the boiler. When the stored water drops to 116°F, the heat pump comes back on. The operational cost has turned out to be the same as when we used a foam-insulated, 80-gallon commercial storage tank—yet provides much more heated water.

A stand-alone unit such as the Geyser can be tied into any larger tank. Since the Geyser has a built-in bronze circulator pump, it can move water to and from any storage tank up to 50 feet away.

An all-in-one HPWH can also integrate as a backup for larger storage tanks. This requires circulating water between the two tanks, but it is doable. A small bronze circulator pump and an aquastat on the larger tank moves hot water in the HPWH tank to the larger tank when it is cooler.

Of course, the easier way to pair renewable energy with an HPWH is with a solar-electric system, since it can simply provide the electricity used by the HPWH.

Access

Tom Gocze (tom@americansolartechnics.com) has been a solar thermal installer and manufacturer since 1979. He holds three patents related to solar heating and heat-storage systems. Many of the unpressurized heat storage systems sold today are based on his work.

Energy Star Heat-Pump Water Heater Manufacturers:

A.O. Smith • hotwater.com

AirGenerate • airgenerate.com

American Water Heaters • americanwaterheater.com

General Electric • geappliances.com

Nyle Systems • nyle.com

Reliance Water Heaters • reliancewaterheaters.com

Rheem • rheem.com

Richmond • richmondwaterheaters.com

Ruud • ruud.com

State • statewaterheaters.com

Stiebel Eltron • stiebel-eltron-usa.com

U.S. CraftMaster • uscraftmaster.com

USI Green Energy • usigreenenergy.com

Whirlpool • whirlpool.com

SHOWCASING Solar

by Juliet Grable

For nearly two decades, solar home tours have been educating and inspiring people to build green and adopt renewable energy.

Comment & Discuss this article @ homepower.com/156.66

Courtesy Denise Ross (2)

Mike Davis of SOS Plumbing explains the Clarks' Velux solar water heating system.

On a chilly Saturday in October, 2012, 20 people crowded into Jason and Jennifer Clark's garage in Talent, Oregon. A rapt audience listened as Mike Davis of SOS Plumbing explained the solar hot water system behind him. Inside, another small group filled the living room, while Charlie Hamilton of Suncrest Homes talked about the home design process and the Earth Advantage program.

The Clarks' Earth Advantage-certified "Platinum" home was the first stop on last year's Rogue Valley Green + Solar Tour (RVGS), organized by independent home energy rater Fred Gant and a small committee. This tour was just one of 578 registered with the American Solar Energy Society (ASES) National Solar Tour (NST). In 2012, more than 90,000 people toured a combined total of 9,000 sites—from single-family homes and rural farmhouses to libraries, schools, and even whole communities—across the country.

Tour-goers run the gamut: Builders, architects, and designers exchange business cards and schmooze while learning about local projects on the cutting edge of sustainability. Renewable energy enthusiasts check out the latest photovoltaic and solar thermal technologies. Folks who want to go solar or build a home join a tour seeking information, connections, and inspiring models.

Nonprofit ASES, one of the largest grassroots organizations promoting solar and other sustainable energy technologies, has been coordinating the NST since 1996. Most tours happen in October, in conjunction with National Energy Awareness month, and although many fall under the umbrella of one of the 55 ASES chapters, anyone can register a tour, says Ariel Braude, ASES community manager and NST coordinator. Often, tours are collaborations; for example, the Texas Solar Energy Society teams up with the Pedernales Electric Cooperative to put on the Hill Country Solar Tour. Regional and local tours typically seek sponsorship, often from companies in the renewable energy or sustainable building business.

One of the earliest solar tours was organized by Real Goods in the mid-1990s.

Courtesy John Schaeffer

Origins

The NST can trace some of its roots to an event that was part marketing, part political activism—National Off-the-Grid Day (NOtGD). Sponsored by solar retailer Real Goods, NOtGD was launched by a Declaration of Energy Independence to promote consciousness of the nation's dependence on fossil fuels.

In a 1993 interview with *E Magazine*, Real Goods founder John Schaeffer said that "the idea was to glorify our customers who were living off the grid...Our idea was to get a house in every region so people could travel a few hours at most, and walk into one of these homes."

The first National Tour of Independent Homes (NTIH) featured fewer than 50 sites, but 500 people visited a single home in Dripping Springs, Texas. In 1994, the NTIH attracted some 5,000 people; in 1995, attendance had doubled to 10,000.

"By the end of 1995," says Schaeffer, "we realized it was costing a lot of money to promote and put on the tour, so we started looking for the right nonprofit organization to take it over." An announcement in the Real Goods catalog invited nonprofits to submit proposals for coordinating future tours.

Beyond Solar

Today, the tour's scope has broadened to include many aspects of greener, more sustainable building; however, solar remains the foundation. A project must include active or passive solar features to be eligible, says Mike DiGrazia, NST coordinator from 2005 to 2008. "But we emphasize that first you want to increase energy efficiency—plug up the leaks, etc.—*then* put on your solar."

The local RVGS tour included presentations on solar water heaters and PV systems, including an explanation of microinverter technology and a demonstration of online monitoring. At the Clarks' house, which features a "laundry-to-landscape" greywater system, visitors learned about Oregon's new greywater code. At the second stop on the tour, an Earth Advantage Gold-rated spec house built by River Lane Homes, a building company based in southern Oregon, project manager Dustin Knapp talked about indoor air quality and ducts; Gant and Earth Advantage technical specialist John Spillman demonstrated a blower door test and discussed the energy performance score concept (see "What is EPS?" sidebar, following page).

A TOUR NEAR YOU

Though many of the tours fall under the umbrella of one of the 55 ASES chapters, anyone can register a tour, including solar installation companies, utility companies, municipalities, nonprofits, and individuals. Some tours span several states and include dozens of projects; others consist of a single house with a PV array. Some tours are self-guided and free; others, like the RVGS tour, include transportation and a fixed schedule.

To locate a tour near you or find information about organizing a tour in your town, visit ases.org.

Courtesy Denise Ross

Earth Advantage technical specialist John Spillman and independent home energy rater Fred Gant demonstrate a blower door test at the second stop on the RVG+S Tour.

Courtesy Nexus EnergyHomes

Many, but not all, tour homes feature photovoltaic systems, like this duplex in the North Pointe community in Frederick, Maryland (see page 70 for profile).

WHAT IS EPS?

The Earth Advantage Institute and Energy Trust of Oregon teamed up to develop the Energy Performance Score (EPS), which rates a home's efficiency and measures it against similar-sized dwellings in the region. A third-party verifier develops a unique scorecard for each home, which includes estimates of monthly energy costs, annual energy consumption (measured in millions of Btu) and carbon emissions (measured in tons of carbon dioxide). The lower the score, the more efficient the home. Though voluntary, EPS is available throughout Oregon; pilot programs incorporating EPS have been launched in several other states.

A blower door test is part of the EPS scoring. This test, which measures a building's airtightness and identifies leaks, is one of a home energy auditor's best tools. A flexible panel is fitted into the frame of an exterior door; a fan mounted into the panel sucks air out of the home, creating a pressure differential between inside and outside, which is measured. Seeking lower pressure, outside air flows in through unsealed cracks and openings. The auditor can also measure the rate of air exchange and determine whether a home needs mechanical ventilation to improve indoor air quality or, conversely, leak mitigation to reduce heat loss or unwanted heat gain.

Three hundred miles to the north, the City of Portland and sponsor Green Depot hosted a companion information fair the same day as the self-guided Build it Green! (BIG) tour. Drop-in workshops were also held at tour sites for the first time. Workshops ranged from rainwater harvesting and Passive House construction (see "Passive House in Portland" profile, opposite page) to greywater reuse and accessory dwellings, which are becoming a popular option for Portland homeowners wanting to build small, green structures on their properties.

"Last year, the tour included about one-third commercial and public buildings," says Braude. "For me, this was exciting." She believes the trend signifies green building's entrance into the mainstream market.

Encompassing 10 states, the Northeast Sustainable Energy Association (NESEA) is the largest ASES chapter and hosts the biggest single solar homes tour in the country: the Green Buildings Open House (GBOH). Though the tour is largely aimed at consumers, its intent is to stimulate the market for green building and support building professionals who emphasize sustainability and energy efficiency.

Mary Biddle, NESEA's director of professional development, says NESEA changed the program last year. The 2012 tour included 300 sites, half as many as the year before. "We focused on the best, most dedicated examples," says Biddle. These included retrofits and renovations that are net-zero or net-positive.

continued on page 74

Tour homes showcase a variety of building efficiency techniques. This Portland, Oregon, home uses a curtain wall to pack in additional insulation (see profile, opposite page).

Courtesy Green Hammer

A mock-up wall assembly, including window flashing, air sealing, and two layers of exterior insulation, provides a model for the construction crew to follow during a home's deep energy retrofit (profile on page 72).

Courtesy Timeless Architecture

PASSIVE HOUSE in Portland, Oregon

Courtesy Brint Borgilt

Passive House principles put to work in this Portland home reduce heating needs by 90% compared to a typical home of the same size.

"I think of the design process as a tripod, with form, function, and budget comprising the three legs," says homeowner Mark Darienzo. "For us, function and budget determined the form."

He and his wife Robin Cash bought a "tear down"—a neglected foreclosed house in northeast Portland—and Darienzo deconstructed most of the house himself, carefully setting aside materials that could be recycled or repurposed. For home-building ideas, the couple attended solar tours in Portland and Bend, Oregon, and after interviewing several architects, hired Portland-based building company Green Hammer to complete the design.

"The budget was extremely tight for a custom design/build," says Stephen Aiguier of Green Hammer. The resulting contemporary saltbox design slashed in half the home's original square footage. The 1,327-square-foot floor plan includes a handicapped-accessible bathroom and home office downstairs.

Green Hammer's Alex Boetzel persuaded the couple to build a house that met Passive House standards, which means an airtight structure that reduces heating needs by 90% compared to a conventionally built home of the same size. Green Hammer achieved this in part by isolating the concrete slab from the foundation with rigid foam board insulation. Attaching a BCI "curtain wall" to the exterior of two-by-four stud framing resulted in 14-inch-thick walls, which were filled with dense-packed cellulose insulation. Triple-pane, fiberglass, argon-filled Cascadia windows helped complete the very tight envelope, and a concrete slab and double layers of interior drywall added thermal mass inside.

Water conservation was another priority. The couple's rainwater harvesting system features a 3,000-gallon cistern, pump, and series of filters, including a UV filter. They have a municipal hookup but haven't yet dipped into city water, though that could change once landscaping is in place.

A Passive House's primary energy demand—for heating, domestic hot water, ventilation, and electric appliances—cannot exceed a yearly threshold of 120 kWh per square meter of living area. The Cash-Darienzo home's primary energy was estimated at 114 kWh per square meter. Because the pump and UV treatment unit uses so much of their allotted energy budget, Cash and Darienzo chose to sacrifice another big energy user: a clothes dryer. Instead, they line-dry clothes outside or in the bathroom. A 3.29 kW grid-tied PV system leased from SunRun offsets a portion of their annual electricity use.

Boetzel determined that the small roof area and modest demand for hot water didn't justify a solar thermal system. Instead, a waste-heat recovery pipe draining from the upstairs shower preheats incoming cold water, reducing water-heating energy consumption.

The couple's house was featured on two tours in 2012: Solar Oregon's Goal Net Zero tour in June, and the City of Portland's Build it Green! tour in September. The home was also the site of drop-in workshops on rainwater collection and Passive House design.

Cash-Darienzo Passive House

Tour	Build it Green! Tour
Owners	Robin Cash & Mark Darienzo
Designer	Communitecture & Green Hammer
Builder & contractor	Green Hammer • greenhammer.com
Project location	Portland, Oregon
Date completed	Summer 2012
Type of residence	Single-family home
Square feet	1,327 (calculated according to Passive House specifications)
Construction method & materials	4 in. concrete slab; 2 × 4 advanced framed walls with continuous plywood sheathing; 9.5 in. BCI curtain wall attached to exterior walls; 24 in. parallel cord roof truss system with Custom-Bilt metal roofing
Passive solar	Long east-west axis; large windows on south-facing wall; concrete slab & two layers of interior gypsum provide thermal mass
RE system	3.29 kW grid-tied PV system
Heating & cooling	Mitsubishi MSZ-FE09 minisplit
Water heating	Marathon 50-gal. electric water heater, EF 0.90; RenewAbility Power Pipe waste heat recovery
Insulation	Foundation: 10.5 in. extruded polystyrene foam (R-50), walls: dense-packed cellulose (R-50), roof: dense-packed cellulose (R-80)
Windows	Cascadia 300 series triple-paned, argon-filled, fiberglass frame, tilt-and-turn windows
Lighting	LEDs & CFLs
Miscellaneous	Design and tight construction reduced heating & cooling energy by 90% over conventional home; ventilation ducts inside thermal envelope
Air-quality features	Zehnder ComfoAir 200 heat recovery ventilator, 95% efficiency; open windows for night ventilation
Other green features	Forest Stewardship Council-certified; rainwater collection with 3,000 gal. cistern & filter including UV; clothesline; materials recycled from original house; recycled-quartz countertops.
Rebates & incentives	State tax credit of $1,500/year for PV system covers cost ($6,000) of leasing system within four years
Certifications & awards	Passive House; Earth Advantage; Energy Performance Score; FSC; Northwest Energy Star

A MODEL DUPLEX in Frederick, Maryland

Courtesy Nexus EnergyHomes

The North Pointe community features townhouses, duplexes, single-family homes, and custom homes. Each home has its own PV array and a geothermal heating and cooling system.

Passive House building philosophy guided this duplex's design at a net-zero energy development at North Pointe, earning Emerald-level certification through the National Green Building Standard. Homes in this Frederick, Maryland, development are built with structural insulated panels (SIPs), and sprayed foam insulation seals and insulates the band boards (rim joists) and rafters to create a very tight envelope.

"Insulation is a big one," says Mike Murphy, construction division president of Nexus EnergyHomes, the design/build firm behind the development. "We build to achieve one air exchange per hour or less, with the ultimate goal of 0.6."

Nexus EnergyHomes won Builder of the Year in 2012 after a decision to embrace sustainable building. Murphy cites as inspiration a home designed and built by John Spears, architect with the Sustainable Design Group, that produced more electricity than it consumed. Studying a stack of electric bills from that project sealed his conversion.

"Month after month these bills were zero, -$5, -$10," says Murphy. "I thought, 'Why aren't we doing this?'"

Wanting to build a production model for the masses, the Nexus team took a systematic approach, breaking down each component of the typical American home and rethinking it. The Department of Energy (DOE) and the National Association of Homebuilders (NAHB) guided the process. Nexus broke ground on a new conceptual model home in January 2011 and opened it to the public in June, to much acclaim.

Duplexes in the North Pointe community start at around $270,000, slightly more than a similarly sized conventionally built new home in the Washington, D.C., area. Clients can customize and upgrade features in their selected floor plan.

"You can get a well-appointed home for less than $300,000," says Murphy. "Plus little to no electric bill." The $15,000 in dollar-for-dollar tax credits sweetens the deal. In addition to the 30% federal tax credit available for geothermal and PV systems, the state of Maryland offers $1,000 grants for each system.

Each home at North Pointe comes with an iPad programmed with NexusVision software; the homeowner can track how much energy is produced and consumed down to the circuit-breaker level, and detect and adjust usage patterns from any computer with Internet access. Nexus EnergyHomes is planning another net-zero project for Frederick County. The 14-lot development will center around a common green space and feature solar street lamps; each home will include rainwater harvesting.

"The R&D never stops," says Murphy. "Our projects are in line with the national agenda of making homes more energy efficient. It makes me think we can contribute to energy independence."

Nexus EnergyHomes Model Duplex

Tour	Maryland Tour of Solar & Green Homes
Owner, designer & builder	Nexus EnergyHomes • nexusenergyhomes.com
Project location	Community at North Pointe, Frederick, Maryland
Date completed	June, 2011
Type of residence	Duplex townhouse
Square feet	2,000 (+720 basement)
Construction method & materials	Conditioned basement; 6 1/2 in. SIPs wall; conventionally framed roof
RE system	4.7 kW grid-tied PV system
Heating & cooling	Geothermal
Water heating	Desuperheater; excess heat from mechanical equipment heats water
Insulation	Foundation: 2 in. rigid foam (~R-13); Walls: 6 9/16 in. SIPs (~R-25); Roof: 9 1/2 in. Agribalance polyurethane open-cell spray foam (R-44)
Windows	Jeld-Wen low-e, argon-filled, double-pane
Lighting	LEDs & CFLs
Miscellaneous	Ducts in conditioned space; blower door & duct blaster tests to ACH of 1.0 or lower; Energy Star appliances
Air-quality features	HEPA whole-house air filtration; central vacuum; low- to no-VOC adhesives, sealants, paints & stains
Other green features	NexusVision home communication system; recycled content drywall & carpet
Rebates & incentives	30% federal tax credit for geothermal & PV systems; state grants of $1,000 for each system—equals $15,000 to $18,000 per home
Certifications & awards	2012 National Energy Value Housing Award; Builder of the Year; Energy Star Partner; EPA Indoor Air Quality Partner; National Green Building Standard Emerald-certified

SOLAR STRAW BALE
in Holmen, Wisconsin

Courtesy Marilyn Pedretti

Thick straw bales in the walls of this off-grid home help moderate interior temperatures. The home's south-facing windows admit the sun's heat energy, reducing the need for mechanical heating.

Marilyn Pedretti's house was inspired by the two years she spent in El Paso, Texas, helping build straw bale homes for an affordable housing community called Tierra Madre. While these structures were embraced in the south, says Marilyn, "people [here] thought I was crazy." Not only were straw bale structures practically unheard of in her small community of Holmen, Wisconsin, but Pedretti planned to act as general contractor for the project while maintaining her other jobs.

She attended the Midwest Renewable Energy Association's annual energy fair for ideas and built a garage to gain some skills. She also started collecting materials, including windows and doors, and hired architect Todd Osman to help with the design. With the help of friends and family, and theme parties like "Get Plastered with Marilyn," Pedretti completed her house in a year and a half.

The home's thick, insulated walls and passive solar design help moderate indoor temperatures, even during Wisconsin's chilly winters and humid summers. Few, narrow windows on the north side minimize heat loss, while multiple windows on the south face admit solar gain, warming the space in winter. Adequate overhangs on the south shade these same windows from the hot summer sun. To the west, an eight-foot-deep porch keeps the sun out on late summer afternoons.

For backup heating, the four-inch concrete slab contains hydronic tubing. Pedretti sets the temperature of the concrete at 72°F to 74°F, resulting in ambient temperatures between 58°F and 65°F. The hydronic system relies on a propane-fueled instantaneous water heater.

A pole-mounted 1 kW PV array and battery bank provide the home with electricity and power the pump for her well. Pedretti relies on a portable generator "six to 10 times a year" for backup; she goes through a single 300-gallon propane tank annually. "November and December can be pretty challenging; sometimes we get three to four days in a row without sun," she says. She considered a grid-tied system but didn't relish the notion of spending $4,000 just to bring electricity to the house, not to mention a basic monthly fee of nearly $30 just for the privilege of selling electricity back to the grid.

Since its completion in 2007, Pedretti's house has been featured on the MREA's Wisconsin Solar Tour four out of six years. She regularly opens up her house to groups from schools and colleges, and other community groups. Though her home may not have earned any official certifications, Pedretti enjoys what she calls a "happy living award." Nobody calls her crazy anymore, either.

Pedretti's Straw Bale Home

Tour	Wisconsin Solar Tour
Owner	Marilyn Pedretti
Designer	Todd Osman
Builder	Marilyn Pedretti
Project location	Holmen, Wisconsin
Date completed	2007
Type of residence	Single-family home
Square feet	1,200
Construction method & materials	Concrete slab-on-grade; straw bale walls with 4 × 4 ft. post-and-beam frame; interior & exterior stucco; metal roof
Passive solar	Long east-west axis; adequately sized overhangs; deep porch to block late afternoon summer sun; small, narrow windows on north side
Renewable Energy	1 kW pole-mount off-grid PV system with backup generator
Heating	Radiant (hydronic) floor; supplemental wood heater
Cooling	Windows provide natural ventilation
Water heating	Bosch on-demand propane water heater
Insulation	Foundation: 2 in. rigid foam (~R-10) under slab & along frost wall; Walls: 18 in. straw bales; Roof: blow-in fiberglass (R-38) plus blow-in cellulose (R-20) added in 2009
Windows	Pella & Andersen double-pane, double-hung; U = 0.33
Lighting	CFLs
Air quality features	Nontoxic materials throughout; natural clay plasters
Other green features	Metal roof; rain barrels; recycled materials & salvaged fixtures, mirrors, furniture; deck made from recycled materials; kitchen cabinets from locally harvested lumber; cork floor with natural stain
Cost of systems	PV modules & inverter: $9,000; batteries: $3,000; installation: $1,500
Rebates & incentives	Federal income tax credit
Certifications & awards	"Happy living award"

A DEEP ENERGY RETROFIT in Quincy, Massachusetts

Courtesy Timeless Architecture

The Halls expanded their living space but shrunk their energy bills by investing in energy-efficient building techniques and a 6.25 kW PV system.

Thomas and Margaret Hall bought their house in Quincy, Massachusetts, 15 years ago. As their family grew, they decided to expand the two-and-a-half-story, 1903 home. Their three children had been sharing a single bedroom, and they wanted a home office and to accommodate an aging parent. The plan started out with a very simple second-story addition.

"Part of what an architect does is set a vision for the client," says Henry MacLean, principal architect for Timeless Architecture. The Halls were open to MacLean's ambitious proposal—that they take part in a Deep Energy Retrofit pilot program hosted by National Grid. At that time the utility company, which serves several eastern states, including Massachusetts, was offering incentives of up to $42,000 for single- and multi-family residences that met rigorous standards for a whole-house energy retrofit.

The Halls decided to go one step further and participate in the Thousand Homes Challenge (THC). These projects must demonstrate a 70% reduction in energy use through a year's worth of monitoring. National Grid kicked in an additional $10,000 incentive for projects that met the standard (see "A Thousand Paths to Energy Efficiency" sidebar on page 74).

MacLean cites cooperation among the team of builders, subcontractors, and consultants as the key to the project's success. Building Science Corporation, an architecture and building science consulting firm, acted as energy consultant throughout the process. One of the teaching tools was a mock-up wall assembly, which included window flashing and air-sealing details and showed the attachment of the two overlapping layers of exterior insulation.

The revamped design retained the home's original footprint but added more than 900 square feet of living space, including a full second story and two home offices on a new third floor. A 6.25 kW grid-tied PV system and six-collector solar hot water system provide up to 60% of the home's annual energy and hot water needs.

The climate in Quincy is challenging, with cold winters and hot, humid summers. Air conditioning was a requirement. Hydronic floor heating was installed in both the basement and first story; a hydro-air system heats the rest of the house. The heating is from a trifuel system: in solar-thermal mode, the gas is "locked out," regardless of outside temperature.

A Carrier air-to-air heat pump takes over when the solar thermal can't meet demand. The heat pump works well during the swing seasons but becomes less effective at lower temperatures. Natural gas is used only when the outside temperature dips below the balance point—36°F and when the solar thermal heating isn't available.

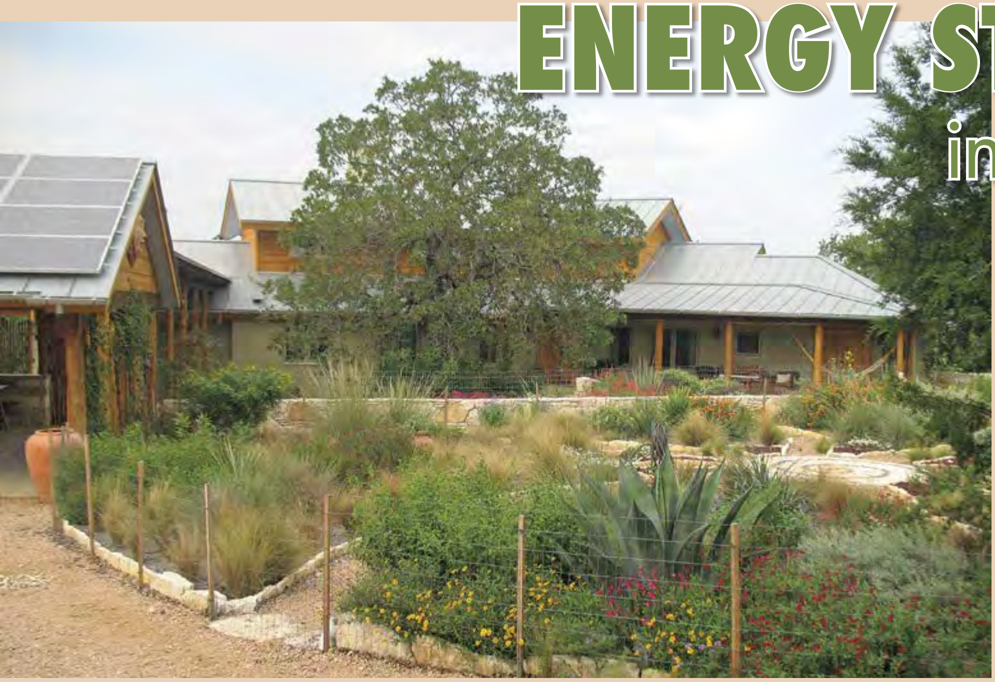
The THC total energy consumption threshold was determined at 11,522 kWh per year, which includes grid electricity and natural gas (converted from Btu). To put this in perspective, similarly sized homes in the area use an average of 70,000 kWh per year. The Halls monitored their energy usage from July 2011 to July 2012—the fossil fuel consumed totaled 8,936 kWh, or 77% of the threshold.

MacLean praises the Halls for their cooperation and involvement. Before embarking on their project, he had three or four clients consider a DER, but reconsider during the design/development phase. "Even with the incentive, it's an eight- or nine-year payback," he says. "That's a big commitment." The Halls' project represents the first DER south of Boston, and one of about 20 statewide.

The Halls' Expanded Efficiency

Tour	Green Buildings Open House Pro Tour; sponsored by Northeast Sustainable Energy Association & National Grid
Owners	Thomas & Margaret Hall
Designer	Timeless Architecture • otimearch.com
Builder	Grifcon Contracting
Project location	Quincy, Massachusetts
Date completed	December, 2010
Type of residence	Single-family (includes two home offices)
Square feet	3,560 (from 2,647; retained original footprint)
Construction method & materials	Wood frame with two layers overlapping exterior rigid insulation & Hardie fiber-cement siding; concrete slab over existing granite foundation & basement
RE system	6.25 kW grid-tied PV system; SunRun lease
Heating	Phoenix Evolution VersaHydro radiant (hydronic) floors in a trifuel system: solar thermal first, then electric heat pump. Natural gas is used as when temperature is below 36°F and no solar thermal is available
Cooling	Carrier air-to-air heat pump (COP 4.08 @ 47°F; 2.8 @ 17°F)
Water heating	Phoenix Evolution VersaHydro gas storage water heater with heat exchanger for input from six Velux integrated SHW collectors
Insulation	Roof: 10 in. of Icynene spray-foam; 4 in. rigid polyiso foam (R-60); Walls: two interwoven layers of polyiso foam (R-40); Basement: 2 in. closed-cell foam over foundation; 3.5 in. fiberglass batts in framing
Windows	Paradigm triple-paned, low-e argon-filled (U-value = 0.2)
Lighting	CFLs
Miscellaneous	Energy Star appliances
Air-quality features	Lifebreath heat recovery ventilator: 190 ECM, 88% efficiency, installed through AHU & central duct system
Other green features	Rain barrels from rain leaders with overflow to ground
Rebates & incentives	National Grid DER program: $40,000 plus $10,000 for meeting THC threshold; Electricity from grid at set rate of $0.11 per kWh for 20 years
Certifications & awards	National Grid DER (2011); ACI 1000 Home Challenge (2012); NESEA Pro Tour (2012)

ENERGY STAND-OUT in Austin, Texas



Courtesy Environment Associates

Tonalacalli has been featured on both the Cool House Tour and the Hill Country Tour; the couple also host many informal groups, including teachers and journalists. Despite the awards and accolades, Treviño insists the house could be even greener. If she could do anything differently, she would have built a smaller house, and built it out of Hebel block exclusively.

Plenty of thermal mass, deep porch overhangs, and quality windows help this Texas Hill Country house keep its cool during sultry summers.

When Laurel Treviño and husband Carlos Torres-Verdin moved to Austin in 1999, southwest Austin was still "in the country." Not anymore. But in an area exploding with "little boxes" organized in subdivisions, their home stands out as a more sustainable model.

Treviño had nursed the dream of building a green house for three decades, influenced by books like *The Barefoot Architect*, and inspired by outings to rural "eco-homes." It was on a Cool House Tour that the couple met architect LaVerne Williams and learned about Hebel aerated autoclaved concrete (AAC) blocks. Treviño originally wanted to build with straw bale or adobe, but decided against these materials because of the labor involved.

One of the first Leadership in Energy Efficient Design (LEED) certified homes in the nation, Tonalacalli ("house of sun and water") uses passive and active solar, insulation, thermal mass, and quality glazing to achieve its energy efficiency. A 3.3 kW batteryless grid-tied PV system offsets almost of the home's electricity, and a two-collector solar hot water system provides most of their water heating. The AAC blocks balance thermal mass and insulation, decreasing temperature swings inside the home. Deep porches and eaves help keep the hot summer sun at bay, while well-placed operable windows funnel summertime breezes through the house, reducing the couple's reliance on mechanical cooling. Despite the legendary Texas summers, they use their air conditioner only intermittently in the summer months, and rely on ceiling fans, and cross and stack ventilation to cool the home. During colder months, passive solar lowers the heating demand.

The house is not connected to city water and there's no well; instead, 5,500 square feet of roof feed rainwater to three 10,000-gallon cisterns. Treviño says several of their neighbors have rainwater collection systems, too, in part because wells are drying up and droughts are severe and unpredictable.

Tonalacalli features local materials, from the clay plaster to the exterior stonework. Much of the interior wood came from trees on-site. Peeled eastern cedar logs formed the exposed columns; stair risers were crafted from local mesquite; stair railings, fencing, and decking came from mountain juniper harvested on site.

Tonalacalli

Tour	Hill Country Solar Tour
Owners	Laurel Treviño & Carlos Torres-Verdin
Designer	Environment Associates, LaVerne Williams, Principal, AIA, LEED AP • environmentassoc.com
Builder	Custom Building Inc.
Project location	Golden, Radiance & Ila Creek, Texas (near Austin)
Date completed	2007
Type of residence	Single-family home
Square feet	3,080, plus 200 for greenhouse & 400 for carport/shed
Construction method & materials	Concrete slab; Hebel block & mortar (first floor); conventional wood framing (half story) with Hardi-plank siding; metal roof
Passive solar	Long east-west axis; deep overhangs; deep porches; well-insulated metal roof to minimize heat gain; cross & stack ventilation by placing windows & doors in path of prevailing winds
RE system	3.3. kW batteryless grid-tied system (Sharp modules; Fronius inverter)
Heating	Wood-burning furnace provides supplemental heat
Cooling	2 Trane HVAC units (XL 1400, 15 SEER efficiency) with AirCycler; ceiling fans; cross & stack ventilation in fall & spring
Water heating	2 Tinox SHW collectors; 80-gallon electric water heater
Insulation	Walls: AAC block; spray foam in wood-framed second story; Ceiling: spray foam
Windows	Pella double-paned, low-e casement-style
Lighting	Natural daylighting; CFLs or fluorescent tubes; solar outdoor lights
Miscellaneous	Energy Star appliances
Air-quality features	Detached carport; low- or no-VOC adhesives & sealants; paints comply with Green Seal Standard GS-11; no carpet
Other green features	Rainwater collection with three 10,000-gal. cisterns & filtration (includes UV filter); on-site sewage treatment; clothesline; vegetable gardens; mostly native or drought-tolerant plants; compost; pervious driveway
Certifications & awards	5-star rating, Austin Green Building Program; certified LEED Platinum, U.S. Green Building Council; Energy-Star Qualified Home (EPA)

continued from page 68

Last year, NESEA teamed up with EnergySage to create a web page for every project featured on the consumer tour. Users could filter projects by location, manufacturers, mechanical systems, and other features, guiding themselves on a virtual tour of the homes. Braude says ASES hopes to adopt a similar template to facilitate such tours, though she's careful to point out that a virtual tour can never take the place of physically visiting a property and talking with homeowners, builders, and architects.

In 2012, NESEA also hosted a special "Pro Tour" for building tradespeople, consisting of three Boston-area projects participating in National Grid's pilot Deep Energy Retrofit program (see "Quincy DER" profile). "The architects and builders associated with each project were on site to speak, practitioner to practitioner," says Jennifer Marrapese, NESEA's executive director. Participants could even earn continuing education credits through the American Institute of Architects (AIA).

Courtesy Laurel Treviño

High-performance materials like this aerated autoclaved concrete block can contribute greatly to a home's overall energy efficiency (see profile on page 73).

A THOUSAND PATHS TO ENERGY EFFICIENCY

Can a thousand examples of extreme home energy reductions catalyze a movement? Linda Wigington, founder of Affordable Comfort Inc. (ACI), thinks so. ACI developed the Thousand Home Challenge (THC), an initiative to drive a revolution in residential energy conservation.

"The THC seeks to show what's possible in [home energy savings]," says Wigington. "We know what needs to be done, but we need demonstrations of how to do it." The goal? To recruit homeowners willing to reduce energy consumption in their existing homes by 70% to 90%, documenting the process along the way so others can follow in their footsteps.

Homeowners seeking to shrink their home's energy footprint can apply to participate via the THC website. Although ACI doesn't provide financial support, the nonprofit offers tools and resources to help participants meet the program's standards. Of course, homeowners implementing energy-saving projects reap the ongoing benefits of reduced utility bills and, often, improved thermal comfort in their homes.

The THC offers two energy-reduction paths. Option A requires a 75% verifiable reduction in annual energy use based on 12 to 18 months of recent utility bills. Those without access to past energy-use data, and low-energy-use households seeking even deeper reductions. can choose Option B, which factors in climate, occupancy, heating fuel source, and floor area to calculate a unique threshold for each project. This number represents the sum of four categories of demands—heating, cooling, water heating, and "everything else"—for a high-performance house, measured in kilowatt-hours per year. Participants must verify they've met the threshold through 12 months of utility bills or other documentation.

About 80 projects are taking the Challenge before the program officially launches, including 19 that have formally met their thresholds. Not surprisingly, many of the projects are in Massachusetts and California. California utility company PG&E supported ACI's efforts to develop the Challenge. Incentives for renewables, while not directly tied to the THC, make participating a little more affordable. National Grid, Massachusetts' utility company, actively promoted the Challenge by offering an additional $10,000 to the incentives already available through its pilot Deep Energy Retrofit (DER) program.

The Quincy house (see profile) took advantage of National Grid incentive, but a project doesn't have to be a DER to meet the Challenge. Wigington cites one project in a mild climate for which the major expense was $50 on energy monitors and plastic for the windows. The main tool was behavior modification, which lowered energy use substantially. She says the emphasis on behavior modification and community solutions—along with improved efficiency and incorporation of renewable energy technologies—distinguish the THC from programs like LEED and Passive House. She also sees the Challenge as an opportunity for people hailing from different philosophical camps to learn from each other.

Homeowner Ward Lutz heard about the Challenge and hoped to reduce his carbon footprint by remodeling his small Ohio bungalow. Inspired by Passive House standards, he started with the "20:40:60" rule (R-values for foundation, walls, and attic), doing most of the work himself on a tight budget. Lutz's new and improved envelope and willingness to live with cooler indoor temperatures—60°F to 65°F in the winter—enabled close to an 89% reduction in heating energy use. His is one of the first projects to officially meet the targeted threshold.

ACI hopes to collect a range of projects representing a variety of climates, structures, approaches, and budgets, and welcomes projects that already meet the Challenge. The goal of the THC is to "contribute to momentum" by inspiring others.

Lutz officially met his home's targeted threshold after his first round of energy-use reductions. He has since added a 3.5 kW grid-tied PV system and a heat-pump water heater (see "Heat-Pump Water Heaters" in this issue). His home has produced more energy than it used for the last two years.

"That's been one of the real surprises," says Wigington. "People that meet the threshold keep going further. It stimulates an appetite to do more."

Interested in taking the THC? Review case studies at thousandhomechallenge.com.

Get Your Tour On

Many registered tours aren't as well-established and independent as NESEA's GBOH or Portland's BIG tour, so Braude lends special support to individuals and small organizations that want to participate in the tour for the first time.

"People will call to ask, 'This looks like a great event; how can I get my house on it?'" says Braude, who offers tips from her own experience hosting local tours. She encourages individuals to join forces with other people in the community who have solar installations; after all, larger tours potentially attract more visitors.

"Today, ASES's main role is to provide a website for everyone to post their tours, descriptions, and location maps," says Braude. ASES also provides marketing materials. Tour guides, shipped free of charge to anyone who registers a tour, include basic information on solar energy and energy efficiency, as well as information about ASES chapters. ASES will also provide NST yard signs and promotional posters.

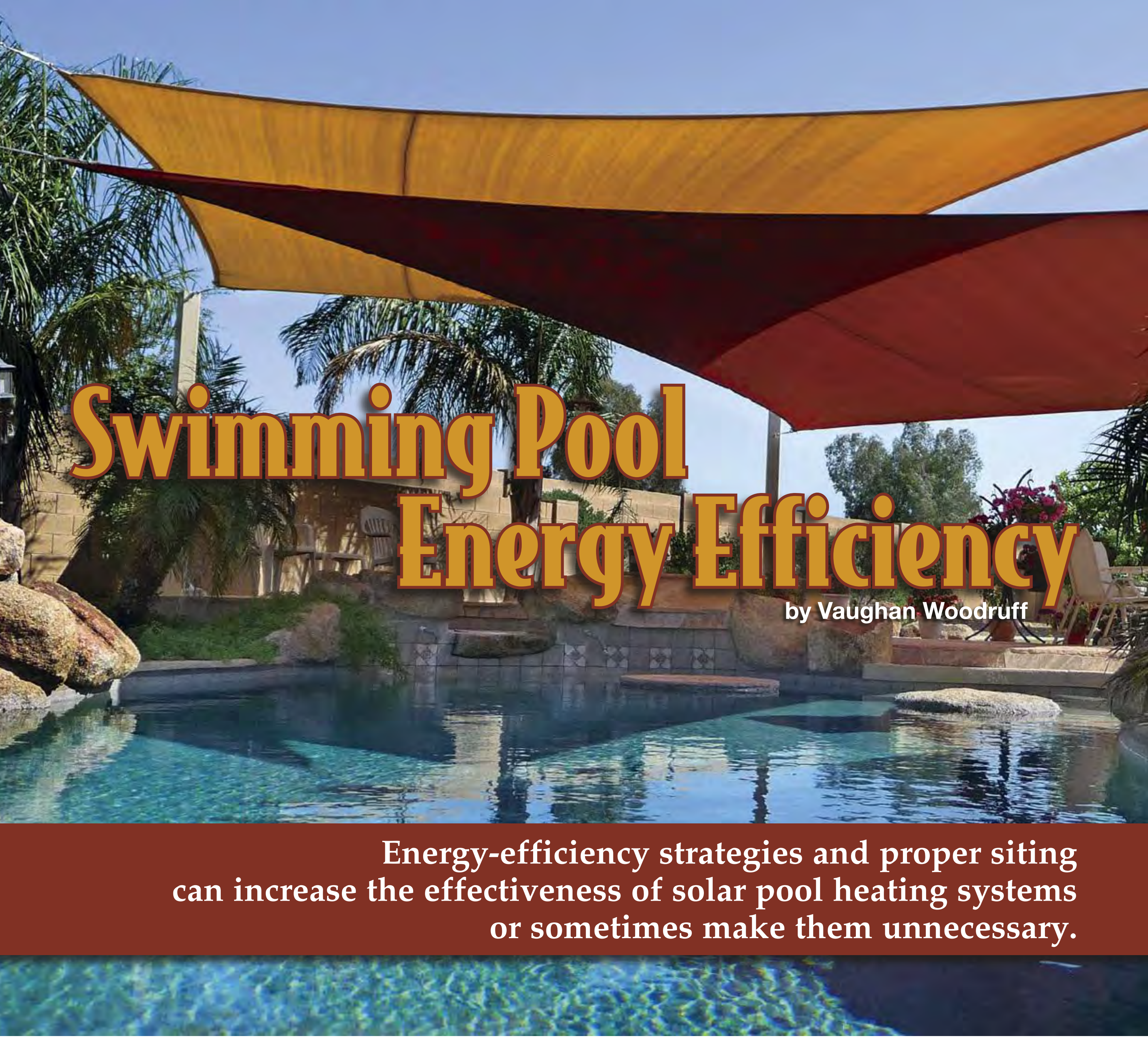
Though the NST has changed over the years, its mission remains essentially the same. "The purpose of the tour is to accelerate the sustainable energy economy," says DiGrazia. This is accomplished through education: direct opportunities to talk with homeowners, builders, solar energy installers, and other energy-efficiency experts—not only about the technology, but about the cost of installation, availability of incentives, and leasing programs.

Like Marilyn Pedretti (see page 71), many solar tour participants are pioneers, leading the way to creating more sustainable buildings.

Courtesy Marilyn Pedretti

Access

Freelance writer **Juliet Grable** (julietgrable@yahoo.com) got hooked on solar tours after attending her local tour—the Rogue Valley Green + Solar Tour—last year. She frequently writes about sustainable building.



Swimming Pool Energy Efficiency

by Vaughan Woodruff

Energy-efficiency strategies and proper siting can increase the effectiveness of solar pool heating systems or sometimes make them unnecessary.

Solar pool heating (SPH) is cost-effective for extending the swimming season and increasing comfort in outdoor swimming pools. But, as with any heating system, addressing energy losses first will maximize the system's efficacy and performance, and provide additional savings.

Siting

Pools themselves are solar collectors. According to NREL's *Conserving Energy and Heating Your Swimming Pool with Solar Energy*, between 75% and 85% of the sun's energy that strikes a pool's surface is converted to heat energy. Many seasonal pool owners capitalize on this and use their pools without supplemental heat. In hot climates, pools may need shade to prevent overheating.

The best opportunity to reduce a pool's energy use is proper siting. The pool should be placed in an area that maximizes the solar gain when it is most needed. In climates with a short swimming season, such as those in northern areas, it is best for the pool to receive unimpeded sunlight from 8 a.m. to 4 p.m. during summer. In hot climates, it can work out best to site for maximum passive gain during the spring and fall, when the pool's heat loss is more significant.

Shading assessment tools can be used to find the best pool siting. Tools like the Solar Pathfinder ($259) or SunEye (starting at $1,995) can assist with this task. A smartphone application that costs $20 to $40 (such as Comoving Magnetics Solar Shading application for Android and Solmetric's iPV application for iPhone) can provide sufficient information for pool siting.

Courtesy Tenshon LLC • tenshon.com

Above: In hot climates, shading your pool to prevent overheating from solar gain can be an effective passive strategy.

Pools are often sited for aesthetics and accessibility, which may limit opportunities for energy efficiency. While an aboveground pool could be relocated if there is a more appropriate location, in-ground pools do not have such luxury. Instead, tree removal may be the only option for increasing an existing in-ground pool's passive solar gain.

Modes of Heat Transfer

Heat can flow into and out of a pool through conduction, evaporation, convection, and radiation. If there is a difference in temperature between the pool water and the earth (for an in-ground pool) or the air (for an aboveground pool), heat will flow through the pool walls. As pool water evaporates, heat is lost from the pool. Additionally, wind blowing across the pool's surface can extract heat through convection and the surface of the pool will radiate heat to a colder sky.

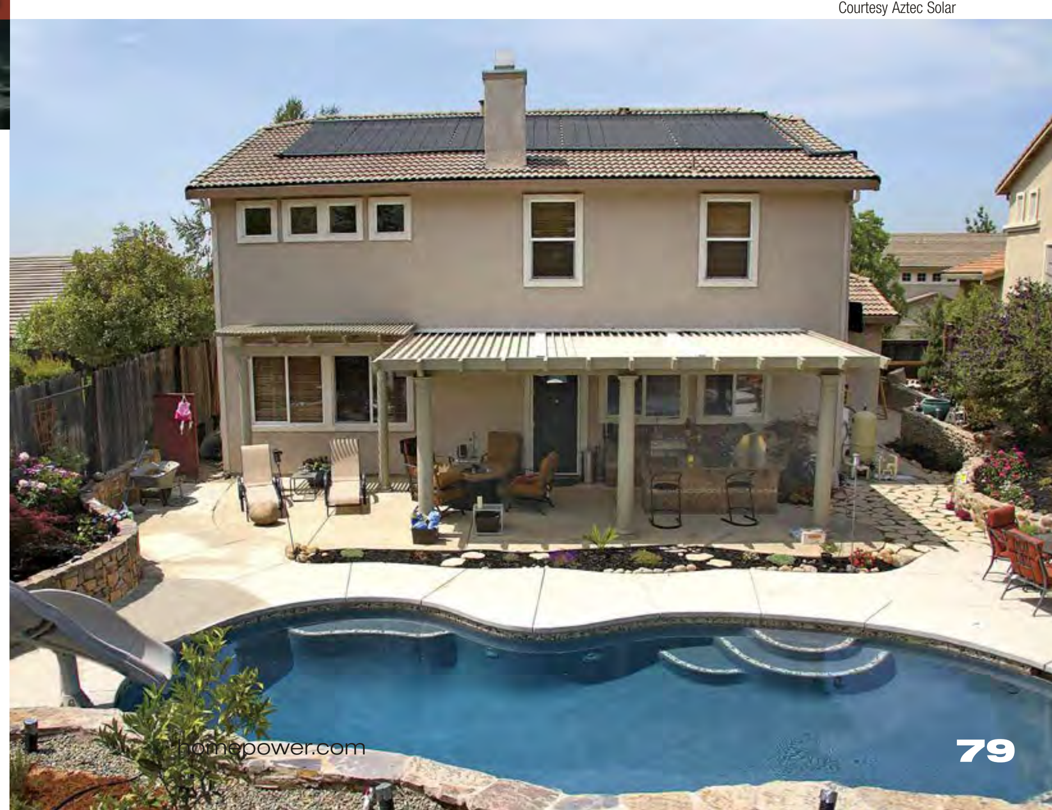
Climate has a significant impact on a pool's heat loss. For example, evaporation is more pronounced in dry climates. Areas with clear, cold nights will experience increased radiation from the pool surface. At higher latitudes, the earth's cooler temperature will lead to greater heat loss through the walls of an in-ground pool.

Conduction through pool walls. In typical situations, the desired pool temperature ranges from 78°F to 82°F. Therapy pools are warmer, between 92°F and 94°F. Since there is often a temperature difference between the pool water and the surrounding earth or air, heat is transferred through the pool walls.

In the United States, most in-ground pools are uninsulated. In areas like Florida, this makes sense, since the ground temperature stays between the mid-60s and the low 80s—meaning that the pool temperature and surrounding soil temperature may be the same. However, the same pool in New Hampshire might *lose* 75,000 to 100,000 Btu per day to the earth. While this difference may seem drastic, the conductive heat loss in northern climates only contributes to about 5% of the pool's heat loss.

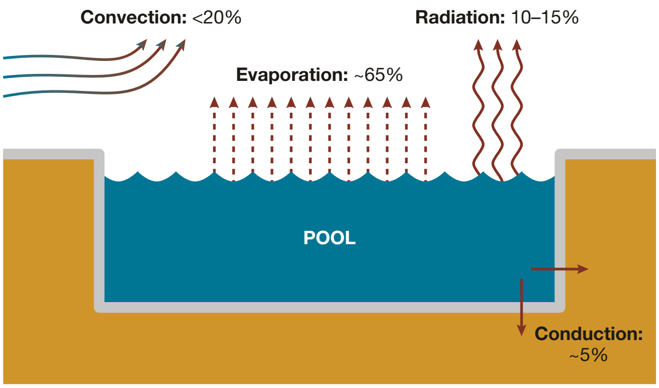
In the grand scheme of pool conservation, insulating the walls of an in-ground pool picks the high-hanging fruit. The contribution of these losses is such a small portion of the total heat loss from the pool that any investment in insulation for the pool walls may be better spent somewhere else. Conductive losses to the earth are typically only a significant issue if the pool is built in an area with a high water table. A dynamic water table can more readily pull heat away from the pool's perimeter than soil can. In this circumstance, insulation might be justified.

Courtesy Aztec Solar

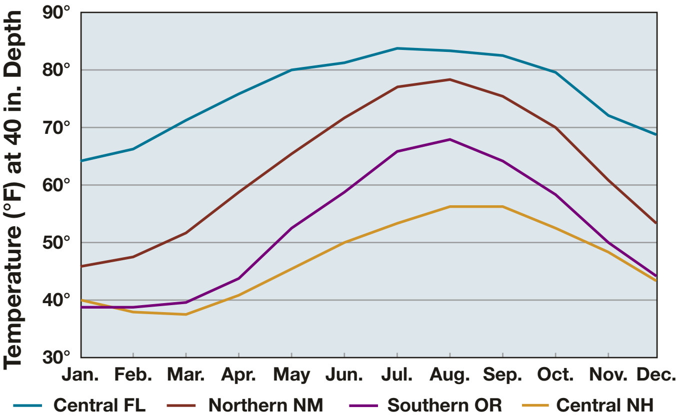


Right: In cooler climates, siting the pool to receive as much sunshine as possible will help maintain a more comfortable water temperature.

Types of Heat Transfer



Ambient Ground Temperatures



Source: Natural Resources Conservation Service

With an above-ground pool, there may be some advantage to adding rigid insulation to the pool walls, especially where there are large diurnal swings in air temperature during the swimming season or if the pool is located in a windy area. If the pool has a metal frame, rigid insulation may be able to be installed, although it will need to be covered to protect it from UV degradation. Above-ground pools with ribs may be more difficult to insulate.

Wind effects. Wind across a pool's surface also steals some of the pool's heat. For pools that are sheltered by buildings, vegetation, or fences, this heat loss is minimal. But in windy areas without protection, convection can contribute up to 20% to the pool's total heat loss.

For pools located in unsheltered areas, windbreaks should be constructed. The windbreak might be a solid fence or shrubbery that protects the pool from the prevailing winds.

In cooler climates, above-ground pools may incur more heat loss through the pool walls compared to their in-ground counterparts.

©istockphoto.com/fury123

Just keep it mind that you do not want your windbreak to shade the pool, since that could impact the passive solar heat delivered. The heat-robbing effects of wind can also be reduced by using a pool cover.

Even with a pool cover, above-ground pools in windy locations can experience significant heat loss through the pool walls. As a cooler wind blows against and past the pool walls, convection removes heat from the pool. An above-ground circular pool with an 18-foot diameter will lose roughly 120,000 Btu per day through its walls when there is a 15°F difference between the water temperature and the air temperature. This value climbs to 240,000 Btu per day with a 7 mph wind.

Surface evaporation & radiation. If a pool is left uncovered, the heat loss from the pool's surface dwarfs the energy loss through the pool walls regardless of climate. Without a pool cover, the pool in New Hampshire could lose as much as 2,000,000 Btu per day through evaporation and radiation. That's the energy equivalent of 25 gallons of propane used by an efficient pool heater.

Roughly 90% of the heat loss from a pool surface is due to evaporation. This is because each gallon of water that is evaporated from the pool removes more than 8,500 Btu of energy. One inch of evaporation from a pool's surface can remove enough heat to cool the remaining water in the pool by 20°F.

This excessive heat loss from the pool surface is why covering the pool while vacant is so critical. If a pool blanket is used at night, the passive solar heat collected during the day is better retained through the night.

When used during times of inactivity, a pool cover by itself may be able to maintain adequate pool temperatures and avoid the need for additional heating in northern climates where pools are used seasonally. The U.S. Department of Energy estimates that an effective pool cover can reduce heat loss by 50% to 70%, and reduce the amount of water lost to evaporation by 30% to 50%. A bonus to reducing evaporation means that chemical loss is also reduced by 35% to 60%.


©istockphoto.com/MariadaDesign

Opaque covers reduce heat loss and algae growth, but can reduce or eliminate solar heat gain.

Cover Savings

Some neighbors asked my company for a bid on a solar pool heating system for their in-ground pool in Maine. They were hoping for a low-cost solution to raise their pool's water temperature.

Before starting a detailed estimate, I asked if they had a solar pool cover. The customer pointed to a shed and explained that the blanket had earned its spot there by being too inconvenient to handle. I touched briefly on the evaporation losses in pools and encouraged them to use the blanket more often.

They were a little hesitant until I explained that they could spend several thousand dollars on a solar pool heating system, or invest $200 in a reel, which would make handling the blanket far easier.

A couple months later, I ran into one of them again. "The blanket works like a charm," she said. I don't think they even bought the reel.

Pool Covers

Opaque cover. For large pools, an opaque blanket with a thin layer (roughly 1/8-inch thick) of polyethylene insulation is sometimes used. Uninsulated, opaque covers are also commonly used with certain automated pool reels or as a safety cover to prevent children or animals from falling into the pool. Opaque covers minimize evaporation—but they also reduce or eliminate passive solar gain. This may be preferable in some climates, such as Phoenix, Arizona, in the summer, but detrimental in others. More robust insulated covers are used with spas and hot tubs due to the high temperature difference between the water and the outside air. Uninsulated vinyl covers cost from $0.20 to $0.40 per square foot, while insulated polyethylene covers may cost $2 to $4 per square foot.

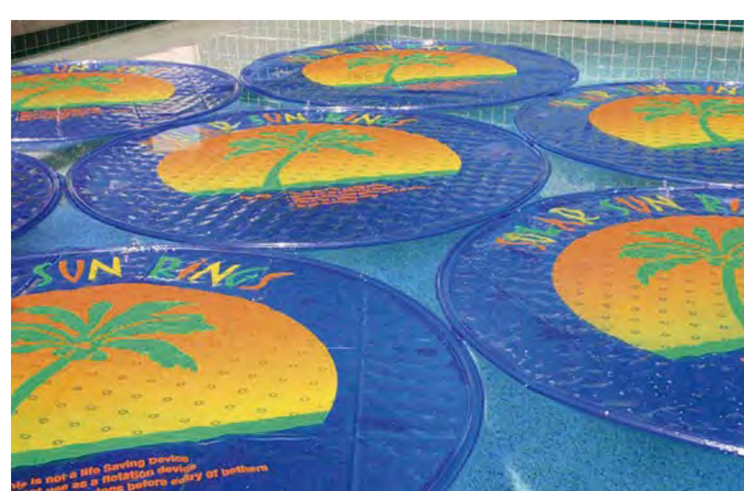
Solar pool cover. A solar pool cover minimizes evaporation without fully sacrificing passive solar gain. These bubble-type covers may reduce the passive solar gain by 5% to 15%, but they also limit the heat lost from the pool's surface due to evaporation and radiation. When the pool is in use, the solar pool cover is stored on a manual or automatic reel. The polyethylene used for solar pool covers is treated to protect it from UV degradation. Solar pool covers vary in price from $0.20 to $2 per square foot. Since the durability of the cover can vary significantly by manufacturer, it is important to consider the warranty duration.

Solar rings. For those who are less inclined to handle a single large pool cover between uses or with irregularly shaped pools that don't lend themselves to a standard pool cover, several smaller pool rings can be used. The 5-foot-diameter discs are made from UV-resistant vinyl and contain magnets along the perimeter to link the individual rings together. The rings contain two layers of vinyl and are slightly inflated to

Translucent solar pool covers have bubble insulation to reduce heat loss, but can still admit solar gain.


Courtesy Skysolarcover

Solar rings are touted as being easier to handle than a blanket cover, but can leave 25% to 30% of the pool's surface uncovered.


Courtesy Solar Sun Rings

Courtesy Flexible Solutions

Liquid pool covers provide a very thin layer of solution that floats on the water's surface to reduce evaporation.

provide additional insulation. Since they are circular, these rings are able to cover up to 75% of the pool surface, thus reducing a majority of the evaporation. Each sun ring costs approximately $30 to $40.

Liquid pool covers. There are a number of alcohol-based liquid pool covers that are applied to a pool through apparatuses that slowly release the liquid. For residential pools, these devices may be placed directly into the pool or in the filter basket. The liquid is biodegradable and specific brands have been deemed nontoxic for pool occupants. Liquid pool covers disperse across the pool's surface, creating a thin film and inhibiting evaporation of the water below. A liquid pool cover costs about $10 to $15 per month for a 20- by 40-foot residential pool.

Pump It Better

Residential pools require mechanical systems to maintain water quality. A pump sends pool water through a filter before returning the water to the pool. The pump is a significant energy user, and can be as large as 2 horsepower and may run for 10 or more hours per day—possibly requiring 20 kWh or more of electricity per day. At $0.15 per kWh, that adds up to more than $3 per day.

Though it may seem counterintuitive, it is best to use a pump that has to run longer to filter the contents of the pool. Let's look at a 20- by 40-foot pool that holds 24,000 gallons of water. The pool's mechanical system should be set up to filter the entire contents of a pool each day. If we wanted to run the pump for only four hours, it would require a flow rate of 100 gpm and a 2 hp pump. A relatively expensive filter and larger-diameter piping are required to accommodate this high flow. A 0.5 hp pump could be used instead that would provide a flow rate of roughly 50 gpm. Though this would double the required pump run time (to eight hours), it would cut the total electricity consumption in half. In addition, the pump would cost about $200 less and the filter would cost about $300 less.

A Whole-System Checklist

If you are planning to build a new pool and want to save energy, water, and chemical use, as well as reduce equipment costs, consider the following:

- ☐ Site the pool to maximize solar gain during the times of year when the heat is most desired.
- ☐ If the site is windy, use wind breaks—fences, vegetation, etc.—to reduce convective heat loss.
- ☐ Select a pool cover that you know you will use. This may be a solar pool cover with a manual reel, an automated pool cover, solar rings, or a liquid pool cover.
- ☐ Select a filter that is appropriately sized for the pool.
- ☐ Invest in a variable-speed pool pump and program the control to run for only as long as is needed to filter the pool's water.
- ☐ Include a solar pool heating system if you want increased comfort or to extend the swimming season.
- ☐ Address other energy uses around the pool. For example, LEDs can be used for in-pool and peripheral lighting.

If you already own a pool and are looking to make it more efficient, compare your pool to the pool described above. Could it benefit from a wind break? Are you using your pool cover regularly? What type of pump is used and how is it controlled?

Some states, like Arizona, California, and Florida, actively promote energy-efficient pool pumps. In Florida, a pool pump with a capacity greater than 1 hp must be multi- or variable-speed. The lower speed(s) are used for standard filtration, and the higher speed(s) can be used if an SPH system requires higher lift to the collector array. In addition, the code stipulates that the pump must operate at a speed that requires six or more hours to filter the volume of the pool.

A variable-speed pump integrates well with an SPH system, and pump speed can be preprogrammed. During the day, when solar energy is available, the flow can be increased. In the evening, when the pump is needed only for filtration, the flow can be decreased. Compared to standard single-speed pumps, these pumps can reduce electrical consumption by up to 90%. Unfortunately, variable-drive motors have not yet found their way into the aboveground pool pumps market.

A multiple-speed pump has a manual switch for selecting between two or more pump settings, but is less efficient than a variable-speed pump. The lowest speed uses the least energy, which allows extended filtration time to improve filtering and reduce total energy use. Two basic strategies can be used in conjunction with multi- and variable-speed pumps.

Vaughan Woodruff

Variable-speed pumps are very energy-efficient and have built-in controllers for ease of function.

Appropriately size the filter and keep it clean. A filter that is undersized or excessively dirty will restrict the pump's flow, which increases run time needed to adequately filter the water. The filter manufacturer can provide pressure loss and flow rate specifications for sizing. The pool owner can determine whether the filter needs cleaning by monitoring the pressure gauge on the filter.

Properly size the piping. PVC pipe is used in pool systems. The larger the pipe diameter, the less the flow restriction. Typically, 1.5- to 2-inch PVC is used. The farther away the pump and filter are from the pool, the larger the pipe that is needed. This is not usually a consideration with unheated pools but can be with systems that require long runs to an SPH.

Jeff Simons, manager at Sandollar Spa & Pool, a swimming pool and sauna company in Brewer, Maine, says that the efficiency measure most pool owners overlook is a pump timer. "Most pools with conventional pumps can be maintained by running the pump for 10 to 12 hours a day," says Simons. "However, without a timer, the owner may forget to turn the pump on or off, either of which quickly increases the operational cost and energy use."

Access

Vaughan Woodruff is a contractor, engineer, and educator. He owns Insource Renewables, a design/build and consulting firm. His pool energy strategy is to relax at his generous neighbors' pool in his hometown of Pittsfield, Maine.

Conserving Energy and Heating Your Swimming Pool with Solar Energy • NREL • bit.ly/NRELpool

Pump efficiency info • bit.ly/PoolPumpEff

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SHOPPING FOR A GREEN CAR

THE SMART WAY

by Curt Lindeman

Shopping for your new green car doesn't need to make you blue if you break down the process into three simple steps.

Courtesy Scion

1 Green Car Certification

The U.S. Environmental Protection Agency (EPA), through its Office of Transportation and Air Quality, has made finding a green car easier. Since 2000, the EPA has rated every new model for its greenhouse gas and smog emissions, and fuel efficiency, allowing shoppers to compare cars for their environmental impact per mile driven. It then certifies the vehicles that it deems to be "green" as SmartWay vehicles (see epa.gov/greenvehicles/), with the very top performers earning the SmartWay Elite designation. This program is much like the EPA's Energy Star program for household appliances. The ratings criteria are assessed annually to ensure that they keep up with the evolving technologies.

The SmartWay program evaluates vehicles against three parameters:

- **Fuel economy**—Measures how efficient a vehicle uses fuel (either miles per gallon or miles per kilowatt-hour of charge).

- **Smog rating**—This rates tailpipe emissions that contribute to local and regional air pollution, creating smog, haze, and health issues. A score of 10 means that the vehicle emits no tailpipe pollutants.

- **Greenhouse gas rating** (GHG)—This measures a vehicle's tailpipe greenhouse gas emissions (carbon dioxide, ethane, and nitrous oxide). This score is based on the vehicle's fuel economy and its fuel type, since each fuel contains a different amount of carbon. Vehicles with better fuel economy receive a higher score; a score of 10 represents the lowest emissions.

The SmartWay program has its deficiencies, such as setting an arbitrary target of certifying 20% of vehicles each model year as SmartWay, and a historical bias toward vehicles that can use high-ethanol gasoline blends. While the auto industry is still in the driver's seat, determining what models hit the roads, and the program evaluates what the industry produces, the SmartWay certification program is still a helpful way for shoppers to navigate through the "green" car universe.

Since fuel efficiency is a critical component of the scoring, the SmartWay definition of green works for those shoppers primarily looking to use less fuel. SmartWay-certified cars have good fuel economy—the primary driver for choosing a green car. According to the J.D. Power and Associates *Automotive Performance, Execution and Layout* (APEAL) study, 47% of new vehicle owners said that gas mileage was one of the most important factors in choosing their vehicle, up from 40% in 2011. With the fuel prices projected to stay above $3.20 per gallon for gasoline and $3.76 per gallon for diesel

US EPA Certified SmartWay®

through the end of 2014, according to the May 2013 U.S. Energy Administration Short-Term Energy Outlook, saving fuel will likely remain a top consideration for car shoppers, and thereby continue to incentivize manufacturers to roll out new fuel-efficient options.

Maybe the best part of the SmartWay certification program is that it allows for an apples-to-apples comparison across different propulsion technologies and vehicle classes and provides a broad-based definition of green. SmartWay-certified vehicles include electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), hybrids (HEVs), compressed natural gas vehicles (CNGs), and hydrogen vehicles (H_2), as well as traditional gasoline and diesel vehicles. This is important since a gasoline or diesel vehicle may be the best fit for your particular situation. Limiting the green discussion to just alternative fuel technologies would ignore both the significant advancements that have taken place with respect to the traditional fuel vehicles, and the fact that alternative fuel vehicles may not be a practical choice for a large segment of the U.S. population.

Beyond the Tailpipe

The EPA's SmartWay rating just considers a vehicle's tailpipe emissions. It does not consider the pollution impacts of fuels themselves. For example, even the pollution from burning gasoline will vary depending on the source (e.g., gasoline refined from tar sands is believed to be potentially much more harmful than if refined from traditional crude oil), as well as the production, refining, and distribution methods. Likewise, the environmental effect of the full life cycle of a kilowatt-hour of electricity will depend on whether the electricity is generated at a plant that burns fossil fuels or produced by wind, solar, or other renewable resources.

2 Discover Your Green Options

There are ways to use the SmartWay certification program as your green guide. Five SmartWay vehicle categories present the options that are realistic choices for most people: gasoline, diesel, electric, plug-in hybrid, and traditional hybrid. Choosing the category or categories that may work best for you is about looking at your lifestyle and determining what is important to you and your family.

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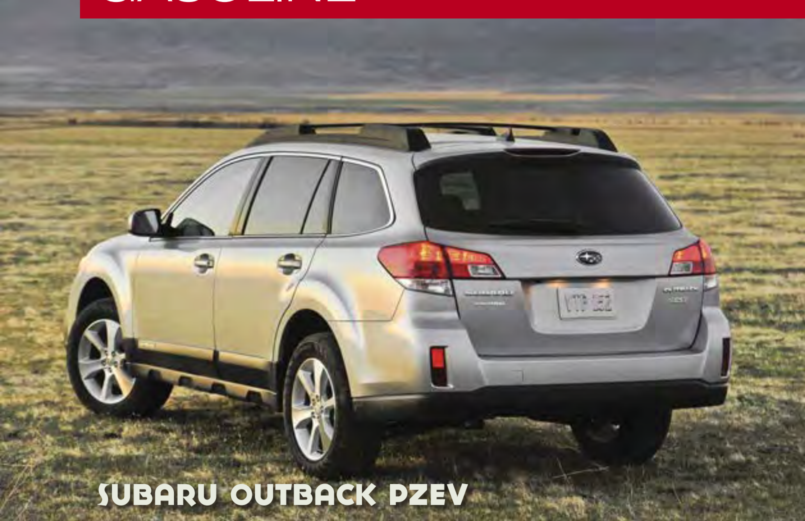
GASOLINE



SUBARU OUTBACK PZEV

Courtesy Subaru

Gasoline vehicles are still the most prevalent vehicles on the market, and also have the most SmartWay-certified models. Due to consumer demand, government regulation, and competition from emerging fuels, more fuel-efficient models than ever are becoming available.

Courtesy Nissan

NISSAN VERSA

DIESEL

Diesel vehicles have been in mass production since the early 20th century and are beginning to shake their reputation for being noisy and dirty. Diesel cars are reemerging in the United States, mostly because as of 2010, all diesel fuel is required to be ultra-low-sulfur—emitting 97% less sulfur when burned. This is important, as sulfur compromises the diesel vehicle's emission control technologies (much like lead in gasoline once did).

Courtesy Audi

Courtesy Volkswagen

Advanced emission control technologies have also been developed to help control the two most harmful diesel pollutant emissions: nitrogen oxide and particulates. Diesel engines have the ability to use biodiesel fuel, made from renewable resources, with few or no modifications to the engine. Biodiesel blends create less greenhouse gas and particulate emissions than petroleum diesel, and can reduce dependence on foreign oil since the oil-seed crops can be grown and processed stateside.

ELECTRIC

EVs have a battery that is rechargeable. Unlike hybrids and PHEVs, they use only electricity and do not have any secondary engine to extend their range. While the cost per kilowatt-hour varies between utilities, plans, and time-of-charge, and the charging efficiency varies among vehicles, the energy cost per mile for an EV can be as little as one-fourth the energy cost of a gasoline-fueled vehicle. For example, the EPA estimates that driving 25 miles in a 2013 Ford Focus EV would cost $0.96 (using an electricity cost of $0.12/kWh), while it would cost $2.90 (using a fuel cost of $3.60/gallon) in the standard gasoline version.

Courtesy Smart

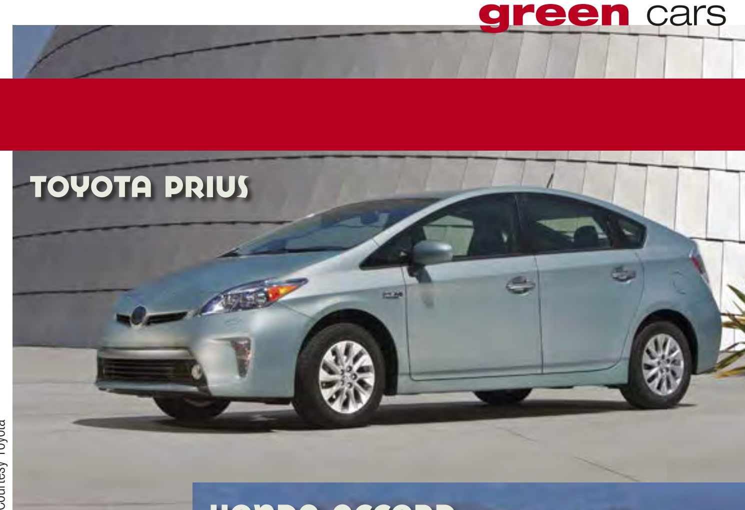
Courtesy Nissan

Courtesy Scion

Courtesy Honda

PLUG-IN HYBRIDS

PHEVs combine the rechargeable battery found in electric vehicles with (typically) a gasoline engine. One type is sometimes called "series PHEV" or "extended range electric vehicle," uses the gasoline engine-generator to power the electric motor. The second type, called "parallel PHEV" or "blended PHEV," is more like traditional hybrid vehicles (see below) in that the gasoline engine and electric motors both serve to propel the vehicle. While the technology is a bit different, the effect is the same—they are electric vehicles without "range anxiety."



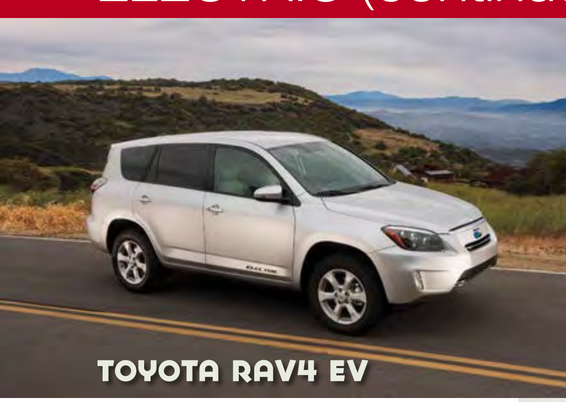
Courtesy Toyota

Courtesy Honda

Courtesy Ford (2)

ELECTRIC (continued)

Courtesy Tesla



Courtesy Toyota

Courtesy Ford

Courtesy Mitsubishi

Courtesy Fiat

HYBRIDS

Traditional hybrid vehicles combine two or more fuel systems, typically a gasoline engine and an electric motor. Among alternative fuel technology vehicles, hybrids are the most abundant. Their increased fuel efficiency means less frequent fueling than with a traditional gasoline or diesel vehicle.

Courtesy Ford

Courtesy Toyota


Courtesy Lincoln

SmartWay Green Car Options

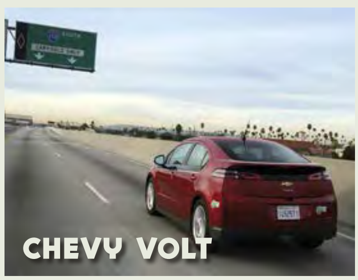
Vehicle Type	Selection (2013 Models)	Representative 2013 Models	Range Limitations	Refueling Infrastructure	Refueling/ Recharging Time	Fuel Cost
Gasoline	>400	Nissan Versa, Scion iQ, Lincoln MKZ	Limited by fuel tank size	Approximately 200,000 stations across the U.S.	5 – 10 min.	Projected to be no less than $3.20/gal. through 2014
Diesel	5	Audi A3; Volkswagen Beetle, Golf, Jetta, Passat	Limited by fuel tank size	Approximately 100,000 stations across the U.S.	5 – 10 min.	Projected to be no less than $3.27/gal. through 2014. Biodiesel currently $4.11/gal. (B20) & $4.29/gal. (B99-B100)
Electric Vehicle	11	Coda, Fiat 500e, Ford Focus BEV, Honda Fit, Mitsubishi i-MiEV, Nissan Leaf, Scion iQ EV, Smart ForTwo Cabriolet & Coupe, Tesla Model S, Toyota RAV4 EV	60 – 250 (Driving style, ambient temperature, etc., all impact range)	Approximately 6,000 public charging stations in the U.S. (but growing)	30 min. – 12 hrs., depending on type of charging station	Cost varies depending on utility, plans, time of charge, etc., but the cost per mile driven can be as little as 1/4 of the cost of gasoline-fueled vehicles
Plug-In Hybrid	4	Chevy Volt; Ford C-Max & Fusion; Toyota Prius Plug-in Hybrid	Limited by fuel tank size	Approximately 200,000 gasoline stations across the U.S. Approximately 6,000 public charging stations in the U.S. (but growing)	Gasoline: 5 – 10 min. Electricity: 30 min. – 12 hrs., depending on type of charging station	Electricity cost varies depending on utility, plans, time of charge, etc. Gasoline is projected to be no less than $3.20/gal. through 2014.
Traditional Hybrid	<20	Toyota Prius, Ford Escape	Limited by fuel tank size	Approximately 200,000 stations across the U.S.	5 – 10 min.	Gasoline is projected to be no less than $3.20/gal. through 2014
Compressed Natural Gas	1	Honda Civic	Limited by fuel tank size	Approximately 586 stations across the U.S.	At a public station 5 – 10 min., but will fill up overnight at home	Currently averaging $2.10/ GGE

*Using federal standards

INCENTIVES FOR GREENER CARS

There are many other potential incentives for purchasing and owning a fuel-efficient vehicle, such as:

- Tax credits—There is currently a federal tax credit of as much as $7,500 for purchasing a qualified electric or plug-in electric vehicle, and many states have similar programs (see afdc.energy.gov/laws/state).
- Special financing programs—Some lenders offer green vehicle loan programs. For example, U.S. Bank offers a slightly reduced interest rate for financing vehicle loans on certified SmartWay vehicles. Check with your lending institution to see if they offer incentives.
- High occupancy vehicle lanes (HOV)—In California, single-occupancy drivers of certain qualifying clean alternative fuel vehicles can use the HOV lanes normally reserved for cars with two or more occupants.



Courtesy Chevrolet

OTHERS

There are two additional categories of SmartWay-certified vehicles, **compressed natural gas** and **hydrogen**, but they are not viable options for most people due to the lack of fueling infrastructure and model availability. There are fewer than 1,000 CNG fueling stations in the United States, and the only mass-produced CNG vehicle is the Honda Civic.

The hydrogen infrastructure is at an even earlier stage in its development, with less than 300 fueling stations *worldwide*, and only about 10 of those in the United States. There are no hydrogen fuel cell vehicles currently for sale, but a few pioneers have been leasing test vehicles such as the Honda FCX and Mercedes Benz B-Class F-Cell in California.

SmartWay Ratings				
Combined MPG or MPkWh	**Smog Rating***	**GHG Rating***	**Federal Incentives/ Rebates**	**Bottom Line**
26 – 38	5 – 9	7 – 9	No	For many people, a SmartWay gasoline vehicle may be the best fit. You may not enjoy the best fuel economy, or drive the latest technology, but you also won't need to make changes to your daily routine.
31 – 35	5 – 6	7 – 8	No	A SmartWay diesel may be a good fit if you are looking for a car with an established technology, or want to use renewable biofuels.
73 – 121	10	10	Yes	EVs are still the best fit for errand-runners who live where at-home charging is possible; work within 30 miles of home so they don't have to search for an at-work charging station; and have access to a second vehicle for longer trips.
Gas 37 – 50 Elec 95 – 100	6 – 9	10	Yes	PHEVs are a great middle ground between EVs and traditional hybrids, offering range flexibility and increased fuel-cost savings through home charging.
26 – 50	6 – 9	7 – 10	No	SmartWay-certified hybrids tend to be a fantastic compromise between fuel efficiency and lifestyle. They don't require alterations to your daily driving routine and are the most available "green" vehicles. They usually cost a little more than their nonhybrid counterparts, but they generally have higher resale values.
31	8	10	No	A viable option for those living close to a CNG fueling station or able to install a home fueling station.

USED GREEN

Could the greenest car be the one you are driving now? Well, that depends on which green you are talking about (Mother Nature or money), and the particular cars. Here are some factors to consider when you are grappling with buying "used" or "new."

- **SmartWay guidance:** Fortunately, the EPA's SmartWay program goes back to 2000, so you can use it as your guide even if you are buying a used car.
- **Price:** Depending on the vehicle, there could be a huge price discrepancy between a new car versus a late-model used car. However, it is important to consider federal and state incentives (especially if you're in the market for an EV or PHEV, since these cars may be eligible for incentives), and more favorable financing terms that are available for newer-model vehicles.
- **Environmental concerns:** Significant advances have been made in recent years regarding fuel efficiency and emissions controls in SmartWay-certified vehicles. For example, four years ago, the minimum gas mileage for a SmartWay-certified new gasoline model was 20 mpg; for 2013 models, it is 26 mpg.
- **Maintenance:** A vehicle's maintenance costs generally increase with age. Costly maintenance expenses may be hedged by purchasing a certified pre-owned vehicle or an extended warranty.
- **Insurance:** Insuring a used car is usually less expensive than insuring a new one because the vehicle's value is less. However, if the new vehicle has significant safety advantages over the used vehicle, then you could actually pay a lower premium.

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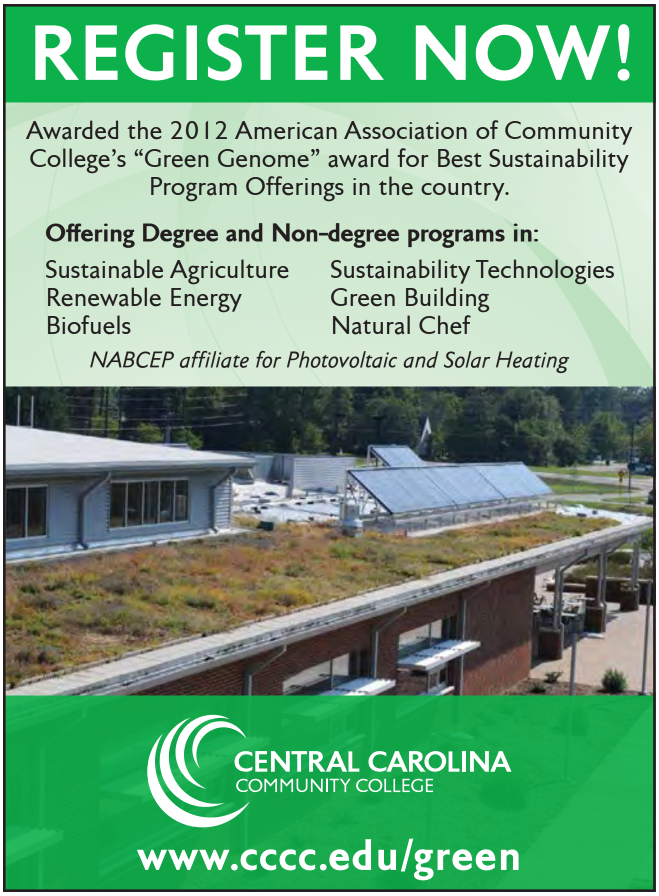
3 SELECT THE GREEN OPTION THAT WORKS BEST FOR YOU

While most of the discussion around green cars is about EVs, PHEVs, and HEVs, the bottom line is that it is really a personal decision that involves matching a technology to your lifestyle. When analyzing your options, consider the:

- Number of available models
- Range limitations (maximum distance that may be traveled between refueling/recharging) and the current state of the fueling/charging infrastructure
- Refueling/recharging time
- Fueling/charging cost
- Purchase price

Access

Curt Lindeman (curt@eGreenCars.com) is the cofounder of eGreenCars.com, which provides car shoppers with resources to learn about and find their new fuel-efficient, green car.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Workspace Clearances & Accessibility

by Brian Mehalic

PV systems—with expected lives of 25 years or more—will require some degree of preventive maintenance and/or reactive service over their lifetimes. Ensuring that service and maintenance can be performed safely and efficiently must be considered during the design process. A key topic in Chapter 1 of the *National Electrical Code* is required workspace clearance and accessibility—two critical factors in effective system design. These *NEC* requirements are minimums—meeting them does not necessarily mean an installation is "efficient, convenient, or adequate for good service" [Section 90.1(B)]; exceeding them can result in a system that is easier and safer to service and maintain.

Workspace Requirements

The reasons for the workspace clearances defined in *NEC* Section 110.26 are a more user-friendly working environment and safer conditions. Envision an area the size of a telephone booth in front of electrical equipment—approximately this amount of space is required so that workers do not have to stand sideways, reach over the top of a device, or crouch underneath an overhang to access equipment. These requirements apply to systems that are 600 volts (AC or DC) or less, and which are likely to require service or maintenance while energized. This will certainly be the case with most PV systems. Section 110.30, while not covered in this Code Corner, addresses systems greater than 600 volts, which are becoming more common in commercial, industrial, and utility-scale applications.

Numerous hazards—as well as *Code* violations—typically occur when power sheds are used for storage. Violations in this photo are numerous, including exposed and accessible live terminals, unprotected conductors, and lack of workspace clearances.

David del Vecchio

All of the described workspaces are to be kept clear and not used for storage [110.26(B)], and they must be dedicated to the electrical equipment [110.26(E)]. In addition to commonly stored items, other equipment, such as plumbing, ducts, and other systems' components, must be kept out of the dedicated space.

The depth of the workspace required by Section 110.26(A)(1) varies based on the system's voltage. For systems from 0 to 150 volts to ground (for ungrounded DC systems, this is the voltage between positive and negative), a minimum of three feet of depth is required on the sides of the equipment where access is required. (This is typically the front of the equipment, though larger equipment or battery banks may require access to their sides as well). This applies to 120/240 and 120/208 VAC systems, which are common residential and commercial service voltages. When the voltage to ground is between 151 to 600 V—typical on the DC side of grid-connected PV systems with string inverters as well as higher-voltage AC services—the minimum depth required depends on which one of three conditions is encountered:

- **Exposed live parts on one side; no live exposed live parts or grounded surfaces on the other side of the workspace**: 3 feet of depth required.
- **Exposed live parts on one side; grounded parts on the other side of the workspace (concrete, brick, and tile walls are considered grounded)**: 3.5 feet of depth required. If grounded surfaces, such as a concrete block wall, are covered with plasterboard or other insulated (nonconductive) materials, the depth requirement is reduced to 3 feet.
- **Exposed live parts on both sides of the workspace**: 4 feet of depth required.

Section 110.26(A)(2) requires 30 inches of width—or the width of the equipment, whichever is greater—in front of the equipment. This required space must also allow all doors or hinged panels to open to at least 90º, which can also affect the required depth: If the door is wider than 3 feet, then a space of more than 3 feet is required to allow it to open.

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Brian Mehalic

Thirty inches width is required in front of electrical equipment; this zone can overlap with the workspace width of other pieces of equipment, but must not interfere with opening the enclosure covers.

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Equipment does not have to be centered in the minimum 30 inches of required width. For example, an AC service panel can be mounted against a corner and, when multiple pieces of equipment are mounted next to each other, their required workspace widths can overlap—again provided that any doors or covers can open to at least 90° and do not interfere with each other.

Section 110.26(A)(3) requires that the workspace in front of equipment be clear of obstructions, and that it extend from the "grade, floor, or platform" to a height equivalent to that of the equipment or 6.5 feet, whichever is greater. Another key requirement is that equipment does not extend more than 6 inches out from the front of other equipment that is mounted above or below it, to prevent personnel from having to lean over or duck under equipment. A common violation of this requirement occurs when a battery box is located directly underneath a wall-mounted inverter and extends more than 6 inches past the front of the inverter. In fact, the majority of equipment used in PV systems is surface-mounted, while a lot of other electrical equipment—especially that used in residential applications—is flush-mounted; this situation can lead to unintended violations of this requirement.

Section 110.26(D) requires illumination for workspaces. At the very least there must be some plan for lighting, whether it is battery-operated, runs off a generator, or is standard AC lighting. Just keep in mind when you are going to need the light, which is most likely when something isn't working. In particular, installing a DC light in an otherwise unlit battery or inverter room makes a lot of sense for battery-based PV systems, to prevent troubleshooting an inverter problem in the dark.

Space Around Equipment

Section 110.13(B) requires that equipment be mounted in a manner that does not block vents and allows adequate cooling; be sure to follow manufacturers' installation instructions. In fact, you should always read the instructions that are included with listed equipment—Section 110.3(B) requires manufacturer instructions be followed. To maintain adequate airflow and provide cooling, many inverters have specific spacing requirements, whether they are being mounted side by side, close to a corner, or in a closet.

Accessibility

Three separate definitions in Article 100 cover *accessible* as it pertains to equipment, wiring methods, and the concept of *readily accessible*. Equipment accessibility means that the equipment can be easily approached—locked doors or the height of the equipment can render it inaccessible. However, note that Section 110.26(F) states that equipment in locked rooms can be considered accessible to qualified personnel, provided they have access to the key or combination.

The beam in front of these roof-mounted combiner boxes makes them more difficult to work on and does not meet workspace clearance requirements.

Rebekah Hren

Follow the manufacturer's installation instructions to ensure adequate ventilation around inverters.

EV Solar Products

Wiring accessibility means that it is not permanently contained within the building structure in a manner that would require removing material and would result in damaging the building. For example, wiring is not accessible (meaning it is "concealed," per the definition in Article 100) within a framed wall cavity behind plasterboard. It is accessible if it is above a dropped ceiling with lift-out panels, or in a junction box or service panel with a removable cover. Section 690.34 specifically allows junction or pass-through boxes (meaning they do not contain overcurrent protection, switches, or disconnects) to be installed behind PV modules, as long as they are accessible by removing the module (or modules). This is easily accomplished with typical top-down mounting clips and the use of flexible USE-2 or PV wire module interconnects and home runs.

The *NEC* definition of *Accessible, Readily* is: "capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth." Again, locked rooms, limiting access to only those who need it, is an acceptable and common practice. However, if a portable ladder is required to access a rooftop it is not considered "readily accessible;" nor is the wiring on the back of a pole mount if a ladder is required to reach it. A commercial rooftop, with controlled access hatches, is considered readily accessible, as is an attic with pull-down stairs, unless the equipment being accessed requires climbing through rafters and over open ceiling framing.

Accessibility & PV Systems

Section 690.31(A) requires PV source and output circuits greater than 30 volts (per the Section 690.7 maximum system voltage calculation) to be contained in a raceway if they are readily accessible. In reality, this requirement can't be met with the majority of PV modules on the market, which have prewired, quick-connect leads—there is nowhere to connect a raceway to the junction box on the back of the module.

Systems on residential rooftops are typically not considered readily accessible, thus this requirement does not apply. However, module interconnects and home runs on pole- and ground-mounted PV arrays must not be readily accessible if they are to comply. For a pole-mounted system, making it tall enough so a ladder is required to reach the wires will meet the requirement. Making the wiring inaccessible can also be accomplished by putting a fence around the array, or by using lattice, another type of screening, or an enclosed cable tray so that a tool is required to remove hardware and material to access the conductors. Check with the authority having jurisdiction (AHJ) to verify that the measures employed will meet their requirements for rendering the wiring non-readily accessible.

There are a few exceptions, but, in general, Section 404.8(A) requires switches and circuit breakers to be readily accessible and limits the height of their operating handle to no more than 6 feet 7 inches above the platform or working surface from which they are accessed. However, Sections 690.14(D) and 705.70 permit inverters to be installed in non-readily accessible locations. This is a common scenario in residential PV systems where microinverters may be mounted behind modules, or in commercial PV systems where string inverters may be mounted on a parapet wall on a low-sloped roof. In these cases, DC and AC disconnecting means are required either within sight of—defined in Article 100 as "visible and not more than 50 feet away from"—or integrated into the inverter. Since they are equipment disconnects, they must be grouped with the inverter. Depending on the particular string inverter, a combination of internal (such as a built-in DC disconnect, which may or may not also disconnect the AC conductors) and/or external (most commonly, an external AC disconnect

EV Solar Products

Required to be accessible, but not readily accessible, combiner boxes are frequently mounted on roofs. Follow the manufacturer's instructions for placement and temperature limitations to ensure that they maintain their NEMA rating.

switch) is used. With microinverters, the plug connectors on the microinverters must be listed and identified to meet this disconnect requirement (per the Exception to Section 690.17 and the requirements of 690.33). An additional disconnect for the inverter output circuit of roof-mounted (not readily accessible) inverters is required. It must meet the requirements of Sections 690.14(C)(1), 690.17(1) and 705.22, which apply to disconnecting means for PV systems and require them to be readily accessible: installed either on the outside of a building or inside at a readily accessible point, and as close as possible to the entry point of the system's conductors.

Section 690.31(E) requires that DC PV source and output circuits installed inside of a building be contained in a metallic raceway or enclosure, or be metal-clad (MC) cable until the first readily accessible disconnect. This provides additional protection and an enhanced ground-fault current path to sections of the circuit that cannot be easily de-energized.

Section 690.7(D) applies to one- and two-family dwellings, and requires that live parts in DC PV system circuits greater than 150 V *not* be readily accessible when energized, except to qualified personnel. This requirement can easily be met with raceways and/or enclosures like junction boxes that require a tool to open.

Section 690.9(C) requires series fusing for PV source circuits to be accessible, but not readily accessible. Thus, combiner boxes can be mounted on a residential roof that requires a ladder to access.

Section 480.5 requires disconnecting means for the ungrounded conductors connected to storage batteries to be readily accessible and within sight of the batteries. Live parts operating above 50 V must be protected in accordance with Section 110.27 by being:

- Located in a room or enclosure (such as a battery box) accessible only to qualified personnel.
- Behind partitions or screens that permit only qualified personnel within reach of the energized parts.
- Elevated (to 8 feet or more) so that they are out of reach of unqualified personnel.

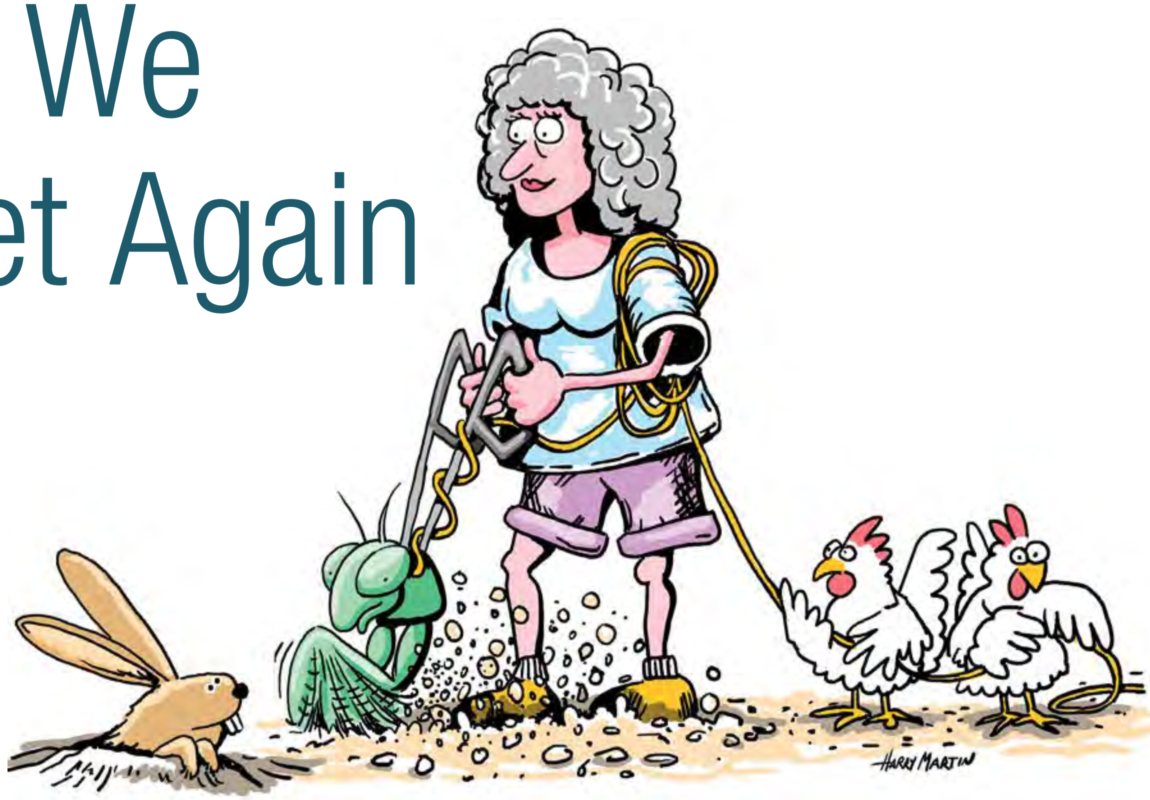
When the Section 110.27 requirement is met by locating the batteries in a room or enclosure, "conspicuous warning signs forbidding unqualified persons" from entering the room or opening the enclosure must be posted per Section 110.27(C).

Workspace clearances around batteries must also follow Section 110.26. A note in Section 480.9(C) states that measurements for clearances are made from the edge of the battery bank rack or enclosure.

Access

Brian Mehalic (brian@solarenergy.org) is a NABCEP-certified PV professional and ISPQ-certified PV instructor. He has experience designing, installing, servicing, and inspecting all types and sizes of PV systems. He is a curriculum developer and instructor for Solar Energy International and a project engineer for O2 Energies.

Till, We Meet Again



by Kathleen Jarschke-Schultze

Bob-O has always used a big Troy-Bilt rototiller for our garden work. Last year, he acquired a used 5-foot-wide tiller for our tractor, which works well on our bigger pasture projects. Wanting some tilling autonomy, I purchased a minitiller about 10 years ago.

Hard Row to Hoe

Our soil is volcanic clay—adobe, really. For the last 23 years, we have amended our soil with as much manure as we could haul home. We used to have an "in" with the local 4-H rabbit teacher. That was worth a couple of mounded pickup loads of manure per year. We shoveled the manure from under the cages, into wheelbarrows, past the dead car in the driveway, and out to our truck. It was a lot of work, but it was great stuff. Then our rabbit connection retired from 4-H.

Luckily for us we live in horse country, where folks amass big piles of manure they would just love to get rid of. We used to shovel the manure into the pickup and then shovel it out again at home. We moved the gardener's gold by wheelbarrow.

Now, we are wiser, so we only get manure if the rancher has a tractor to load it into our dump trailer. Back at home, we dump the load close to whatever garden area we are working on. It's easy to use a wheelbarrow to distribute the manure to specific beds. Like Bob-O says, "Let the horses [as in horsepower] do the work."

Our dirt is in really good shape for planting, although one year without the manure and we would be looking at adobe again, since growing vegetables depletes the organic matter from the soil. Once the dirt was workable after the big tiller had broke ground in the spring, I wanted to use a minitiller. And we had some raised beds and a minitiller would be just the thing for working in the rows.

Mini-Menace

I bought a four-cycle model so I would not need to mix gas and oil. Now I could do some small tilling jobs without having to wait for Bob-O to get a chance. As we made more raised beds, the tiller really shined in prepping the beds for planting.

It was great, except for one thing—although I drained the gas every fall, and even used a fuel-stabilizing additive, I had to take the tiller to a small engine repair shop to get it running again each spring. After one carburetor rebuild, Bob-O had refused to work on the minitiller ever again. (I've heard that carburetor is French for "don't mess with it.") I felt like I was renting the tiller, paying out every spring for the privilege of using the tool for the season.

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For several years, the gas minitiller sat unused. I just couldn't justify spending any more money or energy fixing it. My off-grid gardening buddy Bill Battagin from Feather River Solar had been using an electric minitiller for five seasons—that is some hands-on history. His garden is mostly raised beds, too. He was sold on its attributes: no fuel stink, quiet operation, no carburetor cleaning in the spring, no air filter to clean, no spoiled gas.

Well, I was sold, too—it made so much sense. In the spring, our electricity comes from water, wind, and sun. My minitiller would take advantage of the abundance of that seasonal renewable energy.

Going Electric

I did my research on the Internet, and was familiar with most of the models available. I love reading purchasers' product reviews, which are very revealing. I've found that people will be brutally honest about a product's quality, good or bad. However, in my neck of the woods, there is nothing as golden as a recommendation by a trusted friend. I emailed Bill. Still happy with his tiller after five years, he steered me toward the Mantis electric minitiller. And the reviews I had already read agreed with him.

The Mantis brand was more expensive than most other minitillers, but has a five-year manufacturer's warranty. But what really sold me was the breaker switch on the housing that trips if the motor starts to get too hot. Bill said this could happen if you were tilling a big bed on a hot day. The fact that the machine will turn itself off before it burns itself up is worth the price of admission right there. Bill did mention having to learn good cord management skills. I would need about 200 feet of 14-gauge extension cord to get to the farthest bed in the garden.

The tiller, weighing 20 pounds, has three speeds and tills down into the dirt about 7 to 8 inches. The electrical draw is less than 6 amps, which our system can provide. By the time my tiller arrived I had the extension cords waiting. After eagerly performing the small amount of assembly required, I was ready to till.

I had a small garlic patch along half of one side of the upper garden. I decided to till the rest of that row with the tiller. I planned to plant it with volunteer garlic starts we dug up when we repositioned a raised bed this spring.

A safety switch must be depressed to engage the tines. I started the tiller in first gear. The tiller dug through the soil and chugged to the row's end. It was digging up rocks as big as pullets' eggs. It was small enough that when it bucked on a particularly hard patch of dirt I could easily keep it under control.

After going over the area in first gear, I repeated the tilling pattern in second and third gear. A layer of aged manure was applied and raked flat. (Thanks, Bob-O!) I tilled in the manure using second gear and it smoothed the row into a flat, homogenized planting bed. The garlic volunteers are doing well because they were so young when I transplanted them. Plants are very forgiving like that. After the first test bed, we just needed fair weather for a couple of days to dry out the soil in the main garden enough to till.

Now, our method is that the first spring tilling is done with a big tiller. This means the ground is tilled and a layer of manure is tilled in. Then, using the minitiller, all the raised beds are tilled, manured, and tilled again. As each row is positioned, it receives another layer of manure and tilling with the minitiller. Next, the drip lines are laid out. Finally, the beds are planted with seeds or seedlings.

The planting beds and rows are beautiful—easy to plant in, easy to weed. I could not have prepped the beds to this standard by hand, even with Bob-O's help. My electric minitiller is a tool I feel really good about since it is powered by water, wind, and sun. Like Bob-O would say, "Let the 3/4 horse do the work."

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is experimenting with growing okra at her off-grid home in northernmost California.


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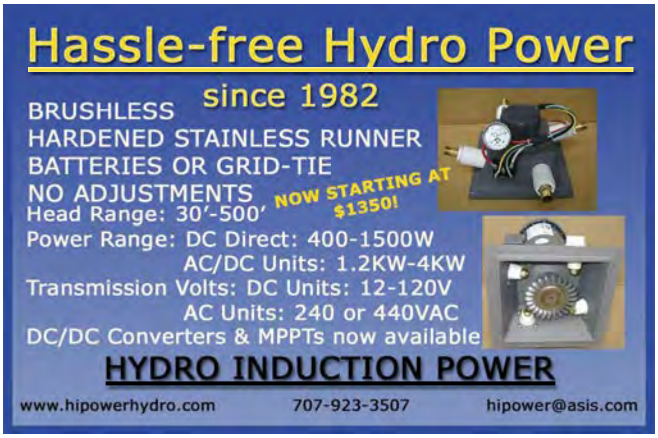
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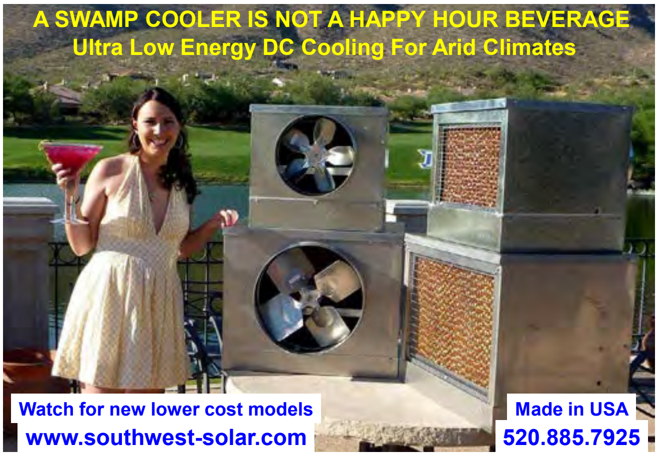
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Analyzing Your Electrical Loads

The first step in any energy project is to assess the *load*—how much energy you are using or are planning to use. Without a load analysis, you can't make a sensible system design, or know how a proposed system will impact your finances or home's energy use.

On Grid

On-grid load analysis can be quite easy—just look at your utility bill. Many utilities show the past year's usage (or more) on each bill. If that information isn't on your bill, request the past few years' data from your utility. I like to convert this information into average kilowatt-hours (kWh) per day. For reference, a typically inefficient North American home uses 25 to 30 kWh per day, if space heating is provided by other fuels. Highly efficient homes may use 6 to 10 kWh per day.

Understanding what a kWh is and how many you use per day is a good starting place. From there, you'll be able to ask RE contractors how much it will cost to generate that much electricity with sunshine, wind, or falling water. Or you'll be able to calculate how much of your utility bill you can offset with the money you're able to invest in a system.

Off Grid

Off-grid load analysis is more complicated, and involves measuring or estimating each load. The method can also be used to estimate electricity usage for on-grid homes in the design stage or for backup systems (for sizing battery banks and inverters). It's also very useful to use this method if you're on grid, to find out *where* you are using all that energy. Then you can develop strategies to reduce your energy usage, which is typically the most cost-effective and environmentally friendly use of your dollars.

Ben Root

An energy meter like the Kill A Watt can help you measure common household 120 VAC loads.

Example Load Analysis

Load	Qty.	x	Watts	x	Hrs. / Day	x	Days / Wk.	÷ 7 =	Avg. Daily Wh
Refrigerator	1		507		3		7		1,521
Fans	2		100		8		5		571
Computers	2		80		8		5		457
Wireless router	1		15		24		7		360
Printer	1		200		2		5		285
Lights	8		25		6		5		107
Clothes washer	1		320		1		2		91
Total Power			1,247				**Total Energy**		5,101

A spreadsheet is the easiest way to gather the necessary information. For each specific load in your home, you'll need either its wattage and daily hours of use or its daily kWh use.

Measure each load's power, since rated or sticker wattage may not accurately reflect actual appliance consumption. When in doubt, round up. Measuring 120 VAC loads is easy with meters such as the Kill A Watt, Brand Electronics Digital Power Meter, or Watts Up?. Any 240 VAC loads will be harder to measure, and you may end up relying on rated wattage or estimates.

The energy use of 240 VAC appliances can be measured with reconditioned utility-style kWh meters. These modestly priced meters can also be installed permanently on major loads like water heaters and heat pumps for ongoing performance evaluation.

Accounting for all these loads may be an eye opener on several levels. You'll likely be surprised at what is and isn't a significant energy load. Because energy is power (watts) multiplied by time (hours), high-power loads can be no big deal if they are only used for short periods of time, while "small" loads can add up if they are on most or all of the time. You'll need to work on your measuring *and* estimating skills to get accurate results.

Load analysis gives you a view into the biggest factor in off-grid design, and is key to understanding the value of on-grid systems. Careful and detailed attention to this end of your RE project will pay off with better understanding of what you're getting into—and what you're going to get *out* of your renewable energy investment.

—Ian Woofenden

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