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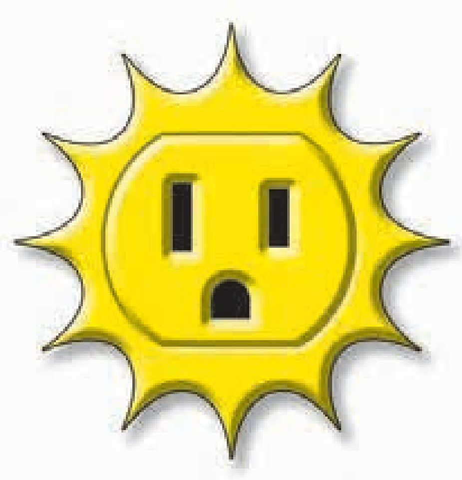

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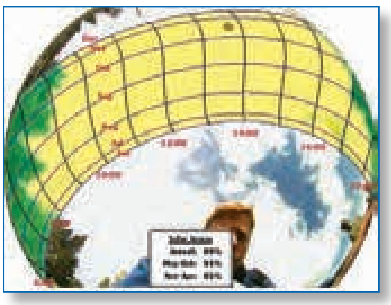
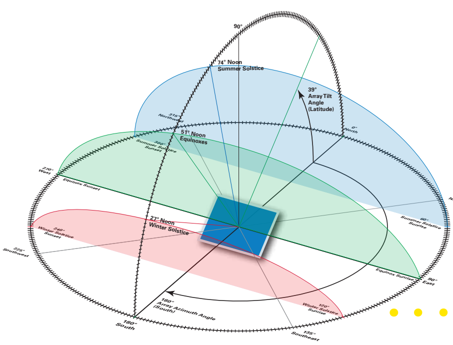
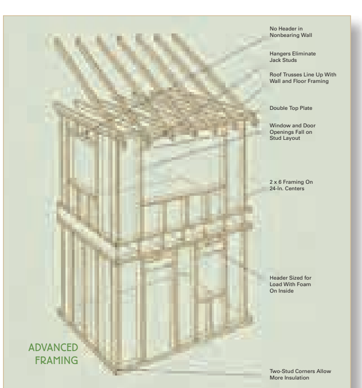
April & May 2009







Clockwise from bottom left: Laura Richardson, The Taunton Press Inc., *Home Power* staff, www.solmetric.com, www.gepower.com/solar, www.directpower.com, Courtesy Don Richmond, www.evenergyfilms.com

On the Cover

Sanyo bifacial PV modules provide an elegant and high-performance patio structure at this Nevada home.

Photo by Erin O'Boyle

Regulars

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

Comfortably **Conservative**

What do the Great Depression, living off-grid, and today's economic recession have in common? What can we learn from each? More than you might think.

The Great Depression lasted for the better part of a decade—long enough for people's consumption and saving habits to change, permanently. The resourceful behavior still portrayed by many Americans who lived through the Great Depression was brought about by necessity. Resources, financial and otherwise, were limited and people learned to use them wisely. Truly conservative living was the result.

Living with renewable energy, especially off-grid living, has some similarities, and some core differences as well. In the 1980s, the early adopters of solar energy tended to be cash-and-carry types. Off-grid land was inexpensive compared to purchasing property in town. Not carrying a big mortgage (or even any mortgage) was often the result. Homesteads were built slowly as money became available. RE systems typically grew slowly too, module by module. The idea of being deep in debt ran counter to the sustainable and independent-minded ethics many off-gridders held, and still hold today.

Most people drawn to simple off-grid lifestyles choose to do so willingly, not out of necessity. But just like Depression-era individuals, they learn to live within limits when it comes to resource use. During sunny days, with the batteries fully charged, appliance use grows. When the funky weather sets in, usage slows. Living off-grid forms habits that quietly make their way into other aspects of our lives. Don't spend what you don't have. There are consequences. Resources are finite.

So what does all this have to do with today's economic recession? At its core, our nation's current economic trouble is caused by people spending what they don't have, as well as the financial institutions that have made it enticing for people to do so. Instead of cash and carry, we have credit and carry. It's textbook unsustainable behavior and the consequences are apparent wherever we look. Even more unsettling is what happens when consumer habits do undergo a rapid and widespread change from spending to saving—the economy stalls out.

Most of my neighbors are off-gridders. We live in small but comfortable houses we built ourselves on land that was cheap. We don't have utility bills. When we talk over the fence, we share stories of friends and acquaintances who have been hit hard by the economic downturn. From time to time, the conversation turns to what might be in store for us down the road. But in general, the comfortably conservative lifestyles we've chosen make things less precarious. Friends who have built similarly sustainable lifestyles in town echo this attitude. Living with solar energy is our daily reminder to keep it simple, live within our limits, and to enjoy the abundance when spring, like it always does, comes around.

—Joe Schwartz for the *Home Power* crew

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—Barack Obama, 44th U.S. president

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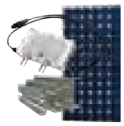

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KC130TM	$519.00	$3.99/watt
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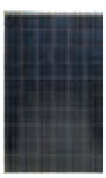

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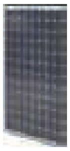

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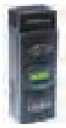

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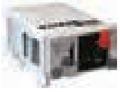

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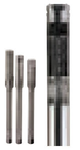

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Renewable Energy Support in the White House

Hope for renewable energy is running at an all-time high with President Barack Obama's picks for his energy and environment squad. The team is diverse in both public service records and personal biographies, and many environmentally concerned citizens will be looking for this "dream green team" to provide decisive action on climate change and push RE technologies to the forefront of U.S. energy policy. Here's a roster of movers and shakers who are set "to prepare the nation for a new age."

Secretary of Energy—Steven Chu

The Job: Head the U.S. Department of Energy; serve as the President's principal adviser on energy policies, plans, and programs.

Credentials: Obama dipped into the academic world to nominate Steven Chu for Secretary of Energy, a challenging role that supervises the sprawling Department of Energy's nuclear weapons supply and nearly every other aspect of government regulation and information about energy supply and infrastructure. Chu is a physicist and Nobel Prize winner who should be up to the task. Since 2004, he's been at the helm of the Lawrence Berkeley National Laboratory, leading studies in advanced biofuels, artificial photosynthesis, and other solar energy research. He's been quoted as saying that coal is his "worst nightmare." Even after grilling from the confirmation committee on his public statements, the secretary only slightly stepped back from his bold words and clarified, "If the world continues to use coal in the way we're using it today…that's a pretty bad dream." While his stance in support of renewable energy is heartening, Chu has his detractors. Critics express concern that the professor lacks the necessary inside-the-Beltway experience and political savvy to be a major player in the cabinet, and question his support for the $18.5 billion in new reactor loan guarantees already approved.

Hope for renewable energy is running at an all-time high with President Barack Obama's picks for his energy and environment squad.

EPA Administrator—Lisa Jackson

The Job: Head the U.S. Environmental Protection Agency; set standards that safeguard the nation's air, water, and land.

Credentials: A chemical engineer from New Orleans, Jackson has more than two decades of experience as an environmental regulator. She spent much of her early career with the EPA's New York regional office, managing various

Used with the permission of Matt Wuerker & the Cartoonist Group enforcement programs and overseeing cleanup of hazardous waste sites under the Superfund program. During her 33 months as the commissioner of the New Jersey Department of Environmental Protection, she conducted compliance sweeps to crack down on polluters and established goals for reducing the state's carbon emissions. Where renewable energy and alternative transportation are concerned, she is refreshingly outspoken. In 2007, she announced that the Garden State would join other states in suing the Bush administration for its ruling that prevented states from enacting tougher fuel-efficiency standards. She openly condemned her future employer, saying the EPA was more like "the Emissions Permissions Agency."

However, Jackson is not without some baggage: Critics claim she is too close to industry and moved too slowly on her 2006 pledge to clean up New Jersey's toxic waste sites.

Chairwoman of the White House Council on Environmental Quality–Nancy Sutley

The Job: Ensure a safe, healthy environment for all citizens.

Credentials: This Californian has more than 10 years of policy-making experience in the Golden State concerning energy and water issues. Sutley presently works as the Los Angeles Deputy Mayor for Energy and Environment. Her priority in the new administration will be to the EPA, where her past experience in budget and legislative affairs as a special assistant to the EPA administrator in Washington, DC, will be put to the test once again at the federal level. Also notable were her sharp inquiries about the Federal Energy Regulatory Commission's oversight of California's unstable electricity markets, which led to new policy requiring Los Angeles to produce 20% of its energy from renewable sources.

White House Coordinator of Energy and Climate Policy–Carol Browner

The Job: Energy and climate czar

Credentials: Browner is no stranger to federal environmental work: she was EPA administrator during the Clinton administration and her ties to government stretch back to the early 1980s, when she served as General Counsel for the Florida House of Representatives. She eventually worked her way up to the position of Florida's secretary of environmental regulation. As the "White House Energy Czar," a new position in the administration, she'll be drawing on her private sector experience consulting for The Albright Group LLC, where she developed partnerships with business leaders and community advocates. She is likely to immediately overturn the Bush administration's denial of California's wish for clean air laws that are stronger than the Federal Clean Air Act—the auto industry is quaking in its boots.

LaHood-Winked?

During his presidential campaign, Obama focused on how America must combat urban sprawl with smart growth. So it's not surprising that progressive transportation advocates are up in arms over the appointment of Republican Ray LaHood of Illinois for Transportation Secretary.

The Congressman has no real expertise or background in transportation policy—let alone with smart growth or transit-oriented development. To his credit, he did break with his party to expand Amtrak and spoke out against its privatization. Sadly, that's the high point of his voting record, which earned an underwhelming lifetime voting score of 27 from the League of Conservation Voters. To make matters worse, one of LaHood's largest campaign donors was the Caterpillar Corporation—yes, the same folks that lobby for highway expansion projects.

While Obama has been clear in his desire to improve transportation infrastructure, it seems that he missed the mark with this bipartisan appointment, neglecting the critical links between transportation, land use, and climate change.

Deputy Assistant to the President for Energy & Climate Change–Heather Zichal

The Job: Address climate change policy

Credentials: Before being tapped for the transition team, Zichal spent time as the Obama campaign's policy director for energy, environment, and agriculture. Most of Zichal's experience comes from her seven years serving members of Congress. She served as legislative director to Senator John Kerry, where she coordinated domestic and foreign policy, as well as the environmental polices on the Senator's failed presidential bid in 2004. Her time on the Hill was spent on legislative initiatives to create green jobs, address climate change, reduce dependence on oil, and protect natural resources like the Arctic National Wildlife Refuge. She will work closely with Browner to coordinate this new office within the White House, where they will build on Obama's inaugural promises to roll back the specter of a warming planet.

—Kelly Davidson

Trojan Releases New Battery Line for RE Systems

Last fall, **Trojan Battery Co. (www.trojanbattery.com)** released its new RE Series battery, designed specifically for renewable energy charging sources such as photovoltaic arrays, wind generators, and microhydro turbines.

The new series has three models: L16RE-2V (1,110 Ah at the 20-hour rate; 2 V nominal), L16RE-A (325 Ah at the 20-hour rate; 6 V nominal) and the L16RE-B (370 Ah at the 20-hour rate; 6 V nominal). New features include higher charge efficiency, a 10-year design life, a 30% thicker separator, and a rugged Polyon case.

All models come standard with L-style terminals and a seven-year limited warranty. The introduction of Trojan's large-capacity, 2 V battery design minimizes the number of parallel battery strings required, which promotes a more even distribution of charge and discharge across the battery bank.

—Justine Sanchez

Courtesy www.trojanbattery.com

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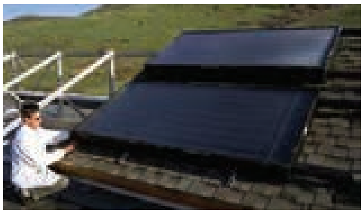

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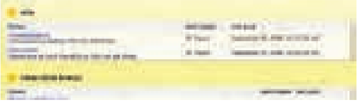
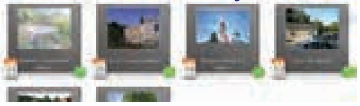


Customer Gallery



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EnerWorks Gets the Star

EnerWorks (www.enerworks.com), a Canadian solar water heating manufacturer, has just announced its qualification for the new Energy Star residential solar water heater program. EnerWorks's solar collectors and pre-engineered systems are also certified by the Solar Rating and Certification Corporation, a requirement for the federal 30% solar tax credit. One of the company's collector models, the COL-4x8-TL-SG1-SD10, includes a patented temperature-limiting device that vents excess heat. This feature is designed to minimize or eliminate the effects of overheating during a typical summer vacation of two to three weeks without hot water use. A thermally actuated spring inside the collector operates the overtemperature-protection device, which opens an air baffle at the top of the collector, venting hot air from inside the collector and maintaining the heat-transfer fluid at approximately 260ºF.

The average U.S. household spends $400 to $600 per year on water heating—the second largest energy expenditure behind heating and cooling. U.S. tax credit legislation requires that a residential solar water heater cut water heating costs by at least 50% to qualify for the credit.

Flexible Tubing Makes for Easier Solar Hot Water Installations

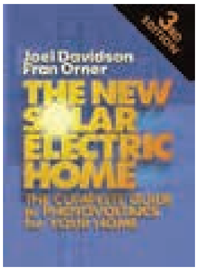
If soldering copper tubing is a challenge or you just want a quicker piping job, **Thermo Technologies' (www.thermomax.com) Easyflex** stainless steel tubing may be what you're looking for. Their insulated Solar Line tubing has a working temperature of 350°F and the 50-foot rolls are manufactured in ½-inch to 1-inch sizes. The UV-resistant insulation has an R-value of 4.8 and the return line includes a sensor wire. Brass fittings with a silicone sealing ring and nylon gaskets include couplings, tees, and adapters for threaded pipe or copper tubing. Bends are easy with the flexible tubing and a pair of adjustable wrenches is all that's needed to tighten the fittings.

—Chuck Marken

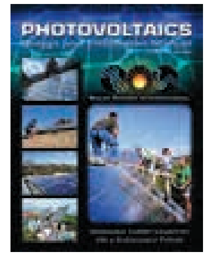
Courtesy www.thermomax.com

RE Primers

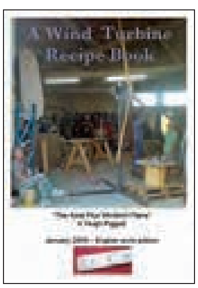
Jump-start your renewable energy education with these time-tested tomes written by experienced RE users.



Want to live with solar electricity? For a classic read on all aspects of solar-electric homes, check out Joel Davidson and Fran Orner's *The New Solar Electric Home* (AATEC Publications, 2008). Now in its third edition, the book uses plain language and easy-to-understand tables to walk you through the process—from sizing and selection to installation and maintenance. View the complete table of contents and purchase at www.solarsolar.com.



Want to install your own system? Get down to the nitty-gritty of PV system design and installation with Solar Energy International's *Photovoltaics: Design & Installation Manual* (New Society, 2007). Go step-by-step through system design and installation, and test your know-how with exercises throughout. The 112-page appendix—with a glossary, solar data, sun charts, and system sizing formulas—is an excellent go-to resource. www.solarenergy.org.



Want to build a wind turbine? Building a wind generator is not simple, but the best instructions can be found in Hugh Piggott's *A Wind Turbine Recipe Book*. Piggott's book gives a real-world account of what it takes to build and operate a wind generator. Find the U.S. measurements edition at www.scoraigwind.com.

Well Read Powell's Books, one of the nation's largest booksellers, is greening its operations with a roof-mounted, 100-kilowatt solar-electric system on its 60,000-square-foot warehouse in Portland, Oregon. One of the largest solar-electric installations in the state, the newly installed system features 540 PV modules (Mitsubishi UD5 series) that will offset about 25% of the building's electricity use.

Grid Alternatives Provides Low-Income Solar Options

Courtesy www.gridalternatives.org

Courtesy www.habitat.org

Marvas McCladdie and his daughter, Camille.

Marvas McCladdie always dreamed of buying a home, but with the high cost of housing in Northern California's Bay Area and rising energy prices driving up the cost of living, he never thought it would be possible. He tried saving for the down payment and closing costs with little success: A single father raising two teenage girls, Marvas often worked extra shifts at his job as a cook at the local hospital just to make ends meet.

Just as he was about to give up on the idea, he learned that his application for Habitat for Humanity had been approved. In 2007, after putting more than 500 hours of sweat equity into the construction, Marvas and his daughters moved from a cramped apartment to a three-bedroom house, made possible by a 30-year, no-interest mortgage through Habitat for Humanity.

Marvas's home is one of 26 built on a reclaimed industrial site in the Sobrante Park neighborhood of East Oakland. In keeping with Habitat's emphasis on green building, each home comes equipped with a roof-mounted 2-kilowatt solar-electric system from Grid Alternatives, an Oakland-based nonprofit group providing low-income families with the benefits of solar power.

Low-income homeowners spend a higher percentage of their incomes on energy. Consequently, they are the hardest-hit by high energy prices.

Founded in 2001 during California's energy crisis, Grid Alternatives is the brainchild of Erica Mackie and Tim Sears—two engineers who previously worked with energy efficiency and renewable energy systems in the private sector. After seeing how rising energy prices practically crippled low-income households, the duo set out to create a program to help low-income communities throughout California access the benefits of solar power.

"Low-income homeowners spend a higher percentage of their incomes on energy. Consequently, they are the hardest-hit by high energy prices. They pay into the tax system that supports rebates and incentives, but most cannot afford the up-front capital investment, and miss out on the benefits of renewable energy," Sears says. "Our goal was to make the economics work for *everyone*."

Their efforts led to two programs: the Solar Affordable Housing Program, which trains and leads teams of volunteers to install solar-electric systems for low-income homeowners, and the Energy Efficiency Team Program, which installs energy-efficiency upgrades for low-income seniors and disabled persons. The programs' success led to the company's current partnership with Habitat for Humanity.

Since 2004, Grid Alternatives has helped Habitat for Humanity provide more than 165 families with solar-electric systems and, in the process, trained more than 2,000 volunteers in solar-electric installation. Habitat for Humanity coordinates the grants, and funding from participating utilities and rebates through the California Energy Commission cover the cost of the systems. The Grid Alternatives crew takes the lead on system design, procurement, and installation.

In the Sobrante project, each system is designed to reduce a family's electric bills by approximately 75%, resulting in more than $15,000 in savings over its expected 30-year lifetime. But for Marvas, the benefits go beyond the monthly savings. "My girls ask lots of questions. It's nice to see them genuinely excited to learn more about renewable energy and understand how it all works," he says. "I am sure they will take this with them into the future."

—Kelly Davidson

Another 28 solar-powered Habitat houses are planned for an adjoining site in Marvas's neighborhood. To learn more or lend a helping hand, log on to www.gridalternatives.org.

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DC Power Systems

Courtesy Donald Aitken

PROJECT: Solar Casita by Aitken & Harwood

SYSTEM TYPE: Residential grid-tied PV with battery backup

INSTALLER: Jsun Mills, Alta Energia
www.alta-energia.com

DATE COMMISSIONED: November 2008

LOCATION: Lake Chapala-Ajijic, Jalisco, Mexico
21.1°N latitude

AVERAGE DAILY SOLAR RESOURCE:
6.0 peak sun-hours

ARRAY CAPACITY: 1.5 kW STC

ESTIMATED ANNUAL PRODUCTION:
2,190 AC kWh

AVERAGE ANNUAL UTILITY
ELECTRICITY OFFSET: 75% (energy); 95% electricity costs

MODULES: 9 SolarWorld, 165 W STC each

INVERTERS: OutBack PS2 GVFX3648, 3.6 kW rated output

BATTERIES: 8 Trojan L-16H, 6 V, 420 Ah @ C/20

ARRAY INSTALLATION: Roof-mounted on concrete roof, oriented true south, tilted at 22°

Under the Mexican Sun–The Solar Casita

Don Aitken and Barbara (Pia) Harwood have both been pioneers in the sustainable building movement in the United States for decades. Aitken is a renowned specialist in international renewable energy policy work. Although currently retired, they tirelessly continue to advance sustainability movements as consultants on both sides of the U.S.-Mexico border—and beyond.

In 2008, the couple purchased a hacienda-style home in an area of Mexico popular with expatriates: Lake Chapala, near the central western coast. They remodeled their home to include passive solar heating, domestic solar hot water, and a 1.5 kW grid-interactive PV system with battery backup, which allows Don and Pia to offset their carbon footprint, almost eliminate their electric bill, and neutralize the unreliable and unruly nature of the electrical grid in Mexico.

Working in Mexico presents its own set of unique challenges, which include frequent power outages, consistently high and low line voltages, severe voltage fluctuations, and a permissible operating range of plus or minus 10%.

Working in Mexico presents its own set of unique challenges, which include frequent power outages (ranging from hours to days), consistently high and low line voltages, and severe voltage fluctuations (spikes and sags). Additionally, there are no real enforceable electric codes, standards, or permitting processes in place for residential applications. Lack of conductor color-coding, inadequate wire-gauge sizing related to amperage and voltage drop, multiwire branch circuits, double-lugging, and nonexistent system and equipment grounding are commonplace and enough to make most U.S. installers faint after opening up the service panel.

Overcoming these obstacles relies on an in-depth understanding of cultural differences, planning and design, specification of flexible system components, and, perhaps most importantly, experience, patience, and persistence. Despite all of the interesting challenges, the system was successfully commissioned, and after a four-month adventure with the federal electric company, was the first official net-metered PV contract in a community of 40,000 people.

Don and Pia have led the "solar charge" in the region: as a result of their initiative, many other residents have had PV systems installed. It gives them great pleasure and satisfaction to receive their bimonthly electric bill: $7. And passing the orange extension cord over the wall to save their neighbors when the power goes out is sweet icing on the solar cake.

—Jsun Mills

System Sizing for Residential Grid-Tied PV

Sizing a batteryless PV system for a home requires considering three main factors: budget, array mounting space, and desired annual energy production.

Courtesy www.ecs-solar.com

Budget-Based System Sizing

Currently, batteryless grid-tied PV systems cost $7 to $9 per installed watt (before incentives). For the example below, we assume a $15,000 budget.

$15,000 ÷ $7/W = 2,143 W
$15,000 ÷ $9/W = 1,667 W

Given this budget, system size would likely range from 1,700 W to 2,100 W.

Available incentive programs can help offset system costs, allowing you to invest in a bigger array. For example, the federal tax credit for solar-electric systems allows for a 30% tax credit. Factoring this in allows you to increase array size, but also requires additional dollars up-front to pay for the larger system—and enough tax liability to take full advantage of the credit.

Roof Space System Sizing

System size also an be estimated based on "usable" square feet of mounting space. Crystalline PV modules generate about 9 W to 17 W per square foot (averaging 12 W per square foot), while amorphous silicon products generate about 6 W per square foot.

To find "usable" area for PV array mounting, there are several things to consider. (For more information, see "Solar Site Assessment" on page 46.) After accounting for aesthetics and working space around the array, typically only 50% to 80% of sunny roof space can be used. For this example, we will assume a usable area of 300 square feet.

300 sq. ft. x 12 W/sq. ft. = 3,600 W (crystalline silicon)
300 sq. ft. x 6 W/sq. ft. = 1,800 W (amorphous silicon)

Desired Annual Energy (kWh) System Sizing

System size can be based on annual energy production goals as well. Given your household's annual electricity consumption, peak sun-hours for the array location, and an average 70% system derate factor (to account for temperature losses, dust/dirt, wiring losses, inverter efficiency, module production tolerance, etc.), you can calculate the array size needed. For this example, we'll assume the system will be located in Flagstaff, Arizona, and oriented to true south and tilted at 35° (an angle equal to Flagstaff's latitude). It will be designed to produce approximately 3,000 kWh per year, which will meet about half of the household's annual electricity needs.

- Find the average daily peak sun-hours for the site (see Access). For Flagstaff, it's 6 sun-hours per day.
- Divide the annual PV production goal by the number of days in a year. Divide this total by the number of average daily sun-hours to arrive at your estimated initial array size.

3,000 kWh/year ÷ 365 days/year = 8.219 kWh/day
8.219 kWh/day ÷ 6 sun-hours/day = 1.37 kW

- To account for system inefficiencies, divide the result by 70% (0.7) to calculate the total system size.

1.37 kW ÷ 0.7 system derate = 1.96 kW or 1,960 W

Alternatively, the PVWatts online program (see Access) can be used to find annual kWh production values for various PV array sizes. Variables such as non-optimal orientation and tilt angles can be factored in easily.

Efficiency First

Reducing annual energy consumption through the use of energy-efficiency strategies (such as replacing incandescent lights with compact fluorescent lighting) will yield a smaller PV system, lower system cost, and less required space.

Access

Photovoltaics Design & Installation Manual, Appendix B (New Society, 2007) • Solar data, including peak sun-hours

PVWatts • www.nrel.gov/rredc/pvwatts/ • PV production estimator

—Justine Sanchez

the circuit MAIL

Courtesy Gail Geraghty

Courtesy Bud Anderson

CUTTING WOOD WITH THE SUN

For many, there's nothing quite like the feeling of accomplishment in the sweat and labor it takes to cut wood to heat your home. Imagine, then, how good it would feel to eliminate the need for gas and oil to cut wood, as well as much of the sweat and labor?

John Howe has done it by creating a firewood operation where the sole source of energy is the sun. "This is fun," says the retired mechanical engineer as he drives his solar-powered golf cart noiselessly down a tote road near his rural farmhouse. And even more importantly, he says, it's the only way you can cut a tree in the woods without fossil energy—which is beginning to run out.

Parked in the sun, the cart's onboard solar-electric array adds PV energy to its 10 kWh battery pack, which supplies a 2,500 W, 120 V inverter. He easily lifts his 6-pound electric chain saw and connects it to a 150-foot extension cord plugged into the cart. One of his other innovations is an electric 60-year-old Ford 8N tractor. Logs are skidded out by using a 6,000-pound winch attached to the tractor through a standard three-point hitch.

Back at the woodshed, the same golf cart powers the same saw to cut the logs to stove length. Once the logs are cut to length, he swings them over to a waist-high 6-ton splitter and splits them down to firewood size. Nearby, the Ford tractor recharges by being plugged into another tractor: a Farmall Cub with a four-module array.

For Howe, showing how to process firewood without gasoline is as much a demonstration project as are the tractors, the golf cart, and even a solar-powered MG Midget he owns. "In Maine, we are in very serious trouble because we heat with oil," says Howe. "Solar electricity is the way to go. If we don't make use of it, we will absolutely fail as a society."

Gail Geraghty • via e-mail

SOLAR CHORDS

As a child who grew up in the 1970s, I was constantly amazed by the ways my dad would find to join the "green movement" and make our lives more energy efficient. The best part about it was the fact that everything he did was something he did on his own—and many of his nature-powered inventions included materials that were recycled.

Now in his retirement, you'll find my dad traveling to parks and playing his solar-powered, amplified guitar for people of all ages. It's his way of introducing people to the fun (and affordable) reality of solar energy.

Bud Anderson • via e-mail

NET METERING FOR NEBRASKA

This is a call to action for net-metering proponents in Nebraska.

Nebraska has had two bills introduced on the subject of net metering. The first, LB436, is pro-consumer and pro-energy independence. However, it will undoubtedly meet severe opposition from our public power lobby. Nebraska has no private utilities—all electricity is provided by publicly owned utilities.

The second bill, LB663, is much less desirable, but at least addresses the need for net metering in Nebraska. It has many good provisions and, with serious amendment, can be made more pro-consumer than its current pro-utility focus.

The legislature may be finished with both of these bills by the time you read this—the point of this letter is to provide a focus for organizing toward passing a bill like LB436.

You may contact us by phone or email: 402-685-4333 or 402-307-0280; waterdog@nerenew.com.

Robert Byrnes • Oakland, Nebraska
Stonie Cooper • Prague, Nebraska

PAYBACK? CONSIDER USAGE FIRST

I read with interest "PV vs. SHW" in *HP127*. One factor often overlooked in these sorts of payback analyses is utilization. In the case of a grid-tied 2 kW PV system, utilization is likely to be 100% if annualized net metering applies. On the other hand, solar hot water (SHW) is a use-it-or-lose-it proposition, so utilization is likely to be substantially less than 100%.

During warm weather, much of the capacity of a SHW system is wasted unless the system is undersized relative to the annual load. Unfortunately, most systems end up being oversized, pushing payback well beyond the life of the system. This happens because hot water use is routinely overestimated, especially for conservation-minded households without children. Moreover, there seems to be a mind-set that more is better. *Energy Design Update* reviewed an interesting zero-energy case study in its March 2008 issue that demonstrates this point. *EDU* estimated a simple payback of 489 years for the SHW system! (See www.nrel.gov/docs/fy08osti/42339.pdf.)

David Butler,
Environmental Building Solutions •
Sierra Vista, Arizona

RENEWABLE INSPIRATION

Last October, a friend invited me on a two-hour drive from Philadelphia to the gentle rolling hills of southern Lancaster County, Pennsylvania. The house of an acquaintance, Jay McGinnis, was part of the National Solar Tour, organized locally by the Susquehanna Sustainable Business Network (SBN). Jay owns a 500-acre working farm that's been in his family for several generations.

We parked by a tidy, two-story farmhouse flanked by an old hay barn and some outbuildings, and were greeted by a cheery SBN volunteer in the garage that serves as the workshop for Jay's Woolen Mill Fan Company, which produces interesting belt- and pulley-driven ceiling fans. Looking past the workbenches, I noticed the workshop had hot and cold lines for radiant heat sunk into the concrete floor. Also, next to the utility meter, I saw a box labeled "Grid Tie Solar Inverter" manufactured by Xantrex. The tour had begun.

Outside, Jay showed how the back of the workshop's peaked roof was half covered with photovoltaic modules. Since it was installed in March 2005, the 3 kW array has produced 13,543 kWh. His solar-electric system feeds electricity back into the utility grid through the inverter, running his electric meter backward on a sunny day. Using the grid as his "battery" earns him a nice check from his local utility, which buys the kilowatt-hours he generates at the retail rate. As a bonus, Jay also gets to sell his clean energy production "credits" separately, netting a few thousand dollars every year.

The tour proceeded to a two-story clapboard shed a hundred paces away, where the 50-foot-tall steel frame of an old-time Aermotor windmill sprouted from its roof. Enclosing the base of the windmill's steel frame with a post-and-beam shed provides Jay with a workspace for using the wind power with any device he might need. Inside, the mechanical drivetrain spun fitfully with the mild breeze, turning a leather belt that led ultimately to a 5-gallon "hand-cranked" ice cream maker. Jay explained how he uses the Aermotor windmill to compress air into several large, repurposed propane storage tanks to drive the air tools in his workshop. Although a more modern-looking Skystream wind generator was next to his tractor garage, it had not generated the electrical output Jay hoped for, due to lower-than-anticipated winds in the area.

On the roof of the tractor garage, we saw more Sharp PV modules (3.3 kW, and newer than those on his workshop). These had generated 4,490 kWh since November 2007. On the other side of that garage, Jay had recently drilled three bore holes to a depth of 300 feet for the closed-loop geothermal system he planned to install later in the season. Jay also pointed out the long, clear cylinders of a Sunda solar hot water system on the roof of his home's breezeway—48 vacuum tubes for household hot water. After that, we got to tour the house and a dazzling showroom of all the belt- and pulley-driven ceiling fans Jay manufactures. What a treat! Check them out at www.architecturalfans.com.

The story I took home is how over the last five years, Jay declined his financial adviser's advice, cutting his IRA contributions in favor of renewable energy options for the home and business. I didn't calculate his outlay and return numbers to determine a payback point. But I find his example of exploiting a full spectrum of solutions inspiring, and will seek to take a similar tack in my urban homesteader context.

Tim Siftar •
West Philadelphia, Pennsylvania

ERRATA

The Web site address listed in the "Charge Controller Buyer's Guide" (*HP129*) for Apollo Solar should be www.apollosolar.com.

METER MAIL

After reading about monitoring 240 VAC loads in *From Us to You* (*HP129*), many readers asked where they could get meters. Author (and metering maniac) Ian Woofenden recommends reconditioned meters from www.hialeahmeter.com.

TO CONTRIBUTE

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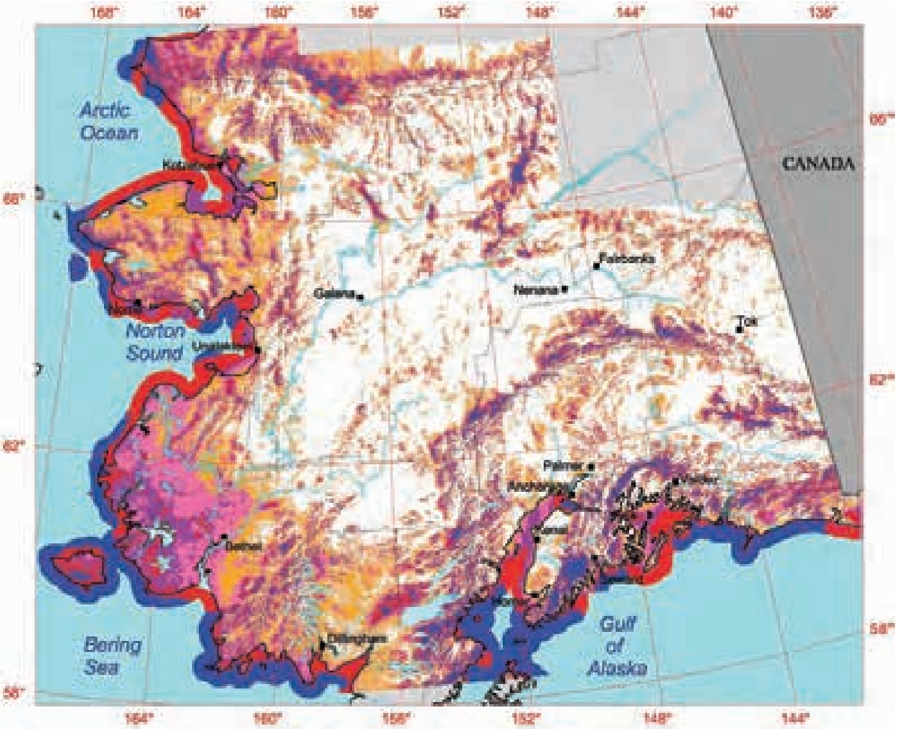
Ask the EXPERTS!

Wind-to-Heat Viability

About 80% of the cost of home energy use in my home state of Alaska is for heating; the remainder is for electricity. For folks who don't have access to natural gas or cheap wood, heating with fuel oil or propane may be the only option.

However, it seems like directly dumping 48 VDC power from a wind turbine into a resistance heater submerged in a large water-storage tank would allow a homeowner to heat water at a reasonable cost. With this setup, there's no need for an inverter or sophisticated controls—the resistance element could take whatever the wind can deliver and a backup element could be installed in case the primary element fails. Are there any pitfalls to implementing this type of system?

Andy Baker • Anchorage, Alaska



Wind Power Class	Resource Potential	Wind Power Density (W/m^2)	Wind Speed (m/s)	Wind Speed (mph)
1	Poor	0 – 200	0.0 – 5.3	0.0 – 11.9
2	Marginal	200 – 300	5.3 – 6.1	11.9 – 13.7
3	Fair	300 – 400	6.1 – 6.7	13.7 – 15.0
4	Good	400 – 500	6.7 – 7.3	15.0 – 16.4
5	Excellent	500 – 600	7.3 – 7.7	16.4 – 17.2
6	Outstanding	600 – 800	7.7 – 8.5	17.2 – 19.0
7	Superb	> 800	> 8.5	> 19.0

Alaska Mainland Winds at 50 Meters

Courtesy www.windpoweringamerica.gov

At first glance, this direct wind-to-heat approach makes sense. Wind is a good match with heating—it's often windy when it's cold, and small wind turbines can indeed be a useful source of heat. I do use my turbine for heating, but only as a by-product of electricity production.

Making *only* heat with wind power is the questionable part for most homes. Wind is variable—and although wind turbines can often produce a surplus, when the wind's not blowing, you'll suffer shortages. Plus, when you don't need more heated water, wouldn't you want to use the wind energy to offset your electrical usage? On the other hand, perhaps you'll be able to heat a home with wind energy for half of the time, but you will still need a backup heat source. Either way, integrating your wind turbine and heating system with the utility grid makes a lot of sense.

As far as cost, a heat-only system is cheaper to set up, but it sometimes doesn't pay off, because heat and thermal energy are relatively inexpensive compared to a "high-grade" energy source like electricity. Your heating fuel costs will need to be high and your wind resource excellent to make a wind-to-heat system pencil out. In most cases, money spent on improving insulation levels in your home will have a better return.

That does not mean that nobody should do it (including just for fun), but I would not promote this method as a way to save money in most situations. Using the wind energy for other electrical loads as well makes more sense, since you will be able to use *all* the wind energy, not just what you need for heat. A grid-tied system that offsets your utility bills allows you to treat the grid as a big battery and store your surplus—the best of both worlds.

Hugh Piggott • Scoraig Wind Electric

"Your heating fuel costs will need to be high and your wind resource excellent to make a wind-to-heat system pencil out."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Now is the time to go solar. Prices are better than ever. The new 30% Federal Tax Credit, state rebates and other incentives reduce the cost of your system by up to 50%. New financing options are available. Going solar has never been more affordable or easier. Contact SunWize for a site evaluation.
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Grid-Tied Inverter Safety

What happens when the utility grid fails? Does a grid-tied solar-electric system need an automatic transfer switch to stop sending electricity to the grid? What are the differences between a PV system with and without battery backup when the grid goes down? I don't want to have an electrocuted worker on my conscience.

Jorge A. Dávila • via e-mail

Paul Fawcett/iStockPhoto

For the safety of line workers, inverters must stop sending electricity to the grid when there is a grid failure. As you can imagine, this is a serious concern for utilities because they do not want any utility lines to be energized while they are trying to fix the cause of the power outage.

The condition where an inverter continues to electrify the grid during an outage is called islanding. To prevent this situation, Underwriters Laboratories' Standard 1741 lays out the electrical requirements for grid-tied inverters, including anti-islanding. To receive UL listing, an inverter must be certified to be nonislanding, meaning it will not send electricity to the grid during a grid failure. By installing a UL-listed grid-tied inverter, you can rest assured that your system will not pose a threat to your local linemen and will shut down or disconnect from the grid when it fails.

There are several ways inverters accomplish this. The first and easiest is that an inverter monitors the voltage and frequency of the grid. If either one falls outside set parameters, the inverter will shut down. This method works the vast majority of the time. The trouble comes if the loads attached to the inverter happen to match the inverter's output power at that time and it detected no noticeable change in frequency or voltage when the grid failed. In this case, a more sophisticated detection scheme is necessary. To account for this possibility, inverters employ a variety of methods to effectively push and pull slightly on the grid voltage and frequency. When the grid is present, this little push-and-pull has no effect. However, if the inverter is the only source supporting an islanding grid, it will quickly push the voltage and frequency outside the inverter's acceptable window of operation, triggering the inverter to shut down.

The differentiation between battery-based and batteryless inverters is an important one. In either case, the inverter shuts down its connection to the utility when it detects a grid failure. Batteryless inverters remain off until the grid is back up and running again. And, immediately after turning off its output transistors, battery-based inverters will also use a transfer switch to disconnect from the grid. Once disconnected, however, battery-based inverters will reactivate the output transistors to continue supplying electricity to loads wired into the critical load subpanel. This switching takes place in less than 16 milliseconds, which is fast enough not to disrupt computers and the like that are backed up by the system. The key to installing a battery-based grid-tied system is to make sure that all loads that require power when the grid is down are wired into a separate critical load subpanel and to isolate that subpanel from the grid (i.e., it should be powered only via the output of the inverter). This way, when the grid goes down and the inverter is sending power only to the critical load subpanel, PV power is prevented from energizing the utility lines.

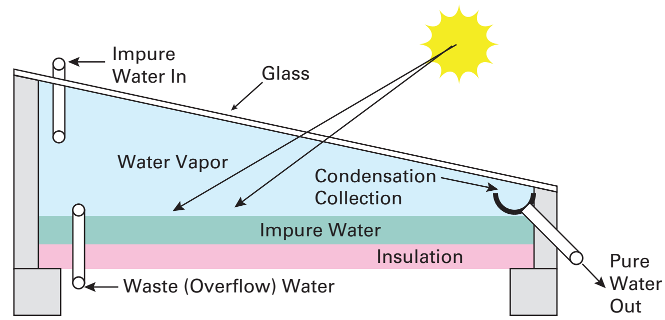
Dana Brandt • Ecotech Energy Systems

"The condition where an inverter continues to electrify the grid during an outage is called islanding."

Solar Still

I'd like to distill my spa water to purify it, eliminating the need for nasty chemicals. I have noticed the similarities between a solar still and a solar box oven. Are they interchangeable? What is the best tilt of the still's glass for optimal under-glass distilled water collection?

Steven Coles • Phoenix, Arizona



While a solar still and a solar box cooker may look similar, for optimum performance their construction is quite different. The most common solar still is the single-basin type, which consists of an airtight basin that holds the water to be distilled. This basin is covered by a sheet of glass that is tilted. The cover allows solar radiation to enter the still, where it heats and evaporates the water, leaving contaminants in the basin. The water then condenses on the underside of the glass and runs down the glass to a collection trough. Water exits the trough through a tube directed into a container.

In a still, the thinner the glass, the better. Thin glass will stay cooler on the inner surface, which helps the water condense faster. In a solar still, the slope of the glass should be between 8° and 12°. Setting the glass at a greater slope increases the volume of air inside the still, reducing the system's efficiency. A lower slope makes it more difficult for the condensed water to run down the glass, and water droplets may just fall back into the basin. Also, the closer the glass is to the water, and the less air space in the still, the more efficient the still will be. According to solar still pioneer Horace McCracken, who designed and built solar stills for more than 30 years, a glass cover that is no more than 2 to 3 inches from the water surface will allow the still to operate efficiently.

There are commercial solar stills on the market and plans are available to build your own. However, the small amount of water produced in a solar still will make your application very difficult. A 30- by 48-inch commercial solar still like the SolAqua Rainmaker (www.solaqua.com) can produce up to 1.5 gallons per day. Spas contain several hundred gallons of water, and cycling that much water through solar stills every few days would take a massive array.

Laurie Stone • Solar Energy International

Battery & Generator Housing

I am planning to build a battery shed and want to know if the same shed can be used to house a backup engine generator. What are the exhaust and other safety considerations?

Berry Roper • via e-mail

The *ideal* power shed has three rooms: One for the batteries (assuming they are vented batteries), one for the inverters and other electronics, and one for the generator. Flooded (and therefore vented) batteries must be isolated from any spark source and adequate ventilation provided to exhaust the explosive and corrosive gases generated during charging. Inverter(s) and associated electronics contain spark-generating switches and relays, so they should not share an enclosed space with the batteries. Some power rooms have a sealed and vented battery box within the electronics space. Generators also pose a spark hazard, and should not share the same space as batteries. They also create too much heat to share a room with the electronics, and should be isolated from the inverters.

Courtesy Miller Solar

Consider these tips when you're designing your power shed:

- **Inverter equipment layout.** The side of the inverters with the DC connections should be nearest the batteries and receive conduit from the DC charging sources. The side with the AC connections should be nearest the generator and conduit to loads. Electronics need plenty of room in front for safety during service (the *National Electrical Code* requires a minimum of 3 feet of clearance). Follow the manufacturers' recommendations for clearances on either side of the equipment.
- **Battery room.** No light switches are allowed in the room—locate them outside the shed within a weatherproof cover or in the inverter room. Use sealed, "explosion proof" light fixtures. Allow plenty of room to service the batteries. Seal conduit between the battery and inverter rooms. Secure batteries so they can't overturn in an earthquake.
- **Generator housing.** The generator's electrical connections also require 3 feet of clearance in front for service. The manufacturer may provide additional recommendations for clearance for service and ventilation. The manufacturer will also provide exhaust and intake requirements. Port the generator exhaust to the outside with flexible exhaust pipe.
- **Size.** You probably won't regret making your power shed too big, but you'll always regret it if you make it too small.
- **Grounding.** Specify a Ufer ground (in which the concrete acts as the ground rod) in the foundation of the building. The Ufer ground should be in the electronics room.

William Miller • Miller Solar

Net-Zero Energy Manufactured Home?

My boyfriend thinks that it's possible to retrofit a manufactured home and turn it into a net zero-energy home. Because manufactured homes are typically less expensive than custom-built homes, he believes that we could take the money we saved from buying a manufactured unit and use these savings to make the efficiency upgrades. I feel that manufactured homes are not built well enough to achieve this high level of energy efficiency. Even it were possible to make it a zero-energy home, it seems that the resale value would be less than a site-built or modular home. What's your take?

Kristin Holleran • Vancouver, Washington

By choosing a manufactured home over a site-built one, you will likely save on a square-foot to square-foot basis, but the savings won't be enough to make net zero-energy retrofits cost effective. Any net zero-energy strategy is likely to involve a significant investment in renewables. Depending on your heating, cooling, and electricity use, the expense of the systems to cover 100% of your energy use may approach the cost of the house. However, there are some cost-effective products and design strategies to consider.

In the Northwest, homes built under the Northwest Energy Efficient Manufactured Housing (NEEM) program typically offer more savings through efficiency than a conventional manufactured home, offering lower utility bills that make up for the home's comparatively higher price. Incentives for NEEM homes are available from many regional utilities; Oregon and Montana also offer tax credits for NEEM homes. In addition, NEEM homes have a higher resale value than other HUD code homes, as reflected in industry-recognized appraisal tools.

If you decide to purchase a NEEM home and the retailer won't offer high-efficiency lighting and appliances, order the home without lighting fixtures or appliances, and purchase Energy Star fixtures and appliances yourself.

Maximize solar heating by selecting appropriate floor plans and orienting the longest side of the home to face south. Install heavy drapes and blinds, and consider exterior awnings for shading.

Heating Costs for NEEM vs. HUD Homes

	Avg. Heating (kWh/Yr.)		Annual Savings	
City	NEEM	HUD	Electric	Gas
Portland, OR	5,900	11,295	$404	$320
Boise, ID	7,725	14,375	499	396
Spokane, WA	10,005	18,335	625	490
Missoula, MT	11,845	21,610	733	584


Greg Nicholas/iStockPhoto

Make sure the retailer uses state-certified and state-trained installers. Proper home setup focuses on correct installation of the heating system's crossover duct and the building's marriage line at the walls, floor, and ceiling. If you have concerns, hire an energy professional to conduct a blower door and duct-blaster test to check the home and ducts for air leakage.

Make sure your home is "solar ready," with roof designs that allow easy installation of solar hot water collectors or PV modules. Pipe and conduit can also be run to the roof for connecting the collectors or modules to the home's hot water or electrical system.

Check out the Building America Industrialized Housing Project (www.baihp.org), which is investigating cutting-edge technologies and design strategies for manufactured homes, including rigid and spray-foam insulated wall systems, highly efficient window technologies, high-efficiency ductless heat pumps, and solar-ready design.

If you do consider modular or traditional construction (site-built) homes, check out the Northwest Energy Star program (www.northwestenergystar.com), with energy standards designed to exceed state codes by 15%.

In general, if you're considering a manufactured home, before trying to reach the apple all the way at the top of the tree (net-zero), we suggest starting with the low-hanging fruit—a NEEM home and Energy Star technologies.

Mike Lubliner & Andy Gordon •
Energy Specialists, WSU Energy Program

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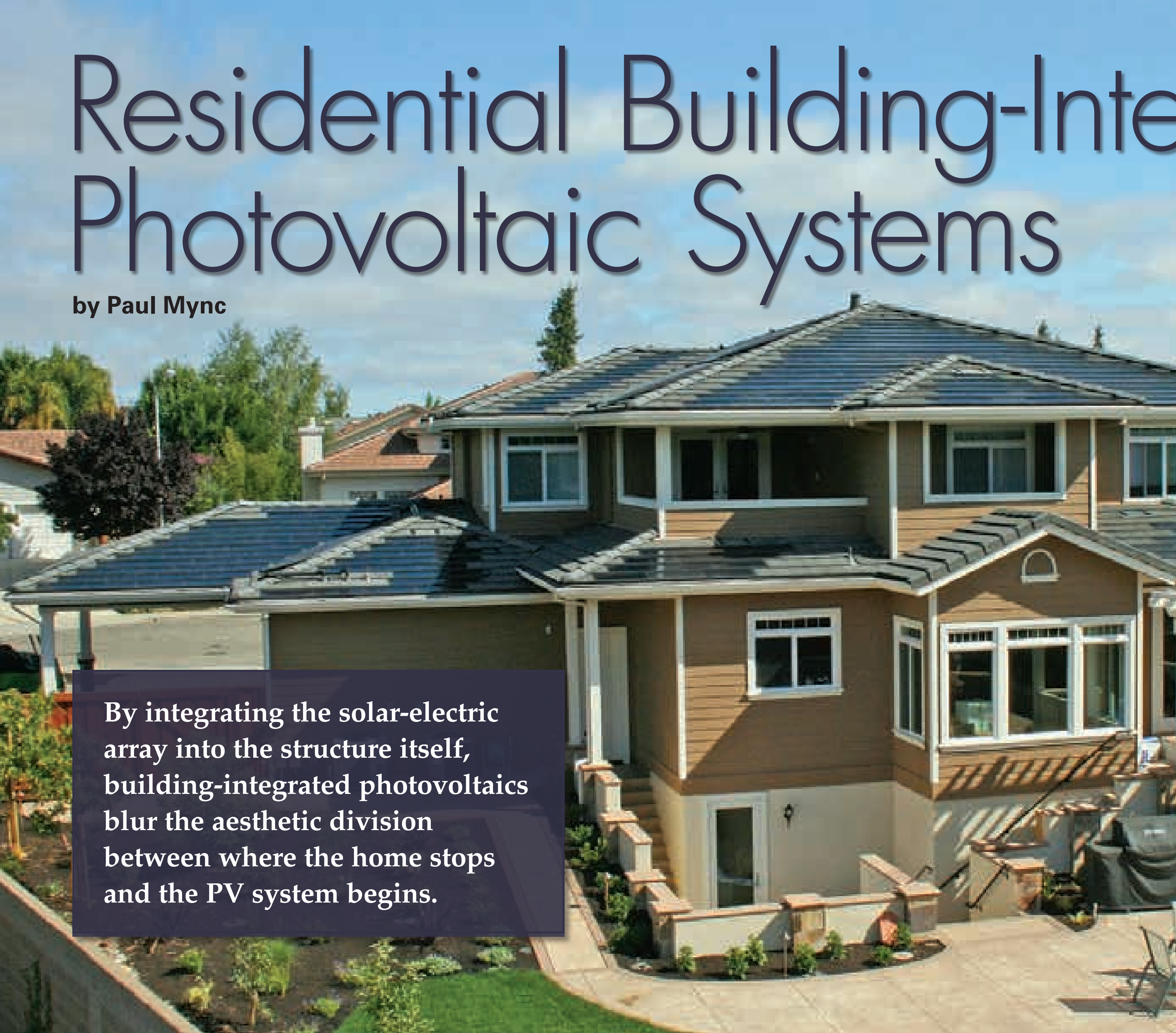
by Paul Mync



By integrating the solar-electric array into the structure itself, building-integrated photovoltaics blur the aesthetic division between where the home stops and the PV system begins.

Until recently, most residential solar-electric arrays consisted of rigid modules attached to a roof-mounted rack. There's no mistaking this type of system—most of them are quite visible and easily identifiable. But while some folks view a standout system as a chance to educate and enlighten, others don't like the looks or just want the system to inconspicuously blend in, generating clean energy without standing out. If you fall into this latter group, a building integrated photovoltaic (BIPV) system might just be what you've been looking for. For roof retrofits, expect to pay a little more, but if it's for new construction, the costs of BIPV can be very similar to a typical framed PV array.

BIPV Applications

The most common home-scale BIPV application is in new home construction. Due to the ever-growing demand for energy-efficient, "green" homes, many homebuilders have begun to offer some sort of BIPV product as an option or as part of a planned green-housing development.

Another opportunity to incorporate BIPV into an existing home comes during reroofing, when the roof's structure is exposed. The PV mounting hardware is installed first, and the roofing is placed around it, resulting in more trustworthy weatherproofing.

Solar roofing PV modules integrate seamlessly with the roofing material. They are attractive, not only because the modules blend in aesthetically but also because they serve a second purpose as the roofing material.

Atlantis Energy Systems, BP Solar, GE Energy, Sharp, SunPower, Suntech, and Uni-Solar all offer ready-to-install roofing tiles. Some of these products are not directly available to end users or installers, and several

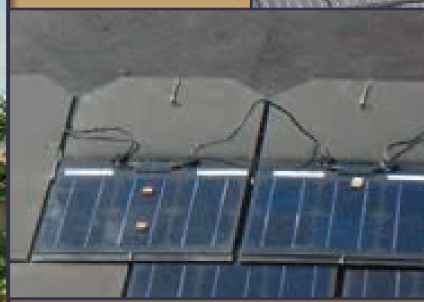
egrated

Courtesy www.appliedsolar.com

products are only available to roofing companies and new home builders/developers. Lumeta also has BIPV roofing products that are currently undergoing the Underwriters Laboratories' certification process and are to be released later this year.

For Installers & End Users

Atlantis Energy Systems' Sunslate is a PV shingle made of six single-crystalline cells on a fiber-cement backing. Sunslates can be incorporated into a concrete tile, composition, wood shake, metal, or slate roof. These modules are mounted using a traditional roofing

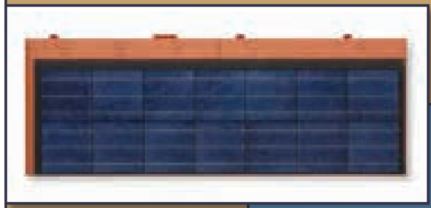


Courtesy www.atlantisenergy.org (2)

Atlantis Energy Systems' Sunslates blend with the surrounding shingles almost seamlessly.

Courtesy www.uni-solar.com & Actus Lend Lease

Uni-Solar laminates use an adhesive backing to stick to standing-seam metal roofing.



Courtesy www.suntech-power.com (2)

Suntech PV roof tiles come in colors to match the surrounding roof surface.

Courtesy www.sharpusa.com

Sharp's roof-integrated module is designed to replace five standard, flat cement tiles.

Courtesy www.bpsolar.com (2)

BP Solar's Energy Tiles are made with multicrystalline PV cells to maximize efficiency.

method, with an underlayment of standard 30# felt tar paper. The roof deck is prepared with vertical 2 by 2s fastened through the deck and into the rafters. One-by-fours are nailed horizontally to the 2 by 2s to create a raised batten framework. The Sunslates hang on supplied hooks nailed to the 1 by 4s. The spacing behind the slates allows airflow to help reduce PV cell temperature and associated power loss.

GE Energy's PV Roof Integrated Modules can be used with flat concrete-tile roofs.

Courtesy www.gepower.com/solar (2)

Sunslates are typically connected in series strings of 24 slates, using a proprietary connector system (designed to hold a bypass diode for each tile). Failure of a single slate presents a challenge for replacement, for a section of the slates will need to be removed to gain access to the failed slate. Installations typically require multiple strings, with all strings grouped together and entering into a single penetration into the attic. This product comes with a limited 20-year power warranty.

GE Energy's PV Roof Integrated Modules are designed to integrate with flat concrete-tile roofs. Each module contains 18 multicrystalline cells and one bypass diode. Modules are wired together with Solarlok connectors. To install, brackets are screwed down to unraised battens. Modules are secured to the roof with clips into the brackets. This product comes with a 20-year limited power warranty.

Sharp manufactures a roof-integrated module that is designed to replace five standard, flat cement tiles. The modules are comprised of 18 multicrystalline cells with one bypass diode per module and are wired together with Onamba C3 quick connects. These modules are secured to standard unraised battens with gasketed screws. The limited power warranty is 25 years.

Uni-Solar manufactures a thin-film laminate for standing-seam metal roofs. An adhesive seals the modules to the metal, avoiding roof penetrations. Laminates are wired together via MC connectors, with the connections routed through the roof's ridge cap. Bypass diodes are wired across every cell in Uni-Solar products, which makes the modules more shade-tolerant than PV products that protect multiple cells with a single bypass diode.

Manufactured with triple-junction thin-film amorphous silicon, these modules offer better low-light and high-temperature performance. The primary disadvantage is the lower efficiency of amorphous thin-film products (see "Efficiency vs. Roofing Space" sidebar). This product comes with a limited 20-year power warranty.

(continued on page 42)

Blurring the Edge of BIPV: Solar Awnings

With hardware and wires hidden, the underside of a well-designed solar awning is aesthetically pleasing.

Integrating typical framed PV modules into solar awning structures is becoming an increasingly popular method to combine both form and function. When properly sited, solar awnings can reduce a home's cooling load and supply energy at the same time. Compared to standard roof mounts, awnings allow for maximum airflow along the backside of the modules, reducing cell temperature and decreasing the efficiency hit that high ambient temperatures can take on PV performance.

Standard solar modules with opaque backsheets can be used with a racking structure to create awnings, but using glass-backed modules allows some light to pass through, which can be desirable for functional and aesthetic reasons. Sanyo's HIT Double series are "bifacial" modules, which generate electricity from both sides. Used with a reflective ground surface, they can increase energy production, Sanyo estimates, by 15% to 20% compared to standard modules. Actual energy increase from bifacial modules depends on site specifics, such as the amount of incident light reflected from the ground.

Bifacial awnings typically require a customized mounting frame to create a watertight structure, support the modules while not obscuring light transmission, and hide module wiring for better aesthetics. Several companies cater to the bifacial awning market niche, providing custom and prefabricated awning systems.

Awning structures are now one of the more common ways to integrate PV into a home. But in the commercial PV sector, many companies are offering custom BIPV glass products to architects and engineers working on high-profile projects. For example, Applied Solar provided custom-built, glass PV modules for a 172 kW canopy at the California Academy of Sciences in San Francisco's Golden Gate Park. Over time, it's likely that these commercial solutions and products will also make their way into residential BIPV installations.

—Justine Sanchez

From the top, the array blends into the structure's architecture.

Underneath, filtered light comes through.

Courtesy www.floriansolarproducts.com (3)

Courtesy www.lumetasolar.com (2)

Lumeta's Solar S and Solar Flat products visually integrate with S-type or flat concrete tiles.

Available to New Home Builders & Roofing Companies

BP Solar's Energy Tile is a solar roofing product designed to integrate with flat concrete roof tiles. With 18 multicrystalline cells, each tile uses one bypass diode. Tiles are wired together via MC connectors and secured to the roof via standard, unraised battens. The limited power warranty is 25 years.

SunPower's SunTile is another product for S- or flat concrete tile roofs. SunTiles have 22 monocrystalline cells per tile, with all of the cells' electrical contacts on the back. Without gridlines on the cell fronts, more sun gets through, which means higher efficiency (the manufacturer claims up to 22%). The tiles each have one bypass diode and include MC connectors. SunPower does not require a raised batten system, as the SunTile design allows for continuous airflow beneath the array. Mounting clips are integrated, and the tiles attach to the roof with gasketed screws. The power warranty is 25 years. SunTiles are only available for new housing developments of 25 or more homes.

Efficiency vs. Roofing Space

Because they can be deposited on flexible surfaces and can offer better high-temperature performance, thin-film PV cells are used in some BIPV roofing products. However, this type of PV technology is about 50% less efficient per square foot than a traditional single- or multicrystalline PV technology. This lower efficiency results in about twice as much surface area needed to produce an equivalent amount of power. If your roof space is limited, consider products made from single- or multicrystalline PV cells.

Suntech's SolarSave roofing tiles are sized to integrate with flat concrete tile or S-tile roofs. With 14 multicrystalline PV cells, each tile has one bypass diode. Tiles are wired together with MC connectors. Suntech recommends installing tiles on raised battens to increase airflow and reduce power loss from high temperatures. The tiles are secured to the batten structure either with nails or deck screws, and can be installed with wind clips to increase wind-load ratings. The limited power warranty is 25 years.

Coming Down The Pike

Lumeta's Solar S and **Solar Flat** tiles are for profiled and flat concrete or clay tile roofs. Each tile has 12 monocrystalline cells, with one bypass diode per tile. Tiles are wired together using locking connectors. Each solar S- or flat-tile is designed to replace three standard cement or clay tiles. Depending on the roof pitch, battens may be required. The tiles are attached to the roof with stainless steel screws. This product comes with a 25-year power warranty.

BIPV Characteristics & Considerations

Designing BIPV into a home creates significantly different challenges than installing a standard PV system, since the successful integration of the system often relies on the home's design. If the home is using solar tiles or shingles, roofing design and collaboration with the roofing contractor become essential, since the tiles are installed along with the roofing and can affect the roof structure. Solar tiles usually require a manufacturer-designated mounting method. The roofer can help with mounting the BIPV, sealing roof penetrations, and dealing with any roofing issues that may arise.

The electrical characteristics of BIPV products also differ from standard PV modules. A BIPV roof tile is usually smaller than a PV module, containing fewer cells. That means lower output voltage, requiring many more BIPV roof tiles connected in series to attain the input voltage of a modern residential grid-tied inverter. It's common to have more than 30 solar tiles in series to reach the operating voltage of the inverter. Requirements for series fusing or combiner boxes may not apply with only one or two strings.

Troubleshooting BIPV systems also can be difficult. When BIPV systems are fully integrated into the building, gaining access to the modules and connections can become an issue, unlike a conventional rooftop-mounted PV array. For example, troubleshooting an individual solar tile may involve removing others to gain access to the malfunctioning one. Plus, just figuring out which tile has failed can be a daunting task: You will first need to isolate each individual string, then each solar tile will need to be tested until the malfunctioning one is found.

More Expensive? Maybe, Maybe Not

Retrofitting an existing home with BIPV products can be more expensive than buying traditional PV modules and racking. However, comparing costs between these two types of installations and even between new home construction projects can be tricky. First, BIPV products generally blend two functions (roofing and electricity generation) into one product, which can help offset their higher cost. Second, BIPV roofing tiles are usually sold to large-scale homebuilders, who are given pricing based on the size of the projects. Complicating the issue further is that many BIPV roof-tile companies do not sell direct to the end user. For new home developments, grid-tied BIPV systems cost about the same as standard, non-BIPV ones: about $7 to $8 per rated watt.

Another consideration is that incentive programs aimed at new homes may boost the BIPV market, eventually lowering costs. For example, the California Energy Commission's New Solar Homes Partnership gives state rebates and tax credits for PV systems included with new homes. New homes and newly constructed affordable housing projects have their own incentives set aside, highlighting California's goal of spurring PV design from a project's inception.

In general, the BIPV market is still relatively a niche market, so these products have not been exposed to the trend of cost reduction that the industry has seen with traditional PV modules.

The Future of BIPV

BIPV installations are increasing every year. Architects and designers are developing new, creative ways to utilize these products and developers are incorporating them into green housing tracts, while manufacturers continue to create new products to meet this market niche. Some companies, such as Sanyo, Schott Solar, Sharp, and Suntech, are working on new BIPV products for facades, skylights, and windows. As the PV market develops and continues to grow at a record pace, keep a close eye on this exciting and creative way to integrate PV technology into the home.

Access

Paul Mync (paulmync@hotmail.com) has been installing, designing, troubleshooting and maintaining PV, solar hot water, and radiant heating systems since 2002. He has worked around the world on PV systems ranging from 100 watts to 18 megawatts. Paul also is an instructor for Solar Energy International.

BIPV Product Manufacturers:

Atlantis Energy Systems • www.atlantisenergy.org

BP Solar • www.bpsolar.com

GE Energy • www.gepower.com/solar

Lumeta • www.lumetasolar.com

Sanyo • www.sanyo.com

Schott Solar • www.us.schott.com

Sharp • www.solar.sharpusa.com

SunPower • www.sunpowercorp.com

Suntech • www.suntech-power.com

Uni-Solar • www.uni-solar.com

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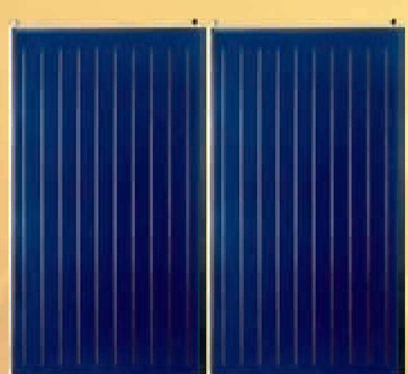

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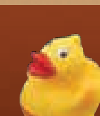

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SOLAR SITE ASSESSMENT

by Justine Sanchez

With PV modules, energy production is golden—as long as sunshine is hitting them. But shade (and even partial shade) can make your modules as useful as garden gnomes.

A PV module's output is directly proportional to the amount of sunlight hitting it. Modules produce electricity when photons—little packets of energy contained in sunlight—hit the cells and knock available electrons loose and into motion. When fewer photons hit the PV cell, for example due to haze or poor orientation, fewer electrons are put into motion, and less electricity is produced. But shade—even a small amount—can in some cases shut down production completely.

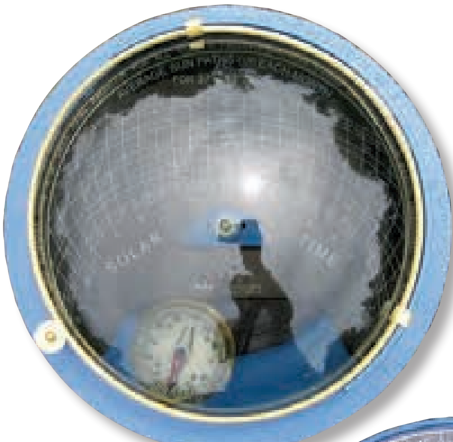
Most modules are manufactured with built-in bypass diodes that can help mitigate the effects of partial shading (see "Bypassing Shade" sidebar), but even a shaded row of cells can disable the module. Shading's impact necessitates careful site planning and design considerations for solar-electric arrays.

Most sites will have at least some shade to consider, whether it is a neighbor's multistory home or trees on your property. And while wide-open, dawn-to-dusk exposure is ideal, PV system designers generally shoot for a shade-free solar window from 9 a.m. to 3 p.m. ("solar time" for all days/months of the year). These are the hours the majority of solar radiation is available. However, local climate variations may affect that. For example, in some areas, early morning fog can shift the "prime" solar window toward sunnier afternoon hours.

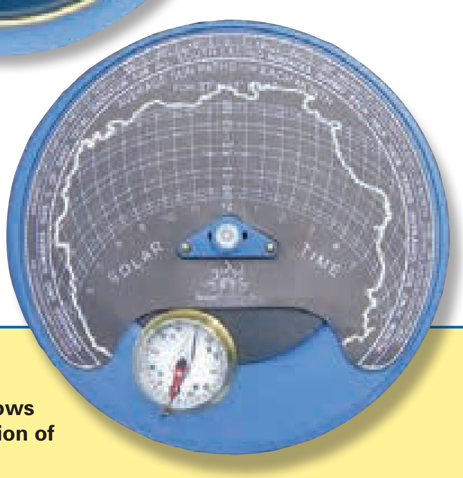
Solar Site Analysis Tools

Predicting shading throughout the year from various obstructions—such as tall trees, nearby buildings, roof dormers, and even chimneys—can be challenging if done

Solar Pathfinder

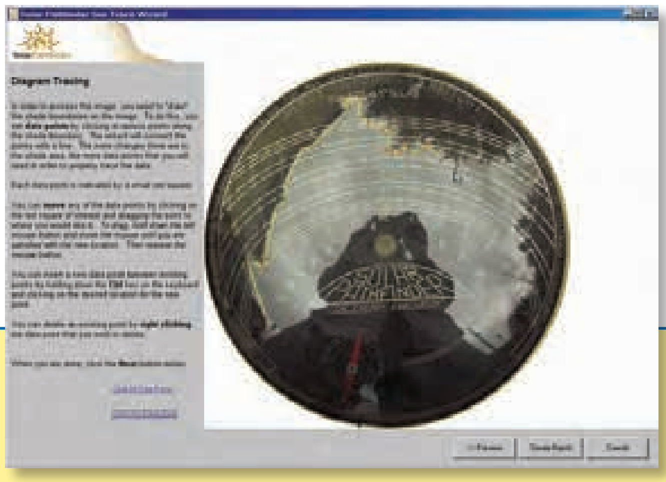


Solar Pathfinder's dome reflects the horizon over a sun-path diagram.



A horizon line sketched onto the sun-path diagram allows for manual computation of solar exposure.

A digital photo of the Pathfinder's dome can be imported into the Assistant software to produce shade analysis reports.



by sight alone, requiring many observations over the course of the year. But several tools, including the Solar Pathfinder, the Acme Solar Site Evaluation Tool, and the SunEye, can help you quickly assess shading on your site throughout the year—with one site visit. Although these tools differ in technique and price, all will get the job done. All require that they be used at a proposed array location to evaluate it.


Courtesy www.namastesolar.com

Architectural details, such as shed dormers and chimneys, can create shade during certain times of the day and reduce a PV system's production.

Solar Pathfinder ($299; with case and tripod) • www.solarpathfinder.com

With its easy-to-tote case and simple instructions, the Solar Pathfinder has been a common solar site analysis tool since the late 1970s. It uses a clear plastic dome over a sun-path diagram to show surrounding obstructions. This device is first oriented and leveled, then users can take a digital photograph of the setup for use in the software program, or trace the superimposed reflections onto the black chart with a white pencil, which reveals which months and times of day objects may shade the array (see photos, opposite page).

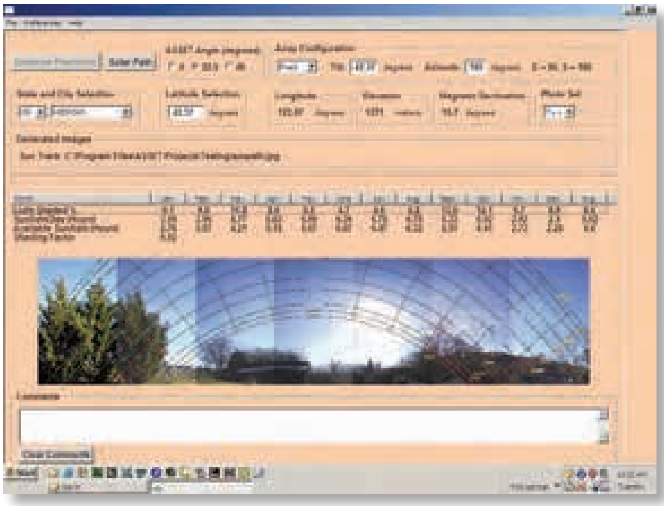
Sun-path charts for different latitudes are available, and each chart includes solar data to show the percentage of sunlight available for each hour of each month. The Solar Pathfinder Assistant software is used with digital photos of Pathfinder readings to generate detailed shading analysis reports ($139; Windows only—Apple computers require running a Windows emulator such as Parallels Desktop for Mac). The Solar Pathfinder Web site hosts several helpful videos on setup, performing a shade analysis, and using the software.

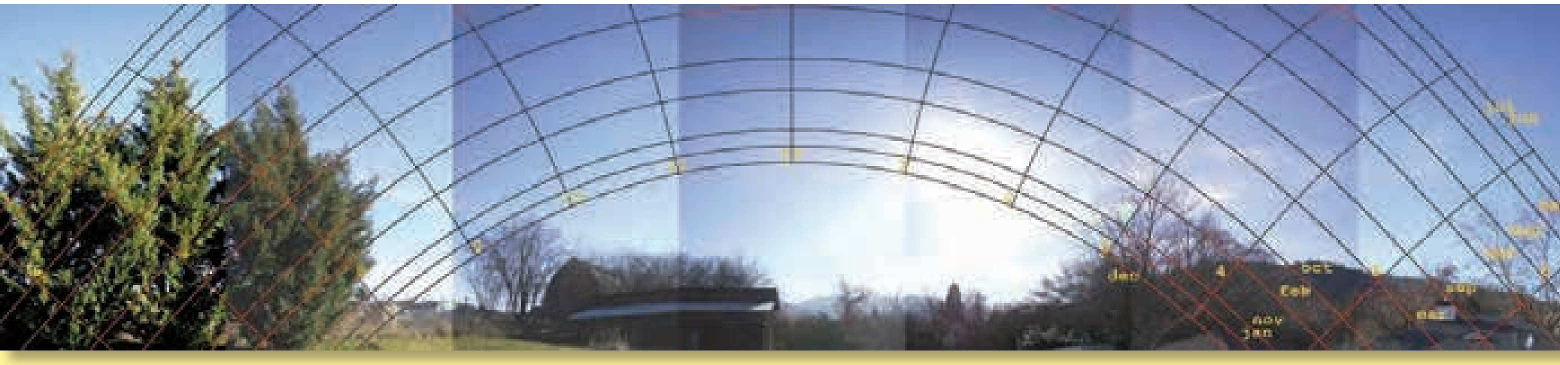
Acme Solar Site Evaluation Tool

Left: The ASSET makes quick work of shooting a panorama of photographs.

Below: A single panoramic image stitched together from the site photos and overlaid with a sun path.

Right: Yearly solar data and shading factor are calculated by ASSET's software.


Courtesy www.we-llc.com (3)



Wiley Electronics Acme Solar Site Evaluation Tool (ASSET) ($599; includes camera, positioning hardware, software, and case) • www.we-llc.com

The ASSET uses software and a digital camera mounted to an adjustable base that's fitted with a compass. Users level and orient the camera on its specialized mount and take several photos (at set sequential azimuth angles). Photos are downloaded onto a computer, where the accompanying software "stitches" them together in a panoramic view from the perspective of the proposed array location. A sun-path diagram is superimposed over the photo, showing obstructions that may pose a shading threat. Once you have entered your particular "project preferences" (including state and city, camera angle, array configuration, etc.), the software calculates "shading factor data," reported as the percentage of light shaded for each month and an overall "shading factor" for the location. Just like the Pathfinder, the ASSET can easily be set up in several locations so you can compare your options and find the best location for your array.

Solmetric SunEye ($1,495; includes software, case, and AC battery charger) • www.solmetric.com

The SunEye is a handheld solar site analysis tool that integrates a fish-eye lens, digital camera, touch-screen interface, and software. This device captures whole-horizon images for a site and generates shading analysis reports on the touch screen for instantaneous feedback. When taking a measurement, you first select your state and nearest city, orient and level the device, and then snap your picture. The touch screen can report the percentage of annual sunlight available and summer versus winter sunlight, along with monthly averages. Reports can also be transferred to a PC via the included USB cable and software package (Apple computers require a Windows emulator). A GPS add-on ($295) can obtain latitude and longitude coordinates (±3 meters) for more accurate sun-path calculations.

Courtesy www.solmetric.com

The Solmetric SunEye uses a fish-eye lens to shoot a 360° photo.

Bypassing Shade

In PV modules, diodes—semiconductors that allow current to flow only in one direction—provide a path for electrons to bypass a shaded section of a module. The more bypass diodes, the better the shade mitigation.

While some flexible thin-film modules incorporate bypass diodes on every cell, standard rigid crystalline PV modules typically provide only one bypass diode per 18 or more cells, since bypass diodes can only be wired in the module junction box. (Note: Even modules that come prewired with "quick connects" have small junction boxes that house these diodes.) For example, a 36-cell module will typically have only two bypass diodes. Each diode is wired across 18 cells, essentially isolating one-half of the module. In this case, one completely shaded cell would cause 50% of that module's output to be lost. With a 48-cell module that has three diodes, one shaded cell would cause a loss of only 33% of the output.

If shading happens to more than one cell, the impact will depend on how much shading occurs and where it occurs. If several cells in each section of the PV module are shaded, then pathways for the electricity for that module are shut down and the module is disabled. (For more information, see "Bypass Diodes" in *HP107*.)

All three tools include bubble levels and compasses, as they must be leveled and aligned to true south (or north in the Southern Hemisphere) before each measurement. Measurements must be obtained exactly where the array may be placed. For instance, if you are considering a rooftop-mounted array, measurements must be taken from the roof. If it's a pole-mounted array you're after, you'll need to take your measurements from a ladder or scaffold set up at the array's proposed height. Take readings at each corner of the proposed array location, and at the top and bottom to assess the solar window over the entire area. You may find that the lower portion of the array would be shaded due to objects on the horizon, or that architectural details (overhangs, dormers) or overhanging foliage creates shading problems on the upper portion of the array.

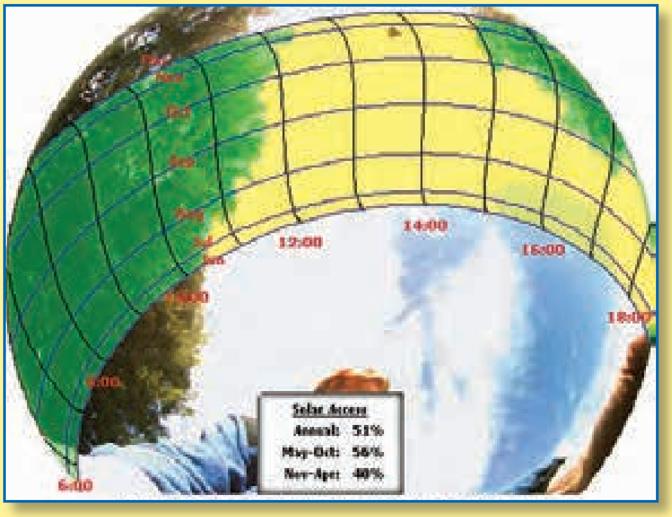
Shading Solutions

You've spotted potential shading in the prime solar window on your property. What now, get out the chain saw? You may have options to either locate the array away from the shaded area or move (or remove) the obstruction. If shading will hit the lower part of your array, you may be able to move the array further up the roof or, with a ground-mounted system,

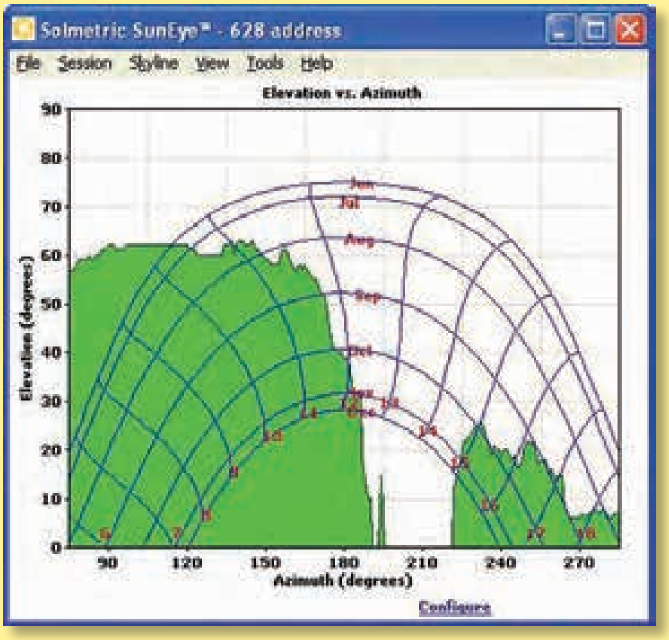
(continued on page 50)

Site Survey with the SunEye

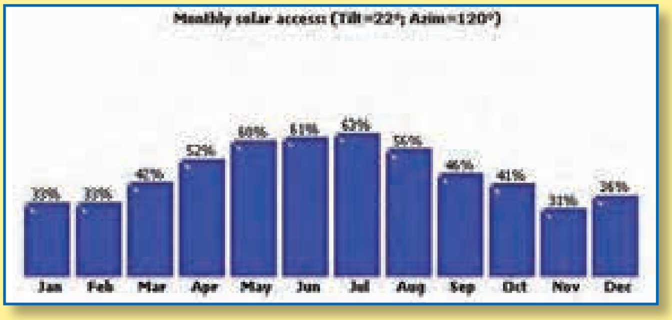
Unfavorable Site



The sun path imposed over the photo reveals excessive shading at this site, especially during the winter months.

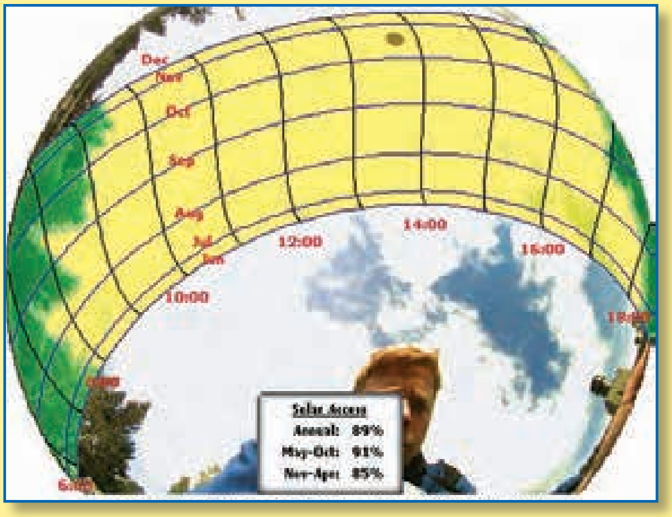


Another screen plots shading obstructions against a sun-path diagram, accurately showing the available solar window.

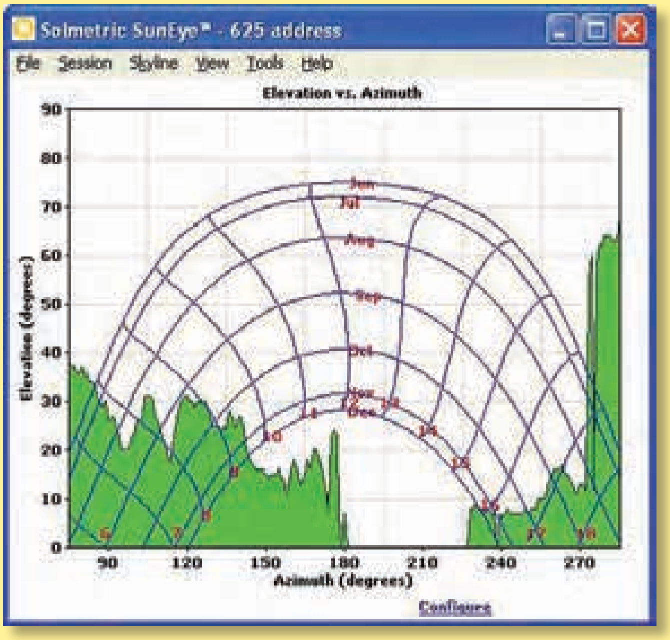


Users can toggle to another screen to see monthly solar access shown by a percentage.

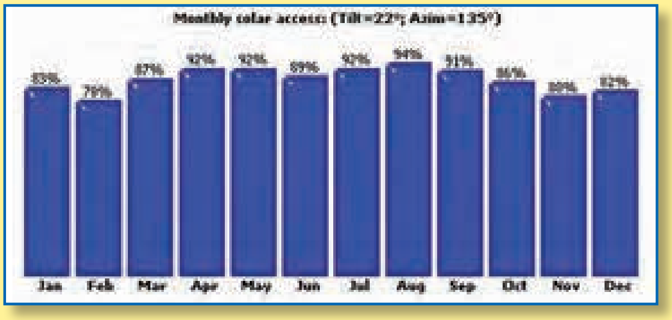
Favorable Site



Even in the winter, this site experiences full solar exposure from midmorning to late afternoon.



This chart reflects that a favorable solar window occurs at this site during most months of the year.



The graphs reaffirm what could be seen in the top images but with empirical detail.

Courtesy www.solmetric.com (6)

elevate it. You also may want to consider a pole mount. If the eastern side of the array is threatened by shade, perhaps you can locate the array more westward. If trees or bushes are shading culprits, consider trimming (or transplanting) them.

In some cases, reaching for your chain saw can cause other problems. Well-placed trees, like those on the west side of homes, can provide much-needed shade during the summer months—removing them can increase the cooling load on the home and increase demands on your air conditioner or fans. This might negate the increase in energy from the PV array that you gained by cutting down the shading offender. Also, remember that trees and bushes grow, so consider future growth (and shading effects) in your array siting and yard maintenance plans.

The software programs for the Solar Pathfinder, ASSET and SunEye can all simulate the effect that removing or adding an object has on your system—for example, how a solar window could be improved by trimming a tree or how much sunlight would be lost if that proposed power shed is constructed too close to your ground-mounted PV array.

If You Can't Escape the Shade

Partial shade and reduced power production affect different systems in different ways. In a stand-alone (off-grid) PV system, even minimal shading can have a big impact. Since shading reduces energy production, this may necessitate more careful load management (reducing energy consumed) or, if a generator is used, increased run-time (and the associated fuel consumption, pollution, and maintenance). If shade affects your PV system's winter production, perhaps a hybrid PV-wind or PV-hydro system could be a solution.

For a grid-tied PV system, partial shading is not as critical—it will merely reduce the amount of utility power the system offsets. All of the mentioned site analysis tools can estimate energy loss due to shade. Because it is important to create realistic energy estimates, these losses should be factored into the amount of projected annual energy production for a grid-tied system. In some cases, you may be able increase the array size to offset the losses due to partial shading.

Given the knowledge and tools to perform a proper solar site analysis, PV system designers can ensure that their systems will not suffer needless energy reduction due to shade. PV systems are substantial financial investments and can only produce electricity if they have sunlight to work with, so it makes sense to make sure they are properly placed to maximize your green energy and your wallet power.

Access

Justine Sanchez (justine.sanchez@homepower.com) is a NABCEP-certified PV installer, *Home Power* Technical Editor, and Solar Energy International instructor. Justine lives, works, and teaches from an on-grid, PV-powered home in Paonia, Colorado.


INVERTER EVOLUTION
2002
Parallel
Stackable
2006
120/240VAC
Split Phase
2009
Apollo Solar
Delivers...
Parallel Stackable, Split Phase,
2200 to 3600 VA, True Sine Wave
Off-Grid Inverter/Charger
ADDITIONAL SYSTEM OPTIONS...
Easy to Install
Switchgear Module
Local and Internet
Monitoring
Our Integrated
Solar Power Center
APOLLO
SOLAR
See Our
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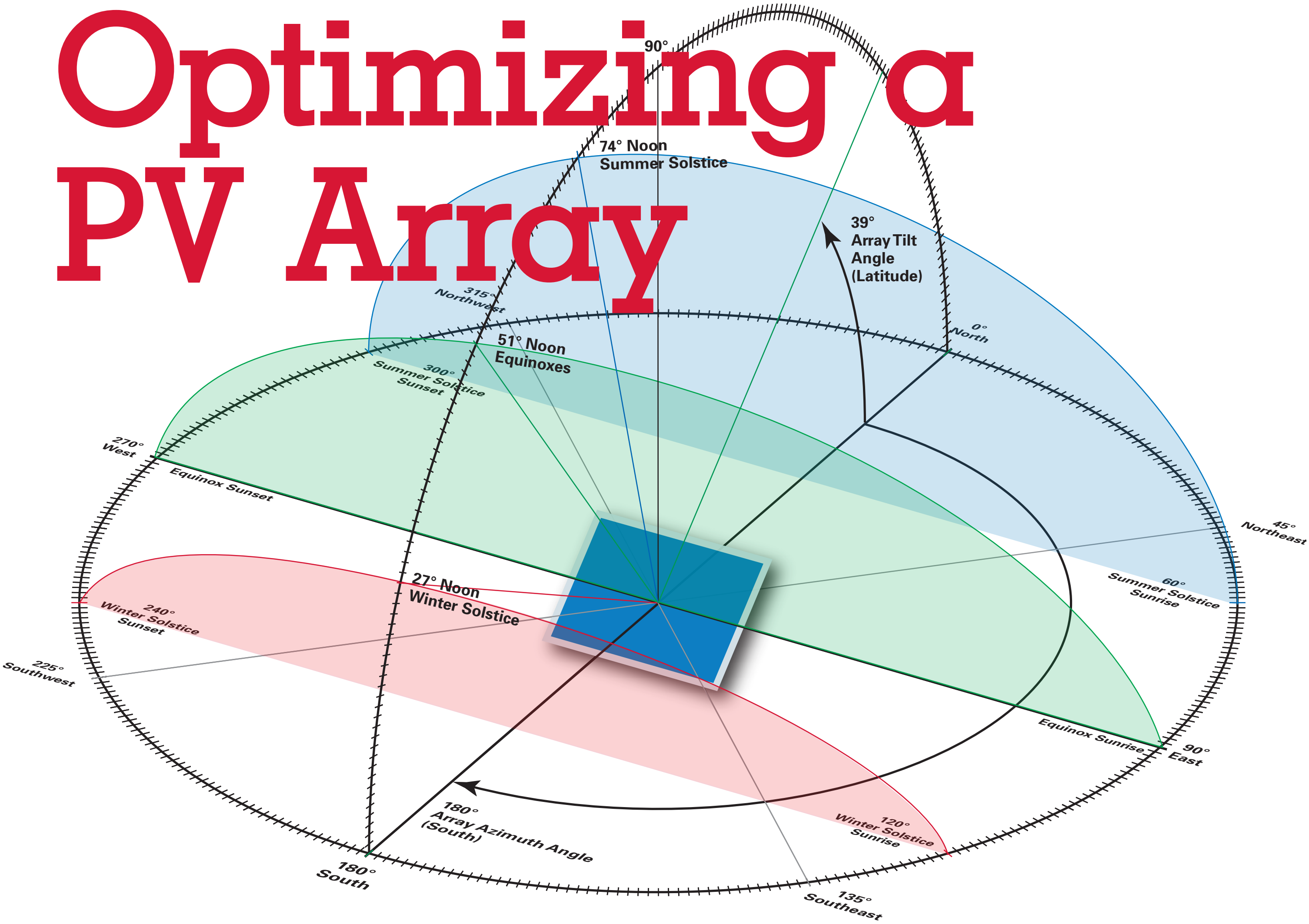
203.790.6400

Optimizing a PV Array



with Orientation & Tilt

by David Del Vecchio

"Just stick 'em in the sunshine, buddy," a coarse voice jabbed at me from the window of the second floor. Years later, I recall those words and chuckle. It must have been quite amusing for that carpenter to watch me methodically roam the grounds in search of the optimal site for the photovoltaic array.

Installing modules in a sunny, shade-free spot and pointing them toward the sun could be considered common sense to many, but properly orienting and tilting your array for optimal performance is not as intuitive. A PV array's output is proportional to the direct sunlight it receives. Even though PV modules produce some energy in a shady location or without ideal orientation, system costs are high enough that most will want to maximize energy yield.

Orientation: Beach Bum Lessons

Sun-worshippers working on their tans will orient their bodies to the sun for the most "exposure," changing their body position to coordinate with the sun's changing position. The lesson for PV arrays is that orienting directly toward the sun results in capturing the most energy—maximum power comes when they're perpendicular to the sun's rays.

Trace the sun through the sky and you'll notice two things changing. Throughout the day, its elevation (angle to the horizon) changes, rising to reach its maximum height at "solar" noon. And its sweep from east to west also changes as the day progresses, depending on the latitude. At high northern latitudes in the summer months, for example, it may rise in the northeast and set in the northwest. The angle it sweeps is known as the "azimuth" angle. Both the elevation and azimuth angle change with the seasons.

Most PV systems are mounted on racks in a fixed position, usually on a rooftop, and don't have the capability to follow (track) the sun throughout the day. Considering this, the best

Courtesy www.seesolar.com

In lower latitudes, PV arrays with shallow tilt angles capture more of the sun's energy.

Courtesy www.namastesolar.com

In higher latitudes, steeper tilt angles catch the low-angled sun and help the array shed snow more easily.

orientation in the Northern Hemisphere is usually due south. However, there are site-specific exceptions to the rule. For example, if your site consistently has fog or clouds at one end of the day, then favoring an orientation away from these times may result in better production from your array.

Correct Your Compass

Before you use your compass to site an array, you must correct for your site's declination error. In the Northern Hemisphere, a compass needle aligns itself along the *magnetic* north-south line. A PV array should be oriented to "true" or "solar" south ("geographic" south), so you'll need to account for magnetic declination—the angular difference between true and magnetic north. The main cause for this discrepancy is the Earth's non-uniform, conductive, fluid outer core that consists mainly of iron and nickel. This layer pushes your compass needle off of true north. Depending upon your location on the planet, the "push" varies in strength and direction. (See *HP120*, "Finding True South the Easy Way.")

The National Oceanic and Atmospheric Administration (NOAA) maintains a Web site that gives up-to-date magnetic declination values for the United States (see Access). Input your zip code in the form, and it provides your current magnetic declination. For example, in Port Angeles, Washington, the angle of magnetic declination is 17.5° east.

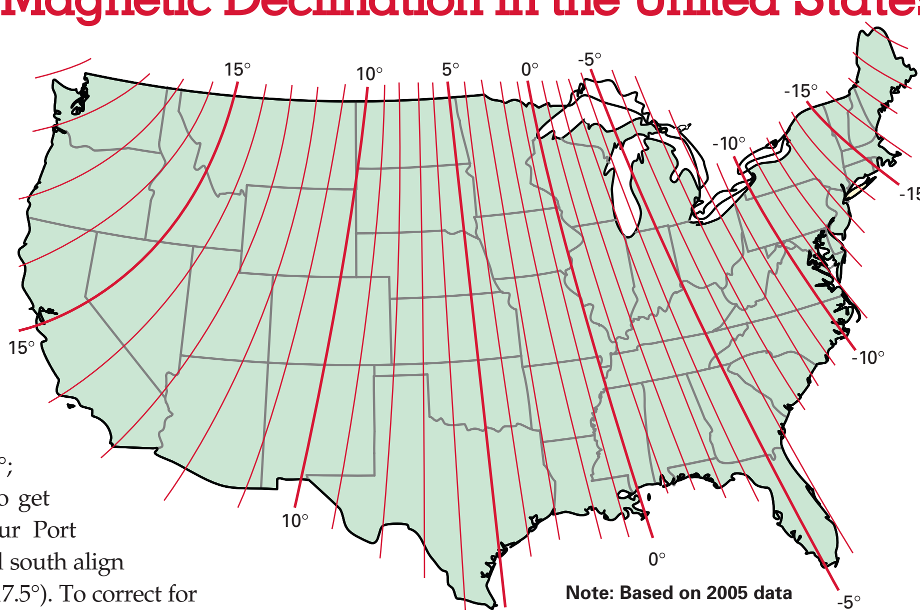
Accounting for declination is fairly straightforward using a compass: If your magnetic declination is *east*, then you *subtract* your declination from the magnetic north (0°; 360°) and magnetic south (180°) readings to get your "true" directional readings. Using our Port Angeles declination of 17.5°E, true north and south align with 342.5° (360° – 17.5°) and 162.5° (180° – 17.5°). To correct for a *west* declination, *add* the declination to 0° (360°) and 180° to get your true directions.

Tilt, Latitude & Altitude

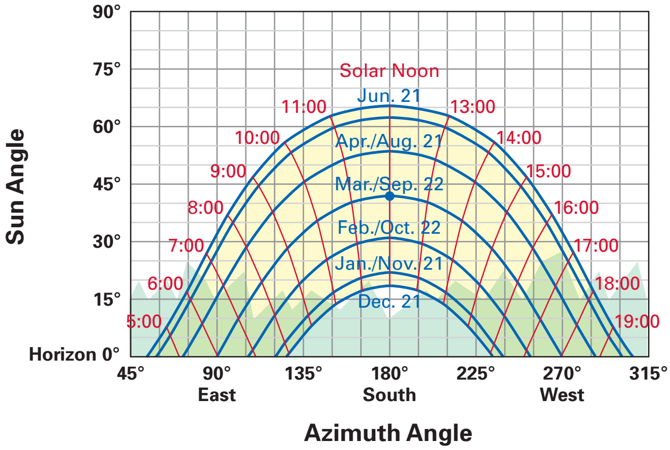
With solar south determined, the next step is to find the optimum tilt for the array. Because a PV module performs best when its surface is perpendicular to the sun's rays, considering the sun's elevation in the sky is important.

In the Northern Hemisphere, the sun rises to its greatest height at noon on the summer solstice (about June 21). It sinks to its lowest angle at noon on the winter solstice

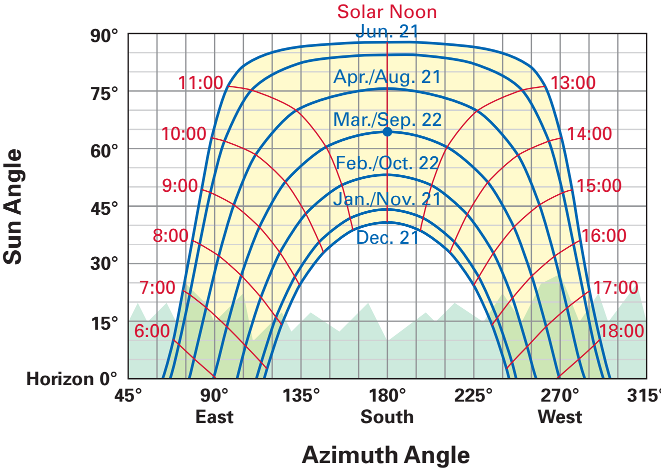
Magnetic Declination in the United States



Sun Paths for Seattle & Miami



Seattle, WA: Latitude 48°; Longitude -122°



Miami, FL: Latitude 26°; Longitude -80°

(about December 21). These elevations vary depending on your location's latitude. In Seattle, Washington, which sits at 47°36'N latitude, the solar-noon elevations span from 19° in winter to 66° in summer. In Miami, Florida, which has a latitude of 26°N, these angles span from 41° to 88°.

Typically, fixed (non-adjustable) PV arrays should be tilted toward the sun's "average" elevation—equal to the latitude of the array's location—to capture the most year-round solar energy. For example, I live at about 36°N latitude. Generally, to produce the most energy over an entire year at my location, a fixed array should be oriented to true south and set at a tilt of 36° from the ground.

With an adjustable-tilt rack—and the willingness to do the chore—an array's output can be increased by 5% or more.

Courtesy www.habi-tek.com

Again, local weather conditions may require special considerations. Very cloudy winters coupled with very clear summers will push the ideal PV tilt to shallower angles. Where snowy winters predominate, a steeper angle may be best for the modules to shed snow. Be sure to pay attention to your local weather patterns.

Another option is an adjustable mount, which can be ground-, pole-, or roof-mounted. The standard adjustment is to add 15° to the location's latitude for the winter tilt angle and subtract 15° from the latitude to arrive at the summer tilt. Adjusting twice a year on the spring and fall equinoxes can increase production by about 5%—with quarterly adjustments, a little more can be gained. In the winter, especially, these few extra kilowatt-hours can be crucial to an off-grid home, but most on-grid system owners choose the simplicity of a fixed array.

Dealing with Roof Pitch & Orientation

Most homes are not perfectly oriented for a roof-mounted PV array, but that shouldn't dissuade your plans to have solar-generated electricity.

For roofs that do not face south, one option is to rotate the PV rack to orient the modules south. This maximizes energy production—but by how much and at what visual cost? An oddly racked PV array is unacceptable to some people

Array Tilt & Azimuth: Effects on Efficiency

	Parallel to Roof (Flush-Mounted)	Optimal (Tilted at Latitude)
Azimuth angle	210° (Southeasterly)	180° (True South)
Array tilt	18° (4:12 pitch)	35°
Annual production (kWh)	1,468	1,550
% of optimal production	94.7%	100%

Source: PVWatts; based on 1 kW array in Amarillo, Texas

Tracked or Fixed?

PV racks fall into two main categories: fixed (nontracking) and tracking. Without any moving parts to fail, a fixed rack is steadfastly reliable, but lacks the capability to keep the modules perpendicular to the sun throughout the day. Trackers follow the sun's position from horizon to horizon. However, the tracker's moving parts require maintenance, and add parts to the system that can fail, decreasing reliability.

A single-axis tracker follows the sun from east to west, but does not automatically follow the sun's elevation, though the mounts can be adjusted seasonally. Dual-axis tracking keeps the array pointed right at the sun throughout the day, without human intervention. Dual-axis tracking can increase array output as much as 40% compared to a fixed array (see "Array Tracking & Energy Production," below).

Tracked systems can significantly increase energy production if the site has no shading. Trackers can really pay off when the east and west horizons have minimal blocking (from trees, buildings, or mountains) or if midday weather is often cloudy. They work great for array-direct pumping where water is needed all day. But with the considerations of added cost and a minor decrease in reliability, many system owners choose a fixed rack. If, for the same output, the cost of adding more PV modules is less than or equal to the added cost of a tracker, then it is almost always better to go with a fixed array.

Array Tracking & Energy Production

Location	Fixed Mount (kWh/Year)	Dual-Axis Tracked (kWh/Year)	% Increase
Sacramento, CA	2,799	3,909	39.7%
Jacksonville, FL	2,571	3,372	31.2%
Newark, NJ	2,366	3,073	29.9%

Source: PVWatts; 2.0 kW array

Courtesy www.habi-tek.com

In the right situation, a tracker can increase array production significantly.

for aesthetic reasons, and may even be disallowed in some communities with homeowner's associations or architectural review boards. While an east- or west-facing array usually won't produce as much energy as a south-facing one, the losses are often less than expected. An array oriented 30° off of true south will typically suffer less than a 5% reduction in production compared to one oriented to true south.

While the best annual performance generally comes from a PV array that's mounted at a tilt equal to your location's latitude, your roof pitch may not match this parameter. Don't worry—an array tilted 15° off from your latitude will still produce 95% of the energy from an array tilted at latitude. For aesthetics and to reduce wind loads, the vast majority of residential roof-mounted PV arrays are installed parallel to the roof plane.

Compare the energy production of the two different racking scenarios for a 1 kW PV array in the "Array Tilt & Azimuth: Effects on Efficiency" table on the opposite page.

Effects of Orientation on PV Production

	East		Southeast		South		Southwest		West	
Array Tilt	Annual kWh	% of Optimum	Annual kWh	% of Optimum	Annual kWh	% of Optimum	Annual kWh	% of Optimum	Annual kWh	% of Optimum
51°	1,121	72.3%	1,398	90.2%	1,495	96.5%	1,373	88.6%	1,085	70.0%
35°	1,228	79.2%	1,466	94.6%	1,550	100.0%	1,444	93.2%	1,197	77.2%
21°	1,293	83.4%	1,458	94.1%	1,517	97.9%	1,444	93.2%	1,272	82.1%

Source: PVWatts, 1 kW array, Amarillo, TX (35°N latitude)

Subarrays at multiple orientations and tilts need special treatment, ideally independent MPPT inverters or charge controllers.

In this scenario, optimal orientation would translate into a more costly and awkward mounting system that will squeeze out only a few more kilowatt-hours per year. Again, slightly increasing the array size with the flush-mount option could make up for these minor losses.

Other Considerations

Many contemporary homes sport complex roof designs with multiple, pitched roof sections of varying sizes, dimensions, and orientations that can present a complex challenge to PV system designers.

A good design practice is to plan for using only about 80% of the area on any particular roof section, leaving enough space around the array for safe access. You may have two adequately sized roof sections with acceptable exposure that face southeast and southwest, and you need both of these sections to accommodate the size of the planned PV array. Ensure adequate solar exposure by checking for shadows from the rooflines, chimney, or HVAC equipment with your solar siting tool of choice (see Access).

Multiple Orientations & MPPT. Most residential grid-tied inverters have only one maximum power point tracker (MPPT) incorporated into their design. A MPPT constantly sweeps the array output to fine-tune its power algorithm, resulting in the maximum power output from the PV array. Modules experiencing the same environmental conditions, i.e., mounted on the same roof surface, can use a single MPPT. But PV modules on separate roof surfaces, whether at different orientations or tilts, experience slightly different environmental conditions and, therefore, different maximum power points. The best performance would come from maximum power point tracking for each PV orientation, either by using multiple inverters or a single inverter with multiple MPPT capability.

Time-of-Use Metering. Typically, utility companies use a constant rate to charge a customer for each kWh consumed: A kWh consumed at 3 p.m. costs the same as a kWh consumed at 8 a.m. However, a growing number of utilities are offering time-of-use (TOU) metering systems that charge different rates based on when electricity is used. Rates are highest during peak hours (typically weekday afternoons) and lowest during nonpeak hours (early mornings and weekends). With net metering under TOU, any energy put back into the grid during peak times is counted at the higher rate—up to three times the value of off-peak electricity.

If you can optimize your grid-tied PV array performance to generate the most electricity during peak rate periods, you'll reap a bigger payoff and help out the utility grid when it needs it most. Examining various orientation scenarios within the context of a net-metering grid interconnection (PV electricity and utility electricity is valued at the same rate) can be a valuable exercise before you site your array. Utility peak times and rates typically vary with the seasons. Before you make a decision about orienting your system to favor TOU metering, check your utility's rates carefully.

Orientation, array tilt, seasonal adjustments, and array siting can all affect the bottom line. Proper planning and smart design will help you get the most out of your PV system and improve your rate of return.

Access

David Del Vecchio (david@solarvillage.com), a mechanical engineer from Georgia Tech, began designing and installing PV systems in 1998 in North Carolina. He's a NABCEP-certified PV installer and owns Solar Seed, a consult/design business. David also teaches PV courses for Solar Energy International, the North Carolina Solar Center, and Central Carolina Community College.

NOAA • www.ngdc.noaa.gov/geomagmodels/Declination.jsp • Magnetic declination calculator

http://solardat.uoregon.edu/index.html • Sun-path diagram calculator

http://www.srrb.noaa.gov/highlights/sunrise/azel.html • Solar position calculator

PVWatts • http://rredc.nrel.gov/solar/codes_algs/PVWATTS • Solar energy calculator

Solar Siting Tools:

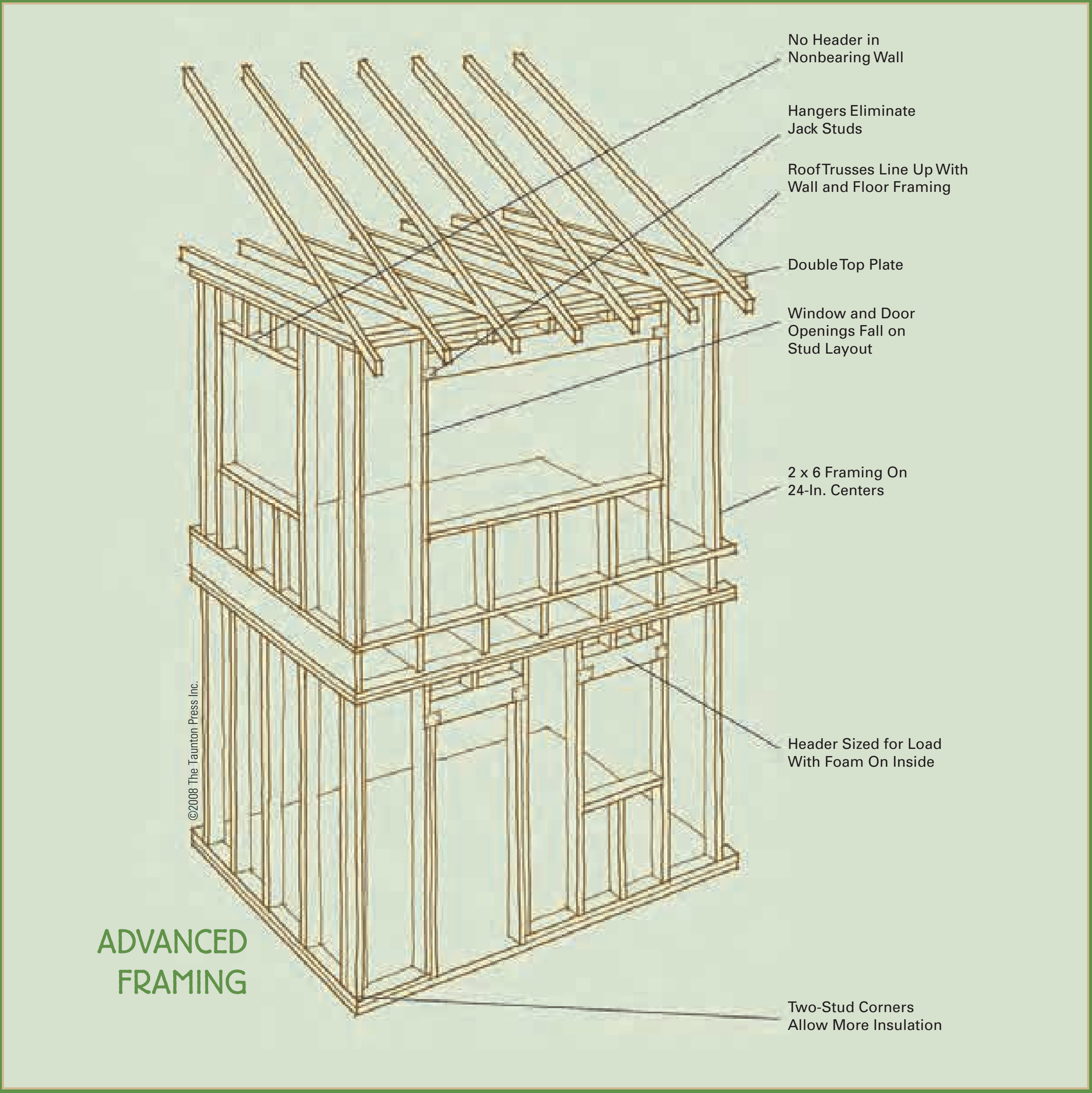
Solar Pathfinder • www.solarpathfinder.com

Solmetric • www.solmetric.com • SunEye

Wiley Electronics LLC • www.we-llc.com • ASSET

green FRAMING OPTIONS

by David Johnston & Scott Gibson



A tremendous diversity of materials, techniques, and traditions have gone into building a home's framework. Some approaches, like rammed earth, adobe, and straw-bale construction, are now well-established—if still unusual—alternatives to more mainstream techniques. Other materials are newer: blocks of aerated concrete, structural insulated panels that combine polystyrene or urethane foam insulation in a sandwich of oriented strand board, and hollow blocks formed with a mixture of cement and recycled polystyrene or wood fiber.

These materials all have their advocates, and they all have something to offer "green" building. But with the exception of structural insulated panels (SIPs), many of these products can be difficult to obtain or they require techniques unfamiliar to most contractors. For most residential builders in the United States, wood reigns supreme. So how can we build better and use this resource wisely?

Improving on Conventional Framing

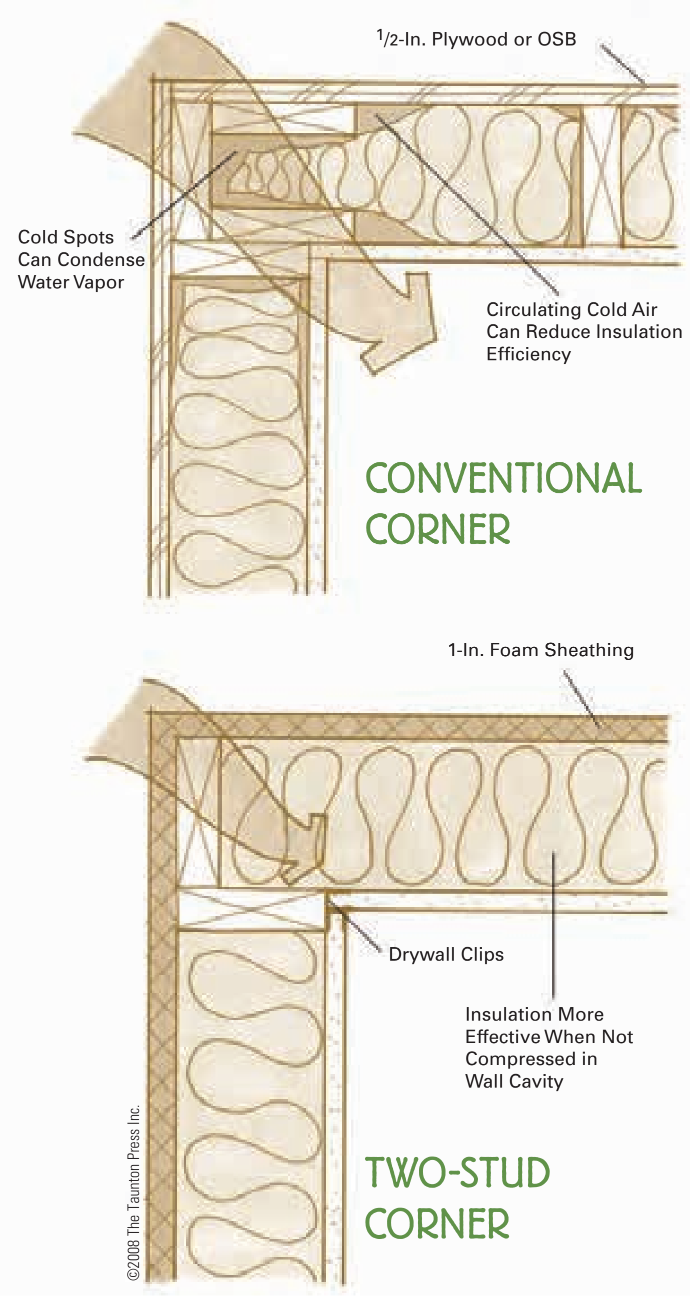
Wood is one of the best-suited renewable materials used in construction. It has low embodied energy, natural durability, high strength, and low toxicity (when untreated). Ninety-five percent of single-family houses built in the United States today are "stick-framed" with dimensional lumber.

Many conventionally framed houses share a common problem that affects their "greenness." There is often too much framing—oversized headers, too many studs placed too close together, and framing that gets in the way of insulation. Call it habit, tradition, or insurance on the part of the builder—the bottom line is that these and other wasteful practices make building envelopes more expensive and less efficient than they could be.

In the late 1970s, during an energy crisis that was likely a practice run for what's to come, the National Association of Home Builders' Research Foundation conducted studies to identify what structural configuration was necessary to maintain superior strength and yet allow the maximum insulation in wall cavities to improve energy efficiency. The result was called optimal value engineering (OVE). Research showed that as much as 20% of the framing material used in traditional construction could be removed without compromising structural integrity. Today, OVE is just referred to as advanced framing.

Advanced framing has two main benefits. First, it eliminates framing members that serve no structural purpose, thereby reducing waste and unnecessary cost. Second, it leaves more room for insulation and reduces cold spots from thermal bridging, making the house more comfortable and less expensive to heat and cool. Here are some of the basics:

- Walls are framed with 2 by 6s on 24-inch centers rather than 2 by 4s on 16-inch centers to increase insulation depth and reduce thermal bridging.
- Corners are made from two studs rather than four to allow more room for insulation and to reduce thermal bridging.



Wasted lumber adds up in unnecessary framing around door and window openings. Much of this lumber serves no practical purpose and makes the building less energy efficient, costs more, and takes more labor.

- Headers are sized according to the load they actually carry, not to conform with arbitrary guesswork or building traditions.
- Roofs are built with trusses rather than conventional framing, reducing the amount of lumber that's needed.
- Floors are framed with I-joists rather than sawn lumber, making stiffer floors that use less material.
- Insulating sheathing replaces conventional plywood or oriented strand board, reducing thermal bridging and making the house cheaper to heat and cool.

We Have Tree Farms, Not Forests

Wood has attractive advantages as a building material, but the stupendous volume of material that goes into residential construction creates a variety of interrelated problems. Homebuilding consumes about 45% of the total lumber used yearly. This year, new residential home projects are predicted to consume 9.5 billion board feet.

One of the biggest controversies in the world of green building is how trees are forested. More than 95% of the original forests in the United States have been razed. Yet, according to the American Forest and Paper Association, there are more trees in the United States now than there were when the Pilgrims landed in Massachusetts nearly 400 years ago. On the surface, that seems like a good thing, but once we dig deeper into the issue, our views may be more tempered.

During the expansion of European–American culture, forests seemed endless and empires were built on what could be harvested. Replanting was unnecessary because there were so many trees yet to cut. As the resource became more depleted, tree farming became a good business practice and tree plantations began springing up across the country. Today, most "forests" are actually tree plantations.

It is only when we visit the tiny pockets of remaining ancient forests that we realize what a profound difference there is between a tree plantation and a natural forest ecology. It takes hundreds of years for a forest to regain its complex interconnections of life-forms and the inherent stability that goes along with them. Clear-cutting a forest only to replant with a single species destroys the forest ecosystem.

Lost habitat decimates natural animal populations. Because they are artificial environments with a lack of natural diversity, tree farms are not places where people want to backpack, hike, or fish. So people flock to our overrun national parks, now so overcrowded they are barely managing the flood of people looking for a glimpse of the real thing.

Reduce Waste & Use Certified Wood

As concerns have mounted over how forests are managed, a number of programs have popped up to certify that lumber harvesting is causing no long-term damage to either the environment or the people who live nearby.

Lumber certified by the Forest Stewardship Council meets standards designed to protect the forest and the people who live there. The standards were adopted internationally in the mid-1990s and include strict requirements for how timber is harvested, how much can be cut, and how the forest ecology is to be protected. The program also mitigates problems when indigenous people are affected by lumber harvesting. FSC relies on a "chain of custody," to track wood from the forest to the point of sale. Each forest, mill, distributor, and retailer must be certified to preserve the integrity of the lumber's sustainability.

FSC protects existing forests from conversion to single-species tree farms, and ensures that the lumber you are buying is sustainably harvested.

Courtesy Forest Stewardship Council

FSC-certified lumber relies on a chain of custody that tracks lumber from the forest to the point of sale.

Clear-cutting forests to create tree farms can wipe out entire ecosystems.

Courtesy What's Working

IMPROVING ON CONVENTIONAL FRAMING

There are good methods to improve frames made the conventional way: that is, from 2 by 4s on 16-inch centers. Building Science Corp. found that wrapping the frame of a house with rigid foam insulation increased the overall R-value of the walls and reduced heat loss.

Some builders have switched from 2-by-4 to 2-by-6 construction because it makes deeper stud cavities for thicker insulation. If you're using fiberglass batt insulation, the nominal R-value jumps from R-13 (R-15 for high-density batts) to R-19 (R-21 for high-density). But spacing 2-by-6 framing on 16-inch instead of 24-inch centers creates structural overkill. Spacing the larger studs farther apart adds room for insulation and decreases thermal bridging.

Courtesy Kelli Pousson

Wood I-joists are made mostly from waste wood products and produce flatter and stiffer floor systems that are not subject to the same warping and checking as solid lumber.

In all, there are more than 50 different forest certification systems in the world, each claiming to monitor a certain amount of acreage. Others in North America include the Sustainable Forestry Initiative (135 million acres), the logging industry's American Tree Farm System (3.15 million acres), and the Canadian Standards Association (170 million acres). A new program, the European Programme for the Endorsement of Forest Certification (PEFC), is being developed to compare systematically all the certification programs globally so there is a common reference for wood procurement. The number and variety of these programs can be confusing. But the programs are at least a step in the right direction, and the benefits of specifying FSC-certified lumber will continue to make new converts among home builders.

Engineered Lumber Makes Sense

Using engineered lumber, which uses chips and small pieces of solid wood glued or laminated together, is another way to make sure that wood resources are not wasted—and engineered products often result in a better house. Once the exclusive domain of commercial buildings and high-end houses, engineered lumber is now commonplace in conventional construction. Two things make this family of products green: engineered products use wood fiber more efficiently than solid sawn lumber, reducing waste; and they can be made from wood species that quickly regenerate themselves.

For example, I-joists are made partly of wood chips and use only half the fiber to perform the same structural function as solid timber. And they do the job better, with longer allowable spans than solid timber of the same width. In addition, they can be made from aspen or other species that regenerate: These trees are really the fruit that springs from an underground root system, undamaged when a tree is harvested.

Finger-jointed studs and glue-lams are another type of engineered lumber. Both are made from solid pieces of defect-free wood glued together to make larger pieces. Finger-jointed

Shawn Schreiner

Glue-lams are one type of engineered beam that can be used in place of solid material. They are straight, stable, and strong.

Courtesy What's Working

Finger-jointed studs are embraced by carpenters because they are predictably straight, eliminating a host of problems associated with warped dimensional lumber.

HIDDEN LAKE STUDY

In 2004, Pulte Homes, one of the largest home builders in the country, conducted a study on advanced framing at its Hidden Lake development in Tracy, California. Pulte built test homes to determine how much money advanced framing would save in construction and to study its effect on heating and cooling costs. The work was supported by the U.S. Department of Energy and the California Energy Commission. The per-home results were impressive:

- Using 2-by-6 wall framing on 24-inch centers cost $1,632 versus $2,749 for a conventionally framed house with 2-by-4 studs on 16-inch centers—a 40% savings in material costs.
- Advanced framing saved a total of 738 studs, amounting to more than 2,100 board feet of lumber.
- Energy costs in the advanced-framing house were a total of $710 (both heating and cooling) a year, compared with $1,003 per year for the conventionally 2-by-4 framed house.
- Whole-wall R-values jumped from 9.4 to 15.2 by switching to advanced framing.

studs have an important advantage over sawn lumber in that they are straight right from the factory—and do not warp afterward. Conventional studs are milled from fast-growing farm trees, famous for twisting, splitting, warping, and checking, making it increasingly difficult to frame a straight wall, which can cause all kinds of problems down the line.

Glue-lams are 2 by 4s or 2 by 6s that are glued together face-to-face to create a beam. Laminated veneer lumber is like plywood but in the dimensions of beams. Parallel laminated lumber is made from long strips of trees that are glued together lengthwise to create beams stronger than the tree itself. These replace large-dimension timbers used for long spans—over a garage door, for instance. Increasingly popular, they save old-growth trees and do the job better, stay straighter, and are typically less expensive.

All engineered wood uses a binder to hold the wood or wood fibers together, which can affect indoor air quality. For instance, urea-formaldehyde is a water-soluble glue that is used for indoor products such as particleboard and medium-density fiberboard. The binder off-gasses (releases) formaldehyde for up to five years and is a major contributor to poor indoor air quality. Phenolic resin off-gasses a mere 4% of the formaldehyde that urea does.

Timber-Frame Construction

In timber-framing, or post-and-beam construction, carpenters become craftspeople, using mortise and tenon and dovetail joints, with wood pegs holding the large pieces of wood firmly together.

Timber-framing provides the structure for the building, and insulation is then added between the posts. SIPs, straw bales, and more conventional insulation can be used to seal the envelope. One advantage is that the frame can be erected quickly to get the building under cover and the infill added once the weather protection is in place.

Since big timbers are the cornerstone for this construction technique, one of the important considerations is where the wood comes from. Timbers should be chosen with care—local FSC certified, salvaged, or milled from standing dead trees are the best choices. Otherwise, there is the possibility that the large-dimension lumber has been taken from old-growth stands and/or clear-cuts.

Another issue is the amount of wood that goes into a timber-frame house. There's a lot of it, certainly more than would be used for a conventionally framed house or one that makes significant use of engineered lumber. Because a key element of green building is an efficient use of materials, there is a sustainability argument to be made that timber-framing is inherently a worse choice than a house built with advanced framing techniques.

Structural Insulated Panels

SIPs are a sandwich of insulating foam and oriented strand board that can be used for floors, walls, and roofs. SIPs are a green building product on every level. They combine insulation and structure in a single product. Houses built with SIPs are efficient, comfortable, and have virtually no air infiltration. Heating and cooling costs are typically half or less of a conventionally built and framed house.

With SIPs, some initial cost savings come from rapid enclosure of the envelope, especially when building in cold weather. Once the frame is up, you can work in an insulated space—and that means jackets come off and productivity goes up. When the job is finished, you have an airtight, highly insulated envelope that also helps cut noise inside. Moisture and mold issues inside wall cavities are thwarted because these units are completely sealed.

Structural insulated panels sandwich foam insulation between two skins of oriented strand board, combining insulation and structure in a single component.

Courtesy What's Working


Courtesy Ecofutures Building

Electrical wiring for switches and receptacles is run through wire chases built into these SIPs.

However, observe several cautions when building with SIPs. First, make sure to protect the oriented strand board on the faces of the panels from water. The OSB gives the panels structural strength. If it gets wet and stays wet, it loses its integrity. Once they're up, careful flashing is also key.

The second issue is running electrical cable. SIPs are made with channels in the foam to accommodate wiring. When ordering, it is imperative to provide an electrical plan so the manufacturer knows where to run these chases. Plumbing should never be run in an exterior wall, so typically there are no chases provided for that purpose.

There also is a concern that insects may burrow into the foam. According to the Structural Insulated Panel Association (SIPA), termites won't feed on the foam core but they may nest there. As a result, manufacturers offer borate-treated panels and the SIPA suggests termites can also be discouraged by a steel mesh barrier placed around the perimeter of the house and at foundation penetrations.

Rigid foam insulation is a vital component of structural insulated panels, and some people wonder whether using a petroleum-based product like that can really be green. The amount of oil used to make insulating foam (which is primarily air) is very small. Compared to the energy used in a home over its lifetime, the small amount of petroleum used in its construction is miniscule. If formaldehyde is a concern, ask the SIPs supplier whether the skins can be made from formaldehyde-free OSB.

The combined thermal mass and insulation of these fiber-cement blocks (below and far right) can offer high performance in building efficiency.


Courtesy www.faswall.com

Alternatives to Wood

Autoclaved aerated concrete (AAC) blocks take the place of a number of components used in standard stick-frame construction, replacing wood, insulation, house wrap, and drywall. The result is a house that's fireproof, mold-proof, insect-resistant, hypoallergenic, sound-absorptive, and engineered to withstand hurricanes and earthquakes.

Aluminum powder added to a mix of sand, lime, water, and cement creates a five-fold increase in volume while trapping insulating air bubbles. It's hardened in a mold and then processed in an autoclave to produce blocks in a variety of configurations. Blocks can be cut on-site with a specialized hand saw or band saw and laid up somewhat like conventional concrete block.

Walls made with AAC block have far less air infiltration than conventional 2-by-4 construction, with insulating values for the 8-inch-thick block as high as R-21.


Courtesy www.safecrete.com

Autoclaved aerated concrete (AAC) blocks replace the wood, insulation, house wrap, and drywall in a conventionally constructed home.


Courtesy www.durisolbuild.com

RETHINKING STEEL

Do steel framing members have a place in green construction? On the plus side, they can be made with recycled material, a central tenet of sustainable building. But steel has high embodied energy and is a very effective conductor of heat—just think of the handle of a cast-iron frying pan that's been on the stove for a while.

When steel framing is used to build exterior walls, all of the sheathing, windows, and door frames have to be fastened with screws. Inside, drywall is also attached to the framing with screws. Those thousands of fasteners increase thermal bridging that substantially circumvents insulation used in wall cavities and conducts heat in or out of the house depending on the season.

The Oak Ridge National Laboratory found that steel framing reduces the effectiveness of cavity insulation by 50% compared to its wood-framed counterpart. In 2-by-6 steel-framed construction, the cavity insulation of fiberglass batts nominally rated at R-19 provides an insulating value of only R-10. The only way around this is to attach a layer of rigid foam insulation to the outside of the building. Adding 2 inches of rigid foam insulation boosts the overall rating to R-20. But that's about what you get with 2-by-6 *wood* framing on 24-inch centers. The only advantage is that the rigid foam insulation blocks a potential thermal bridge that also affects wood framing, though less dramatically. But this incremental improvement in performance adds substantially to the cost of the wall and the labor required to build it.

Light-gauge steel framing is lighter and straighter than studs sawn from solid lumber. But when used on outside walls it creates thermal bridging and lower energy efficiency unless the wall is wrapped in rigid insulation.

Insulated concrete forms include Rastra, which is made mostly of recycled polystyrene with some cement to form a material the company calls "Thastyron." It's made into hollow-core blocks that are relatively lightweight, can be cut with ordinary handsaws, and glued into place. Once stacked into walls, the blocks are reinforced with steel and filled with concrete. The company reports that 10-inch-thick walls have an R-value of 36.

Fiber-cement blocks, such as Durisol or Faswall, are another option. These hollow-core blocks are made from mineralized wood shavings and Portland cement, stacked, and then filled with reinforcing steel and concrete. Manufacturers claim that the material is noncombustible, sound-absorptive, dimensionally stable, and boasts a 78% recycled content.

Products like these share many green benefits and give builders interested in exploring new avenues considerable leeway. They are not as widely available as wood building products and may make the most sense in areas with local or regional suppliers. One more consideration: There is a learning curve in working with new materials, but converts will tell you it's well worth it. These products may have a higher embodied energy than wood framing, due to their use of concrete and other manufactured materials, as well as shipping. But they typically offer higher energy efficiency than a conventionally built wood-framed structure by reducing air infiltration and increasing thermal mass and insulation.

Best Building Practices

Building better doesn't have to be difficult. Here are some tips to keep in mind:

- Use less lumber to perform the same function by adopting advanced framing techniques.
- Use engineered lumber in place of large-dimension sawn lumber.
- Demand FSC-certified lumber from your supplier.
- Use reclaimed lumber if it's available.
- Frame for the highest practical levels of insulation: The house should exceed energy standards by 50%.
- Avoid steel framing on exterior walls unless steps are taken to prevent thermal bridging. Completely avoid steel framing on exterior walls in areas of severe cold.
- Consider building with SIPs or an alternative product such as AAC to eliminate wall cavities, air infiltration, and mold risk.

Access

David Johnston's (david@greenbuilding.com) work in green building has been embraced by homeowners, building professionals, and sustainability advocates around the world. In 2007, he was named International Sustainability Pioneer by the European business community. Johnston's previous book, *Green Remodeling*, is a recognized guide to green remodeling.

Scott Gibson (scottgibson@securespeed.us) is a contributing editor to *Fine Homebuilding* magazine, and a freelance writer and editor.

This article was adapted from *Green from the Ground Up* (The Taunton Press, 2008).

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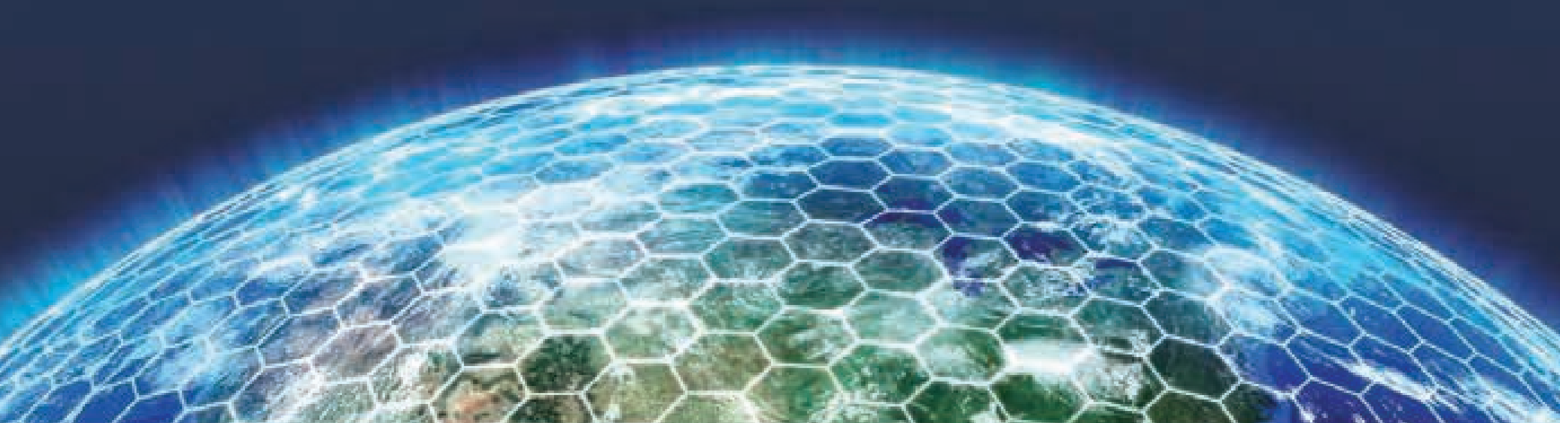

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Empowered RENOVATION

by Laura S. Richardson
photos by Gil & Laura Richardson

In mid-2007, my husband Gil and I decided to try our hand at "house flipping." We purchased a run-down, 108-year-old home desperately in need of renovation in Woodsville, New Hampshire—about 20 minutes from our off-grid, solar-powered home in the White Mountains. Unlike that of traditional flippers, our motivation was not windfall profits but rather a different kind of green: to demonstrate the value in making older homes more sustainable and energy efficient—while inspiring others to do the same.

Before and after the green remodel: The sun porch, with its numerous south-facing windows, provides some passive solar heating for the house and a building-integrated photovoltaic system offsets a portion of the home's electricity use.

Flipping is not for the faint-hearted. It takes a lot of effort—and capital investment risk—so doing some of the work yourself is the best way to save a few bucks and stay within budget. However, the flipping model we developed was not just about making some pretty upgrades and getting out fast. Gil and I wanted to do this project right, making it an energy-efficient, environmental showcase.

While this was our first renovation, we had some construction experience from building our small log cabin in 1997 (now our office). Plus, we designed and oversaw the construction of our superinsulated, off-grid home in 2001. But neither of us had all the skills to tackle this project single-handedly, so we recruited our friend Jean-Paul Downes, an experienced carpenter, to help with hands-on work. What Gil and I had to offer was our knowledge about energy efficiency, green building, and whole-systems thinking. Being dedicated energy misers, we had heard criticism that "normal" people couldn't live happily, comfortably, and inexpensively while using a lot less energy (and money). This project was in direct answer to that complaint.



The asbestos siding was professionally removed, exposing another hazard underneath—lead paint-encrusted clapboard. A layer of closed-cell foam was sprayed over the old siding, encapsulating the paint and improving the home's insulation.

Finding the Property

Woodsville epitomizes New Hampshire's image: an unpretentious, walkable, small town, with turn-of-the-century architecture. The state's "Live Free or Die" motto is evident here—no zoning ordinances, minimal building inspection, and a population (about 1,100) that prefers to mind its own business. All of this made it easier to execute our plan without too much paperwork or fuss.

Though Woodsville is far from progressive and hardly flourishing economically, we hoped to jump-start a green economy. More importantly, we hoped to demonstrate the benefits and feasibility of energy efficiency to the town's many working-class families that pay a lot to heat and power their older, inefficient homes.

Walkability is an important, and often overlooked, aspect of a sustainable lifestyle. The corner–lot New Englander that we found is only one block from the grocery store, elementary school, hardware store, and pharmacy, and an easy stroll to restaurants and other shops. Plus, a big-box department store is only three blocks away.

Though turning a profit was not a top priority, we certainly didn't set out to lose a lot of money in the process. As newcomers, we expected to exceed our budget, but we hoped to learn from this project so that future projects would turn a profit. Given the state of the house and the family-oriented neighborhood, the house was priced appropriately for its condition and fit into our price range.

As for the condition of the house, let's not sugarcoat it—the place was a wreck. Though the foundation and bones were solid, 108 years of hard living and homeowner renovations had taken its toll. Most people winced as they drove by the house and its unkempt yard—but not us. Seduced by the south-facing roof, the big sun porch for passive solar heating, the tin ceiling in the dining room, and other interesting architectural details, we convinced ourselves that the project was manageable.

Under Construction

We paid a lot of attention to the building envelope, working hard to ventilate where appropriate and seal up everything else. From day one, we made sure that our subcontractors knew to seal any holes they made. We liked to tell them, "You own the hole."

We started working on the project in earnest in October 2007 by having the exterior asbestos siding professionally removed, thus exposing the lead paint-encrusted original clapboard. All the windows were extricated and replaced. Then we screwed on furring strips (2 by 4s ripped in

To mitigate moisture problems, the basement crawl space floor was covered with a 6-mil poly vapor barrier. Walls were coated with spray foam insulation.

half) 16 inches on-center, and offset from the original wall studs to avoid thermal bridging. We had closed-cell spray foam applied into those bays. In addition to encapsulating the lead paint, the foam created an air barrier and an insulation of R-10 for the house's exterior walls. For several months, until we finished the siding, we "showed off" the insulation to the community. As autumn faded, we started installing a durable fiber-cement clapboard siding.

The next step was to reveal the interior wall structure to see what we were dealing with. Armed with respirator masks and eye protection, we gutted the half of the house that was in need of structural repairs—everything from the walls and ceilings to the bathroom fixtures and kitchen cabinets.

Layer upon layer of scabbed-on wall/ceiling/floor materials masked problems from earlier "renovations" and a plethora of treasures—including bees in the basement and ossified evidence of former canine residents. In the wall cavities, we discovered empty bottles originally holding cider and hard liquor, but barely any insulation—just a hodgepodge of rock wool, fiberglass, blown-in cellulose, and even crumpled newspaper in some sections.

After gutting half the house, we realized that there were two unique sections—one poorly insulated with fiberglass and other miscellany, the other completely without insulation. The somewhat-insulated section we gutted to the studs and reinsulated with closed-cell spray foam.

Not surprisingly, the oldest section of the house—the dining room, living room, formal entry, study, and the upstairs bedrooms—had no insulation behind the plaster-lath walls. Holes were drilled into the walls and open-cell spray foam was injected into the voids, creating an R-14 wall cavity. While the R-value of open-cell foam is less than closed-cell foam, we

The basement gets a new face: The original brick walls were coated with waterproofing paint. Frame walls were built and insulated with closed-cell foam insulation.

Spray Foam Insulation Comparison

Closed-Cell	Open-Cell
Highest insulating value per inch (>R-6)	Good insulation value per inch (R-3.5)
Low vapor permeability	Higher vapor permeability, but controlled
Air barrier	Air barrier at full wall thickness
Increases wall strength	Lower strength & rigidity
Resists water	Controlled moisture permeability
Medium density (1.75–2.25 lbs./ft.^{3})	Low density (0.4–1.2 lbs./ft.^{3})
Absorbs some sound, especially bass tones	Twice the sound absorption in normal noise frequency ranges
More expensive	Less expensive

Source: www.fomo.com

applauded ourselves for avoiding gutting that oldest section of the house, thus saving the existing plaster-lath walls. However, that plan proved somewhat counterproductive—pressure from the open-cell foam blew out a few of the weak spots and contorted a wall in places, which meant more work later to make those areas presentable. But the end result of this effort and the furred-out exterior was insulation values between R-21 and R-32 in the exterior walls throughout the house.

In the attic crawl spaces, Gil sealed all penetrations around the electrical boxes, plumbing, ductwork, light fixtures, and smoke detectors with polyurethane foam sealant. He ran a thick string from those buried items under the cellulose to the roof rafters and labeled them, making them easier to locate in the future. He also quadrupled the gable ventilation. We then blew in cellulose insulation, which boosted the R-value to more than 50.

In the usable basement area, we coated the brick foundation walls with waterproofing paint, and built a stud wall an inch out from them. We didn't want the studs to touch the brick foundation and act as a thermal bridge or absorb any moisture through capillary action. We sprayed closed-cell foam between and behind the studs, from 18 inches below grade (approximately the depth of the frost in our area) up to the top of the rim joists. All this effectively converted the once cold, creepy dungeon into a warmer and drier space. In the unusable basement crawl space area, Gil laid a 6-mil, poly vapor barrier over the dirt floor. This area also got a coating of spray foam on the walls, from the poly-covered floor to the top of the rim joists, creating a complete moisture barrier. This prevents moisture from entering the building and immediately reduced the musty smell.

New double-pane windows—fiberglass-clad to avoid expansion and contraction—finished off the envelope. The new windows are argon-filled with a low-emissivity (low-e) coating and a U-factor of 0.32, making the home more comfortable by reflecting the sun's heat in the summer while keeping more warmth inside the house in winter.

Upgrading the Systems

While the walls were open for insulating, we addressed heating, electrical, plumbing, and air-quality issues. The heating system was on its last leg, and the electrical wiring—with exposed, live wires in some places—was downright dangerous. The plumbing was corroded and failing, and we needed to mechanically exchange the air since the building was now quite airtight.

The heating system, a 40-plus-year-old oil-fired boiler that served the hydronic baseboard heaters throughout the house, was replaced with a Buderus GB142 propane-fired condensing boiler—a small unit that operates at 95% efficiency, according to its Energy Star tag. The boiler is equipped with an outdoor temperature setback sensor that determines how hot to make the water and six zones to optimize the baseboard heating. Our plumber replaced all of the old, battered baseboard radiators.

Next, our electricians brought everything up to code, pulling out knob-and-tube wiring and wooden conduit and upgrading the whole system, including hard-wired smoke detectors. Fragile and inefficient lighting was replaced with attractive, low-energy compact-fluorescent fixtures throughout.

Then came the plumbing. An old two-holer buried under the kitchen floor was a good indicator of what we were dealing with. A sign in the driveway reading "free" offered passers-by a lot of the still-functional but old and out-of-date accoutrements from the house. The battered kitchen sink was gone within an hour. Our plumber pulled out and sold the corroded copper piping and replumbed with PEX tubing.

Prior to insulating, this house had plenty of fresh air exchange, with expensively heated air escaping to the outside. The foam insulation helped stop air leakage, but also made the building tight. So while the wall cavities were still accessible, we installed a RenewAire energy recovery ventilator (ERV) to

Other Green Renovations

- Low VOC paints & sealants used throughout
- Wellborn formaldehyde-free cabinets
- American Clay finish on dining room walls
- Marmoleum (natural linoleum) on kitchen, bathroom & laundry room floors

Above: The energy recovery ventilator brings fresh air into the home with minimal heat loss.

Right: The plumber installs the new boiler that will feed the new hydronic baseboard heaters.

mechanically exchange the air in the house, transferring the heat from the outgoing air to the incoming air. Following the sizing guide from the manufacturer, Gil set the number of air exchanges per hour by the volume (cubic feet) of the home and the number of expected occupants.

We also sealed the ERV's rigid metal ductwork with a mastic sealant—a requirement of New Hampshire's energy code for new construction.

Going for Solar

Once we realized that there were four layers of asphalt shingles on the roof—two layers being the maximum allowed by the building code—we knew we had to remove all of the shingles before doing anything else. The nails used on the most recent layer didn't even penetrate the sheathing, creating some safety and weight issues. One dumpster was called in, then a second. The shingles were replaced with a new standing-seam roof by McElroy Metals made of 97% recycled steel and guaranteed for 50 years. Its pale green paint has a heat-reflective pigment to keep the roof (and attic) cooler.

From the start, we wanted to add both a solar-electric and a solar hot water system. But as each project took longer and costs mounted, we realized that we'd need to make some concessions. Instead of adding a solar hot water system, we compromised and set up the plumbing for the system by

Energy-efficient appliances, formaldehyde-free cabinets, a natural linoleum floor, and an additional south-facing window round out the kitchen improvements.

Clockwise from top: "Peel-and-stick" PV laminates are carefully applied on the new steel roofing pans. Installing the pans, just like any other steel roof. Modules are connected via wiring at the roof peak, which is covered with a ridge cap.

running copper pipes, electrical conduit, and electrical wire through interior walls from the appropriate roof section to the basement. It probably cost us less than $250 to do all that and will save a future homeowner thousands of dollars—and a lot of frustration.

When it came to solar-electric ambitions, we managed to make a big statement with a relatively small system. A grid-tied, batteryless 950-watt photovoltaic system—14 Uni-Solar PVL68 modules paired with a Sunny Boy inverter—made this home the first net-metered one in town. The "peel-and-stick" laminates allowed our PV installer—KW Management Inc.—to "roll out" and glue down the PV array without having to penetrate the roof.

Besides the minimal visual impact of this array compared to the rigid PV modules that must be attached to a racking system, another benefit of using the thin-film technology is that it performs better in diffused sunlight. Woodsville sits at the junction of three rivers, and the mornings are typically foggy, but even on cloudy days, the system makes some energy. The primary drawback to this amorphous silicon thin-film technology is that it takes about twice the surface area to produce the same amount of power as a standard crystalline PV array, so available roof space limits the PV array size.

Woodsville, serviced by its own municipal utility, Woodsville Water & Light, is not required to participate in the 1:1 net metering and other efficiency programs run by the larger utilities and overseen by the New Hampshire Public Utilities Commission. Having worked with the New Hampshire Sustainable Energy Association to improve legislative policy, I was well-versed in net metering and seized the opportunity to meet with town utility commissioners at one of their monthly public meetings. During a 15-minute casual presentation, I explained how net metering works and how it would be good for Woodsville—feeding electricity into the grid during peak-load periods when energy is typically more expensive, reducing wear-and-tear on their fragile transformers and feeding "free" energy into neighboring homes.

Low Energy, High Efficiency

The house's solar orientation and the spacious enclosed porch on the home's south face hinted that, even in 1900, builders understood the concepts of passive heat gain. The porch is a free-heat machine: Once it warms, we open the interior windows on the adjoining wall and gain free heat until mid-afternoon.

To further improve the home's passive-solar performance and daylighting, we added a south-facing window in the kitchen. The west side of house gets a lot of late afternoon sun, warming up the core of the house without cost. We removed a large, north-facing window to reduce heat loss.

An Energy Star dishwasher and refrigerator, compact fluorescent lighting, and switched outlets round out the energy-saving features. Dual-flush toilets and low-flow faucets will keep water usage low.

Renovation Costs

Item	Cost
Purchase & related costs	$114,747
Subcontracted carpentry & labor	63,755
Plumbing	27,725
Misc. building materials	24,747
Roofing	14,134
Interest on loan	11,289
Spray foam insulation	9,734
Asbestos & lead-paint remediation	8,375
Electric	8,345
PV system	7,814
Cabinets	7,388
Windows	6,429
Siding	4,310
Masonry	3,200
Flooring	3,048
Fuel hookups, installation, fuel & related labor	2,619
Rubbish removal	2,280
Paint	2,129
Appliances	2,077
Portable toilet rental	725
Woodsville Water & Light utilities	655
Energy-efficient products	390
Total	**$325,915**

Headway in New Hampshire

In 2008, Governor John Lynch signed HB1628 into law, giving a one-time incentive payment to residential RE-electric projects. Under the new law, photovoltaic, wind, and microhydro systems will qualify for $3 per watt or 50% of system costs, whichever is less, with a payment cap of $6,000. To qualify, systems must be operational after July 1, 2008, less than 5 kW in size, and located on the owner's property. The Public Utilities Commission is expected to begin distributing payments in July 2009 on a first-come, first-served basis. The fund is established by payments from utilities as an alternative to meeting the state's renewable energy portfolio laws.

Once we got the town's utility on board, the installation was fairly straightforward. The system fit nicely on a south-facing section of the new roof. It took only one day for our installer and roofer to adhere the PV laminates and install the roof pans, run the wiring and conduit, and install the inverter and disconnect. With little fanfare, the lineman from WW&L hooked up the new digital meter. By mid-afternoon, the system was producing pollution-free electricity.

Even though, at 950 W, the PV system is more a symbol than an big energy contributor, it produces 3 to 5 kWh a day, and helps make a connection between household energy consumed and energy generated.

Finished Flipping

From start to finish, the renovations took about nine months of focused effort falling only a few weeks behind schedule—but substantially over budget. All in all, the result was pretty much what we expected. Not bad for first-time flippers.

The finished product: A like-new house with all the old-time charm but none of the dirt, drafts, or danger. Though we decided not to formally pursue Energy Star or Leadership in Energy and Environmental Design (LEED) certification because of the expense, the time involved, and the logistical problems of certification in a remote town, we maintained high standards—meeting the requirements of both programs and surpassing New Hampshire energy code for insulation and air quality.

Thanks to the local buzz and advertising, more than 100 people turned out for the open house. They came to look at the systems and the renovation. They came to get ideas for their own projects, or simply to dream about living in a healthy and low-energy home. Unfortunately, none came prepared to write us a check for the down payment.

In fact, the timing for our first "flip" couldn't have been worse. The house went on the market at the onset of the housing-and-lending fiasco that's taken such a toll on the national economy. Under better circumstances, the renovated house would move fast. Instead of reducing the price, we've decided to rent the house until the economic situation turns.

But we have no regrets. We learned a lot from the experience, and more importantly, we educated others in the process. Not only did people in town marvel at the metamorphosis, our crew walked away with an appreciation for green building. Our carpenter, who came to the project with no green-building experience, is currently building a straw-bale house, and the local hardware stores, who were originally baffled by our numerous "special" requests, are now stocking some of the products we sought.

Access

Laura S. Richardson (laurarichardson@wildblue.net) is the project director for StayWarmNH (www.staywarmnh.org). She and her husband Gil own Empowered Homes LLC and Empowered Answers LLC (www.empoweredanswers.com), and cofounded the New Hampshire Sustainable Energy Association (www.nhsea.org). She, Gil, and their two kittens live off-grid in a PV-powered, wood-heated home in New Hampshire's White Mountains.

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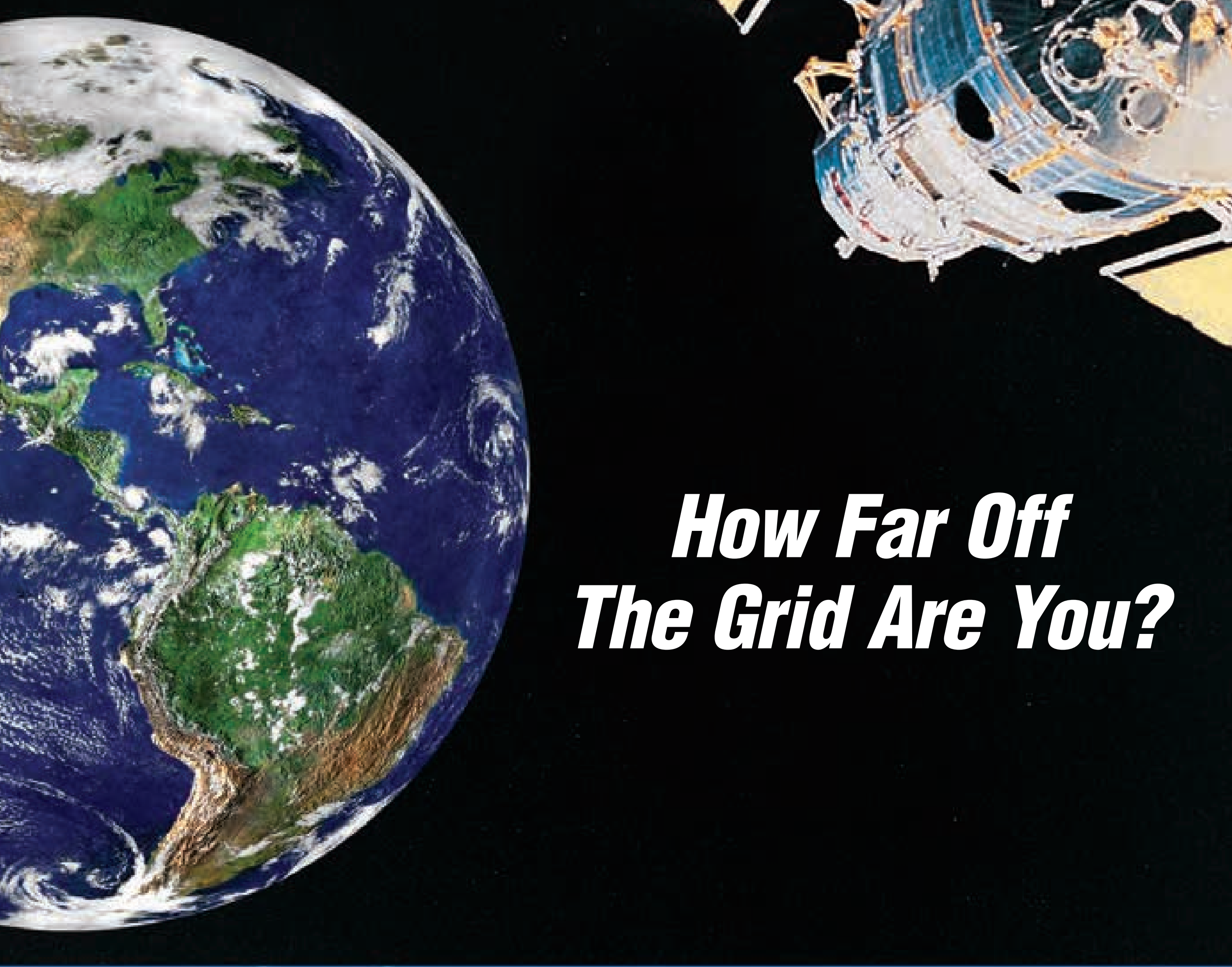

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Pitched Roof Mounting

by Rebekah Hren

One of the many beautiful things about photovoltaic technology is the ability to transform underutilized space—the residential roof—into a clean, renewable, local power production plant. Today's roof-mounting systems can make installations faster and more streamlined than before.

Courtesy www.ironridge.com

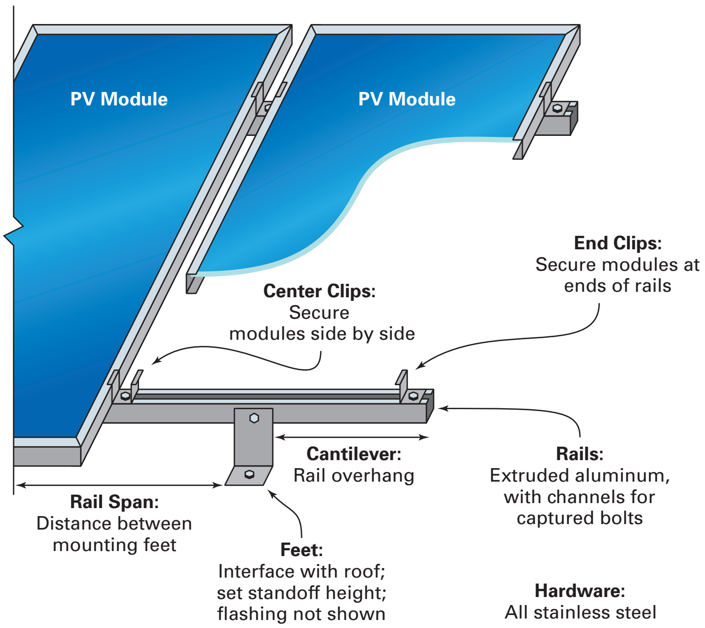
Whether because of limited ground space, better solar access with less shading from structures and trees, or lower installed cost, roofs are the default location for residential solar-electric systems. While the vagaries of residential construction lead to roofs of myriad shapes and sizes, most roofs are designed with a pitch (slope). For the PV system and installer, the pitch is important for ease of installation and for system efficiency, since modules produce greater power the more perpendicular they are to the sun's rays.

Manufacturers' mounting systems for pitched roofs tend to follow a top-down rail mounting scheme. Aluminum or stainless steel L-feet or standoff posts, usually lag-bolted into a rafter, support an aluminum rail at regular intervals. Two rails run under each row of PV modules, and the modules are secured to the rail by means of top-mounted clips. These are bolted down to the rail between modules, with one clip connecting the sides of two adjacent modules.

Parts & Pieces: Feet

Mount feet come in many varieties, and this is one of the places where great innovation has been happening in the industry. Examples include Quick Mount PV's Composition Mount, Thompson Technology's Flat Jack, and Direct Power & Water's

Typical Top-Down PV Mount



Courtesy www.ironridge.com

Courtesy www.unirac.com

Courtesy www.conergy.us

Almost all residential PV racks are "top-down," meaning modules are easily installed from above. Typical examples (from L to R): IronRidge, Unirac, and Conergy. All show foot, rail, and clip.

(DP&W) Easy Feet. The mount you choose to hold your rail depends on a few factors: roof type, climate characteristics, price, and personal preference.

L-feet are lag-screwed to rafters through the existing roofing layers and depend solely on sealant to remain watertight during the life of the roof. PV mounting manufacturers don't recommend a brand of sealant, but refer you to roofing manufacturers. While they are the fastest, least-expensive footing option, L-foot installations may void roof warranties when not flashed (see "Protecting the Roof with Flashing" sidebar). Some types of sealant are designed to work only with certain roofing materials—and will not work properly with others. Leaking mount feet may cause damage to the underlying roof structure, which could lead to mold problems and, in some cases, litigation. When in doubt, consult a professional roofer.

Flashed standoffs resist water infiltration more reliably than a sealed L-foot. Standoffs, or stanchions, are specialized bolts or posts with a solid base that is lag-screwed into the roof rafters. They are the best choice when working with a new roof installation where the decking is exposed and accessible. Roofers can flash around them just like any other vent pipe or duct as the roofing material is installed. Standoffs can also be retrofitted onto an existing roof, although this is a slightly more time-consuming process than using L-feet. Some newer standoffs, such as the Flat Jack and Quick Mount PV's Composition Mount, come with flashing integrated into the mount, and can be slid under existing asphalt shingles, shakes, and tiles. Other standoffs rely on roofing industry standards like Oatey flashings, which slide over the standoff post.

Direct Power & Water's Easy Feet are designed to hold to roof sheathing when rafters aren't available.

Courtesy www.directpower.com

Top-down technology and extruded rails make attaching feet, module clips, and even combiner boxes quick and easy.

Courtesy www.directpower.com

Protecting the Roof with Flashing

Flashing is commonly used around plumbing vents, chimneys, and other roofing joints to keep water from entering and damaging the roof structure. In PV installations, it's also used around roofing penetrations.

On composition roofs, a thin, rectangular piece of metal is typically used. One half is pushed up under a shingle, while the other half overlaps the shingle in the row beneath. For mounting standoffs, the metal sheet has a plastic collar, which fits tightly around the standoff, preventing water entry. Oatey is a manufacturer of flashings commonly used with various PV mounts.

Flashing metal roofs poses more challenges, as the roof metal must be uninstalled, cut, and then refit to allow for an overlap around the hole where the square of flashing can be inserted. Metal roofing specialists do offer flashings that don't require an overlap but instead use sealant to secure the flashing to the metal roof. In these cases, watertightness relies solely on sealant for the life of the system.


Courtesy www.directpower.com

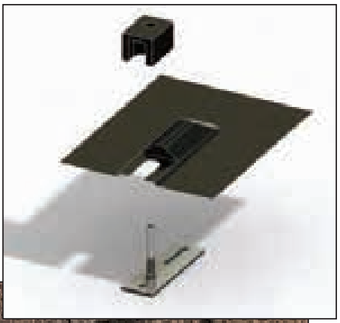
Oatey flashings provide a watertight seal for the mounting post.

With the exception of only a few products on the market, rail supports attach to rafters with stainless-steel lag screws. The screws must be sized based on uplift point loads and wood strength charts like those provided by the American Wood Council (see Access). Racking manufacturers should provide engineering recommendations. Exceptions to lagging into a rafter include the Easy Feet and SunPower's Smart Mount. Easy Feet come with butyl mastic backing and are held down with five screws, which are secured through the roofing material into the decking or sheathing. These are good options in cases where the rafters are inaccessible (as with standing-seam metal roofs, when rafters are inaccessibly located under a V), or when retrofitting a structural insulated panel (SIP) roof, which has no rafters. Note that Easy Feet depend on structurally sound roof decking and should not be used on roofs with compromised decking.

Parts & Pieces: Rails

Nearly every rail on the market is made of extruded aluminum. In the extrusion process, hot aluminum is pushed through a

Thompson Technology's Flat Jack mounting foot uses integrated flashing that slides up under shingles.




Courtesy www.thompsontec.com

Quick Mount PV's Composition Mount is also self-flashed. Shown (below) on a cedar shake roof.


Courtesy www.quickmountpv.com


Courtesy www.ironridge.com

Extruded aluminum rail is the backbone of a PV mount.

die to create the desired profile. Many manufacturers use anodizing, which creates a hard, nonreactive surface film to improve corrosion- and wear-resistance. Generally, an anodized rail retains its silver color , though other anodized rail colors (such as bronze for SunEarth's CompRail system) may be available. The other commonly available rail color is black, which usually means a protective powder coating has been applied. Powder coating is a dry coating that's cured under heat to form a "skin." It can create a hard finish tougher than conventional paint.

Some manufacturers sell both light and heavy rail. Heavy rail is thicker and stronger, and can span longer distances between supports and carry heavier loads. Light rail is considered adequate for the majority of residential pitched roofs. Rail can typically be ordered in lengths up to 27 feet, and splice kits are used to tie lengths together. Rail can run horizontally or vertically on a roof.

Spacing of rail supports, referred to as "rail span" or "foot spacing," depends upon rafter spacing (commonly 16 or 24 inches on center), manufacturer's recommendations, and loading estimates, such as dead load, wind load, and snow load (see "Dealing with the Forces of Nature," at right). Each manufacturer has its own recommendations for maximum recommended rail span wind speeds—some to 90 mph, some to 125 mph. Typically, rail span will vary between 48 and 96 inches when using light rail.

Dealing with the Forces of Nature

Loads from wind, snow, and the combined weight of the system components impact rail span and spacing and rail gauge, as well as roof design limits. If the mounting system isn't sized accordingly, strong winds can put additional uplift strain on your modules and mounts, causing damage to the system and roof structure. Similarly, the additional weight of snow on top of the modules can compromise a roof's integrity. If you're retrofitting a system to an existing roof, you'll need to consult with an engineer to make sure your roof is beefy enough to withstand the added array weight (the roof's "dead" load) and wind load. Similarly, if you're building a new house, you'll need to design the roof accordingly to accept the increased loads of the system.

Wind load (uplift and downlift pressure). Three factors are used to find down-force and uplift from wind pressure:

- Basic wind speed—found by consulting local wind maps or building code officials
- Effective wind area—the total continuous area of modules
- Roof zone—which section of a roof is utilized, whether interior, end, or corner.

These factors come together in an engineering formula or table that specifies down-force and uplift pressure in pounds per square foot according to the input factors. This pressure will then need to be adjusted for other factors, including topography (whether the building is in an urban area or windswept plain), height exposure category (based on building height), and importance factor (such as whether the building is a residence or hospital, for instance, and whether the building is in a hurricane region).

Snow load is the weight of the heaviest snow likely to occur in an area, calculated in pounds per square foot. Data is typically available from local building officials and code books.

Dead load is the additive weight of modules, and rail and racking components, calculated in pounds per square foot.

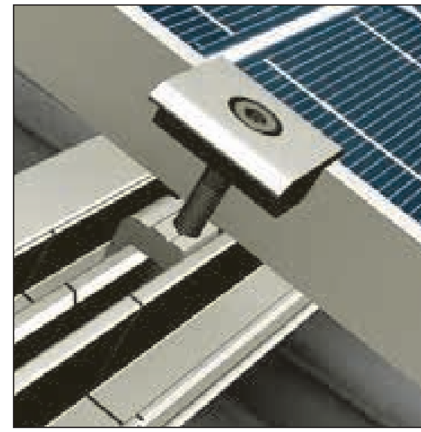
No Penetrations, No Problem

Metal Roof Innovations Ltd.'s S5! clamps don't require any roof penetrations, nor do they penetrate the seam of the roof, but clamp on by means of stainless steel setscrews. The clamps can be mounted from the side of the seam or from the top, and are available with various set-screw hole configurations and clamp profiles to suit variations in standing seams. Depending on the thickness of the metal, tightening specs vary for the setscrews: 115 inch-pounds (for 24-gauge metals) or 150 inch-pounds (for 22-gauge steel). Some S5! installations don't need rail, as the module frames are supported by the top platform of the S5! clamps, and mid- and/or end-clips are bolted directly to the clamp. Other installations use the S5! clamps to mount standard rails.


Courtesy www.s-5.com

S5! clamps are made for various standing-seam metal roofing, and can be used to mount rails or PV modules directly, as shown.

Another facet of rail span is the cantilever or rail overhang—the distance between the rail end and the first support. Manufacturer's instructions will vary: For example, Unirac recommends no more than 25% of module width as an acceptable overhang. DP&W's Power Rail allows an overhang of 32 inches for 125 mph wind load and 36 inches for 90 mph wind load. Of course, the spans and cantilever can be greater for heavy rail. Be sure to follow manufacturer's recommendations.



Though styles vary, almost all top-down systems feature stainless-steel captured bolts or nuts, and module clips.

Courtesy www.conergy.us

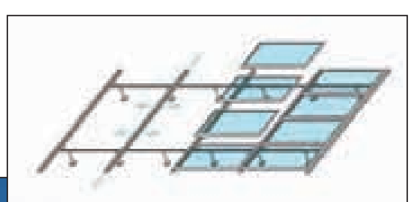
Parts & Pieces: Clips & Bolts

Clips secure the modules to the rail. Two types of clips are used in top-down mounting: **mid-clips**, which fit between modules, and **end-clips,** for the outside edge of the end modules. Clips are either aluminum or stainless steel, and may be powder-coated or anodized. Because modules come in a variety of thicknesses, the clip height must match the module frame height.

Clips are attached to rails with stainless steel bolts and nuts. There are a few basic styles, some with bolt heads that are secured (captive) within the rail. One, such as DP&W offers, uses an oval head bolt that must be slid into position from one end of the rail. (Watch out for rail splices, which can stop your bolt!) Another, such as used with Unirac's SolarMount, uses a T-head bolt, which can be placed in the rail at the appropriate spot, and then twisted to grip the inside of the rail. Care must be taken to make sure it engages properly. There are other approaches as well, such as Conergy's mounting system, which uses specialized nuts ("Quickstones") that can be slid down the channel and into position.

A few systems (such as SunEarth's CompRail and Unirac's SunFrame) forego mid- and end-clips. Instead, two rows of modules share a single, central rail between them. The modules sit on a shelf on either side of the rail, then are secured with a cap that bolts into the rail.

SunEarth's CompRail uses full-length channels instead of clips.



Courtesy www.sunearthinc.com (2)

Beyond Composition Roofs

PV mounts for tile or wood shakes are available from Quick Mount PV and Professional Solar Products. Quick Mount PV's mounts for curved or flat tile replace the tile itself, integrating the tile-shaped flashing and aluminum standoff into one bolt-together unit. The mount is attached to the decking with four $^{1}/_{4}$-inch-diameter lag screws. Professional Solar Products's Tile Trac takes a different approach by drilling, bolting, and sealing through the crown of the existing tile to the decking. The Tile Trac system lag-screws a metal track into the rafter, with a long bolt or standoff running up and through the crown of the sealed tile to hold the rail.

For installations on new seamless metal roofs, flashed standoffs can be used. However, retrofitting standoffs onto an existing roof is more challenging. On these roofs, securing a lag screw for an L-foot into a rafter can be difficult or impossible, as a raised metal V often lands over the rafter line and should not be squashed down by a mount. There are two possible solutions: adding spacers or sisters between the rafters to screw into or using a mount, such as DP&W's Easy Feet, screwed into the existing sheathing. Spacers are boards in an attic nailed between and perpendicular to two rafters, and held tightly against the roof decking's underside to provide a secure attachment point from above the roof. A sistered board is nailed against a rafter to extend the rafter's width.

The rare metal shingle roof or raised profile (shingle-appearance) metal roof should be approached with caution. Regular flashing might work with some smaller metal shingles, but others are in large sheets that resist attempts at flashing. L-feet won't usually work with this type of metal roof either, as the profile will get crimped. The best solutions are to mount standoffs and flashing during initial roofing or, for a retrofit, to remove the metal and reinstall after standoffs are placed.

Other Considerations

Adjustable Array Angle. Using adjustable legs beneath the rail to optimize the tilt of a roof-mounted array is becoming less common, since the production gained is moderate (usually 1% to 5% for fixed-tilt arrays), and most homeowners don't want to climb on the roof to make adjustments. Tilting an array can create a number of difficulties, including more complex wind loading, more hardware needed, more difficult installation, and a perceived lack of aesthetics. Using the National Renewable Energy Laboratory's PVWatts calculator (see Access) to model power production at different tilt angles can be a useful cost–benefit analysis tool (see "PV Performance at Different Pitches," below).

What is easily configurable in flush-mounted roof arrays on rails is the height of the modules above the roof. L-feet and standoffs can be purchased in varying heights. The taller the standoffs, the more airflow beneath the modules, which results in cooler modules and more power output. On the minus side, the farther an array is from the roof, the more it will stand out.

Grounding. Rail and modules must be grounded using UL- or ETL-listed equipment. Wiley Electronics' WEEB (washer, electrical equipment bond) and Unirac's grounding clips are listed to meet UL Standard 467. These clips lay in the rail between module corners, and are faster and less expensive to install than the old standby: the Ilsco lay-in lug. The Ilsco lug is made of tin-plated solid copper, with a stainless steel screw to hold the wire. It screws into the dedicated ground spot on the module frame, and requires a solid copper wire run from lug to lug. (For more on grounding, see *Code Corner* in *HP128* and *Independent Power Providers* in *HP121*.)

Quick Mount PV's Tile Mount is sized to replace an existing roof tile.

Courtesy www.quickmountpv.com

Pitched Roof Performance

Along with the growth in the solar industry have come many advances in PV installation methods. Manufacturers and engineers are trailblazing options that make installations more durable, dependable, and cost-effective. To uphold our part of the bargain as end users, we must install components correctly, and use them only for the jobs they are meant to do. Being part of a vibrant, burgeoning industry means taking responsibility to continually learn on the job and being flexible enough to adapt to improvements in methods when they come our way.

PV Performance at Different Pitches

How much impact does tilt have on a fixed grid-tied array? In Raleigh, North Carolina, on a roof with slope of 25° (a roof pitch between 5:12 and 6:12), a flush-mounted 3 kW array will produce about 3,916 kWh per year. The same size array tilted close to latitude (in this case, 35.9°) would produce about 3,937 kWh per year—a production difference of 21 kWh. Of course, if the array tilt was adjusted throughout the year, the production numbers would increase.

For example, a monthly adjustment to each month's optimum angle would result in 4,139 kWh per year. A quarterly adjustment to optimum tilt would result in 4,127 kWh per year, a 4.8% increase over the fixed-tilt array. Generally, only off-gridders who need to squeeze every winter watt-hour out of their systems are willing to go to these lengths, which can add up to 10% to their system's winter production.

	Array Tilt = 35.9° (Latitude)			Array Tilt = 25.0° (Roof Pitch)		
Month	Avg. Solar Radiation (kWh/m² /Day)	AC Energy (kWh)	Value ($)	Avg. Solar Radiation (kWh/m² /Day)	AC Energy (kWh)	Value ($)
January	3.73	265	$22.53	3.43	243	$20.66
February	4.66	298	25.33	4.40	281	23.89
March	5.38	368	31.28	5.28	362	30.77
April	5.77	372	31.62	5.89	381	32.38
May	5.55	357	30.34	5.83	376	31.96
June	5.77	354	30.09	6.15	378	32.13
July	5.54	352	29.92	5.86	373	31.71
August	5.58	353	30.00	5.77	365	31.03
September	5.35	333	28.30	5.34	333	28.30
October	5.33	354	30.09	5.07	338	28.73
November	4.34	287	24.39	4.01	265	22.53
December	3.51	245	20.82	3.19	222	18.87
Annual Total	5.04	3,937	$334.64	5.02	3,916	$332.86

Source: PVWatts for Raleigh, NC, 3 kW array (www.nrel.gov/rredc/pvwatts/)

Pitched Roof Mount Checklist

- ☐ Inspect roof and, if necessary, replace it prior to installation
- ☐ Use stainless steel and/or aluminum hardware (rails, supports, clips, etc.)
- ☐ Use flashing and/or appropriate sealing for every roof penetration
- ☐ If necessary, reinforce roof with spacers or sistered rafters
- ☐ Use stainless steel lag screws with sufficient rafter penetration for loading specifications
- ☐ Make sure rail supports (standoffs, L-feet, or S5! clamps) are appropriately spaced for all loading considerations
- ☐ Choose rail and module clip color to match module frames
- ☐ Make sure rail and modules are properly grounded (Wiley WEEB, Unirac UGC-1, or Ilsco lay-in)
- ☐ Make sure that all mid-clips and end-clips are tight and square, and the appropriate height for the module frame

Access

Rebekah Hren (rebekah@honeyelectricsolar.com) is a licensed electrician in North Carolina. She designs and installs PV systems with Honey Electric Solar Inc. teaches PV design and installation courses for Solar Energy International, and is coauthor of *The Carbon-Free Home: 36 Remodeling Projects to Help Kick the Fossil-Fuel Habit* (Chelsea Green, 2008).

Roof-Mounting System Manufacturers:

Conergy • www.conergy.us
Direct Power & Water • www.directpower.com
IronRidge • www.ironridge.com
Metal Roof Innovations Ltd. • www.s-5.com • Standing-seam roofs only
Professional Solar Products • www.prosolar.com
Quick Mount PV • www.quickmountpv.com • Flashed mounting anchors only
Shuco • www.schuco-usa.com
Solar Racks • www.solar-racks.com
SunEarth Inc. • www.sunearthinc.com • Compression-style rail only
Thompson Technology Industries • www.thompsontec.com
Unirac • www.unirac.com

Module-Specific Mounting Systems:

Sharp • www.sharpsolaritson.com
SunPower Corp. • www.sunpowercorp.com

Other Resources:

American Wood Council • www.awc.org • Wood-strength tables
PVWatts • www.nrel.gov/rredc/pvwatts/

2009 Energy Fairs

Spring and summer bring us renewal after a long winter—and what better time to renew your interest in energy? Renewable energy fairs offer the perfect opportunity to get the scoop on the latest gear, take advantage of educational workshops, and tap into local RE expertise in a casual, festive atmosphere. Most events are family-friendly, with activities to kindle young ones' interests in all things solar. Admission prices are friendly as well—for the cost of a night at the movies, you can get your solar start, have a great time with other like-minded folks, and maybe even walk away with sweet deals on renewable energy equipment.

April

▶ **North Country Sustainable Energy Fair**
Canton, New York; April 24–26
www.ncenergy.org

May

▶ **Northwest Solar & Clean Tech Expo**
Portland, Oregon; May 1–3
www.nwsolarexpo.com

June

▶ **Rhode Island Sustainable Living Festival & Clean Energy Expo**
Coventry, Rhode Island; June 6 & 7
www.livingfest.org

▶ **RE & Sustainable Living Fair (a.k.a. MREF) 20th Anniversary**
Custer, Wisconsin; June 19–21
www.the-mrea.org

▶ **Michigan Energy Fair**
Onekama, Michigan; June 26–28
www.glrea.org

Courtesy Tom Brown, www.the-mrea.org

Courtesy Jeremy Higgins, www.the-mrea.org

July

▶ **SolarFest**
Tinmouth, Vermont; July 10–12
www.solarfest.org

▶ **Shoreline Sustainable Living & RE Fair**
Shoreline, Washington; July 18
www.shorelinesolar.org

▶ **SolWest**
John Day, Oregon; July 24–26
www.solwest.org

August

▶ **Illinois RE & Sustainable Lifestyle Fair**
Oregon, Illinois; August 8 & 9
www.illinoisrenew.org

▶ **SolFest**
Hopland, California; August 8 & 9
www.solfest.org

▶ **Southern Energy & Environment Expo**
Fletcher, North Carolina; August 21–23
www.seeexpo.com

▶ **Crestone Energy Fair**
Crestone, Colorado; August 29 & 30
www.joinlas.com/cef/

September

▶ **Iowa Renewable Energy Expo**
Norway, Iowa; September 12 & 13
www.irenew.org

▶ **Rocky Mt. Sustainable Living Fair**
Fort Collins, Colorado; September 18–20
www.sustainablelivingfair.org

▶ **Pennsylvania RE & Sustainable Living Festival**
Kempton, Pennsylvania; September 18–20
www.paenergyfest.com

▶ **RE Roundup & Green Living Fair**
Fredericksburg, Texas; September 25–27
www.theroundup.org

▶ **Solar Fiesta**
Albuquerque, New Mexico;
September 26 & 27
www.nmsea.org

Courtesy Jennifer Barker, www.solwest.org

For the Pros & the Public

▶ **Solar 2009**
Buffalo, New York
May 12–16
www.solar2009.org

▶ **PV America**
Philadelphia, Pennsylvania
June 8–10
http://events.jspargo.com/seia09/public/enter.aspx

▶ **Intersolar North America**
San Francisco, California
July 14–16
www.intersolar.us

▶ **Solar Power 2009**
Anaheim, California
October 27–29
www.solarpowerconference.com

A Second Wind

The idea of generating electricity using the wind appeals to many, but the reality is that wind systems demand the most planning, labor, and maintenance of any home-scale renewable electricity system. Homeowners and installers don't always get it right the first time, and there are lessons to be learned when they don't.

by Ian Woofenden

In May 2001, Don and Bev Grim approached Randy Brooks of Brooks Solar—they were interested in a wind-electric system for their home in Peshastin, a small town in central Washington. They wanted to participate in the Sustainable Natural Alternative Power (SNAP) incentive program in the Chelan County Public Utility District service area, which would pay up to $1.50 per kilowatt-hour for green electricity.

Randy and his crew were familiar with SNAP after having installed a Bergey Excel wind turbine to help June and Charlie Nichols reap the program's benefits (see "Betting the Farm" in *HP96*). But Randy was relatively new to wind generator siting, and the available wind maps at the time were not terribly useful. He suggested to Don and Bev that they install a meteorological (met) tower to gather wind data, but they were not interested in the added expense ($5,000 to $15,000) or time required. Don and Bev were convinced that the site was windy, and Randy observed the topography and was inclined to agree.

The tower and turbine at its original site in Chelan County, Washington.

Ian Woofenden

Courtesy Randy Brooks (2)

Inset, top: The forms, rebar, and rebar supports. Inset, bottom: The finished tower footing.

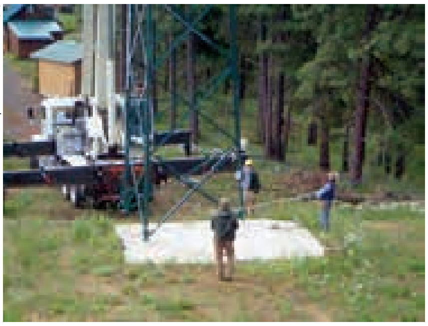
Courtesy Randy Brooks

The turbine was assembled on the tower, then lifted onto the base by a crane.

Off the Drawing Board

The wind installation moved from concept to project over the next few years, with the concrete footing poured in May 2002, and the 100-foot tower and Bergey Excel turbine installed in October 2002. Randy was joined by Bill Hoffer in prepping the site, and by his western Washington crew of Kelly Keilwitz, Rose Woofenden, and yours truly for the tower assembly and crane installation.

Courtesy Don Richmond (4)



Once it was confirmed that a lack of wind was the culprit causing low energy output, the system was disassembled and loaded onto a flatbed trailer for transport to a new site.

We left the Grims' home confident that we'd set them up with a productive system. The turbine went online and began to sell electricity to the Chelan County PUD, with a dedication ceremony in July attended by utility officials, local politicians, and other interested people from the area. Don and Bev received their first check for anticipated green tag earnings.

After helping with an installation, I always look forward to hearing from the contractor and homeowner about how the system is performing, but the first reports in this case were discouraging. After three months, only about 100 kWh had been produced. The full first year of data was even more disheartening: The Grims' turbine had only generated about 500 kWh, or an average of less than 1.4 kWh per day.

At first, we wondered if there was a performance issue with the turbine, and there had been some glitches with the inverter. But the anemometer that had been installed on the tower told of a more permanent problem. The average wind speed reported was very low—less than 6 mph in those first three months. We hoped that the initial period was an anomaly and that the overall average would be much higher. But after 15 months, our fears were confirmed by a wind-speed average of only 4.3 mph. According to the turbine manufacturer's projections, with an 8 mph average, the turbine would have produced about 3,000 kWh per year; a 12 mph average would have produced 11,000 kWh per year.

What happened? The owners' eagerness coupled with a lack of solid resource data led to a waste of time, effort, and 48 cubic yards of concrete in the ground, and about $55,000 spent. While external appearances and anecdotal observation seemed to indicate a good wind site, the reality of low wind speeds and poor turbine production proved otherwise.

Seven years later, the wind maps available are considerably better, and would likely have helped avoid this situation. The free mapping database from AWS Truewind (see Access) indicates a mean average of only 4.8 mph at a 60-meter (197 foot) height at the site—much lower than the 8 to 14 mph suggested for a viable system.

The truck, with tower and turbine ready for transport.

After almost four years, Don and Bev concluded that they had made a poor investment, and advertised the machine and tower for sale. The concrete weighs more than 70 tons, so reusing it in another location was out of the question, but Don and Bev hope to use it as a level surface for a future PV array.

Have Site, Need Turbine

In March 2008, RE engineer Randy Richmond contacted me. His family had purchased property in Ellensburg, Washington, with the express purpose of installing a wind generator, and he was looking for recommendations. I mentioned the Grim turbine, so the two Randys got together to inspect the system. They negotiated a very reasonable price for the complete system, and Randy Brooks put the wheels in motion to move it.

While Randy Richmond worked with local authorities for permission to site the turbine on his vacation property, Randy Brooks gathered his de-installation crew. In early June, we attached a crane, unbolted the tower from the foundation, and tipped the whole thing over. Turbine blades, tail, and then generator were removed and stowed, leaving us with a bare tower.

Brooks had arranged for a flatbed semi trailer to haul the tower and turbine 40 miles to Ellensburg. We decided to partially disassemble the tower into five 20-foot sections. This strategy worked well, and we nested the sections on the semi, with the turbine strapped down on the back end. All then headed south, leaving a bare concrete slab at the Grim property.

The turbine and tower are reassembled and hoisted at the new site—one with a considerably better wind resource.

Courtesy Don Richmond (5)

Relocation & Reinstallation

Randy Richmond and his wife Melissa had multiple reasons for purchasing their weekend cabin in eastern Washington, but their primary motivation was a site for a wind-electric system.

This site clearly had a better wind resource than the Grim site. There are two commercial wind farms nearby, and the wind maps show a 14.5 mph average wind speed (at 197 feet) in their neighborhood. The landscape is largely treeless, and neighbors complain of consistently strong winds. While no on-site anemometry was done, data from nearby sources, including a commercial wind energy company, confirmed our initial observation and verified the wind maps.

When the semi and crane arrived on site, we unloaded the sections and preassembled the tower near the new foundation site. We opted to only assemble the tower without the turbine, getting a head start on the future installation. The installation was scheduled to be resumed a few months later, to give Richmond time to prepare the site. In June, the tower site was excavated, forms were built, and rebar was set in 38 cubic yards of concrete. Richmond also fine-tuned the electrical and monitoring systems for the turbine, including wind monitoring equipment, radio antennas, and a Web cam. Provisions were included for selling space on the tower to local agencies and companies needing radio transmitters and receivers.

The crew gathered to resume installation of the wind system in late August. Richmond had done much of the work already, including routing the transmission cables, both underground and on the tower. We quickly finished up the remaining odds and ends before the crane rolled onto the site. This was the sixth Bergey Excel that our crew had installed in seven years, so we worked like a fairly well-oiled machine.

The crane lifted the tower so we could prop it up for room to install the turbine. We then lifted the turbine head and bolted it to the tower, followed by the tail and new, next-generation blades. The blade upgrade led to some head-scratching over the installation hardware and a field modification to make the nose cone fit properly. Meanwhile, with transmission wires secured, furling cable attached, and damper completed, we were ready to lift.

Once the tower and turbine were up, we ran ground wires to the ground rods, and performed electrical and furling tests on the turbine. We left the turbine running unloaded, an acceptable condition for this particular model.

Once final electrical approval was received from state authorities and the utility in October 2008, the system began to produce electricity. In its first 86 days of operation, the

Courtesy Randy Brooks

Proud new owners of the relocated wind-electric system.

The turbine and tower, at their new home on the range.

Ian Woofenden

Courtesy Randy Richmond

The installation crew.

system has produced 2,047 kWh, or an average of 23.8 kWh per day, a far cry from the low performance at the Grim site. Average wind speed at 33 feet was 8 mph in the fall of 2008, and, Randy estimates, probably 1 to 2 mph higher at the turbine hub.

The Richmonds are earning a 12-cent per kWh state incentive payment for their wind energy. The incentive has a $2,000 per year cap, which Randy hopes to reach. The electricity produced also offsets the energy consumption of the cabin on the property, further improving the payback.

Lessons Learned

Seven years after his initial meeting with Don and Bev Grim, Randy Brooks has more experience with wind site assessment and system installation. His experience with the Grims leads him to be "much more conservative with wind resource estimates."

Wind systems aren't for everyone, or for every site. In fact, truly good wind sites are not all that common. Wind turbines should be installed well above (at least 30 feet) anything within 500 feet of the tallest obstacle, and taller towers are always better. And as the Grims learned, even adequate tower height cannot overcome a site with a poor wind resource.

It's fortunate for all involved, and for the renewable energy community, that Don and Bev realized their mistake and moved on. This gave Randy and Melissa an affordable opportunity to tap into wind energy. And it put a poorly producing turbine into a new environment where it can now earn its keep.

Access

Ian Woofenden (ian.woofenden@homepower.com) enjoys moonlighting on the Brooks Solar crew, which has provided many rewarding wind installation experiences.

AWS True Wind • www.awstruewind.com • Online wind maps

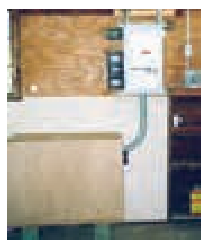
Bergey WindPower Co. • www.bergey.com

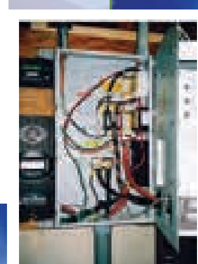
Brooks Solar • www.brookssolar.com

MidNite Solar is Striving for Excellence across the planet

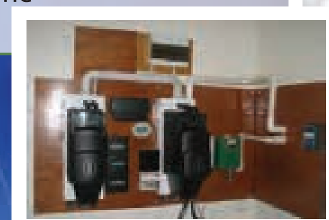
email Testimonials

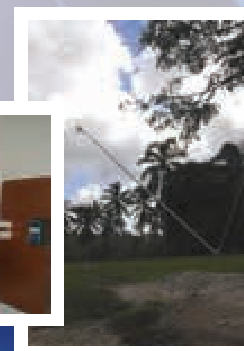
Hi Robin,
Even though I have had an off-grid solar voltaic system for over 20 years, I am a tyro as an electrician. Upgrading to a Magnum Inverter with an Outback MX 60 attached, and getting the system out of the cellar, was cause for a number of hours of cogitation... and fear... and trembling. Central to this neophyte's success was your E-panel. It allowed me to connect this state-of-the-art equipment together with some confidence. I am attaching a couple of photos of my humble project, if you have use, or need, of a testimonial, consider this a rave review of your E-panel.
My thanks for your pioneering work democratizing energy.
Peter Meadowsong



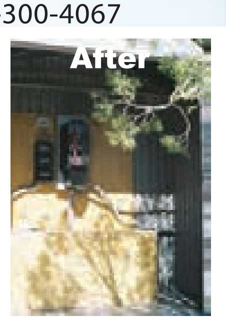


Hi Robin,
Don't know if you remember me, I asked you a few questions last year about a self install using some of your equipment last year in Tonga.
Anyway you had asked for some pics, and I completely forgot until now.
Love your stuff
Paul Stone
Tonga





Robin, I need 6 MNE175ST's
Wow! What are you doing with all these E-Panels?
Just selling a quality product.
Thanks, Ralph P. O'Donnal, Jr.
GSW Power Systems
Kingman, AZ 928-300-4067



Robin,
Thanks for the update on the Classic and beta testing. We are really excited here about this one. It's been such a pleasure working with your products over the years. You and your team are the best!
Jack West
Talkeetna Alternative Energy
Talkeetna, AK 907-733-2035

Hi guys, Independent Power (Auckland, New Zealand) have just sent me an E panel after I performed a single VFX install using the FW250 system. Just wanted to say that the FW250 is a real hassle and the E panel is everything the FW is not! You have a convert here and the MPPT controller you are developing looks great! Reminds me of the Chrysler building.
Cheers,
Bruce Geddes
PowerOn

Robin,
Yes, I just did my first MidNite system and was VERY impressed with the ease of wiring accommodated by the hinged inverter mount. In addition, it cost less then an OB PS2 configuration, takes far less wall space and took me about 1/2 the time to wire it. Also the bypass switch is ingenious and works flawlessly.
For a single inverter, this is surely the way to go!
Todd Cory,
Mt. Shasta Energy Services 530-926-1079

Send your testimonials today to: robin@midnitesolar.com

MidNite Solar, inc

17722 67th Ave NE Unit C, Arlington WA 98223
425-374-9060 www.midnitesolar.com

Mounts for Solar Collectors

OPTIONS FOR GROUND OR ROOF PLACEMENT

by Chuck Marken

This site-fabricated mount-set uses few roof penetrations.

Solar thermal manufacturers usually supply the mounts along with their collectors, and factory solutions for mounting collectors definitely make a solar thermal installation easier. But if you install on a regular basis, you may find that making your own mounts is the way to go. Fabricating your own mount-sets is more time consuming but offers rewards in terms of cost and flexibility.

Mount Materials

Even if you plan to make your own mounts eventually, it is sensible to use racks from the collector manufacturer for the first few jobs. Once you have a good idea of how the factory sets go together, you can design your own. A compromise many installers make is to stick with factory sets for most of their jobs, stock extras of the parts that will put them in a bind if they come up short, and use the materials and techniques discussed here for those custom jobs that are bound to come up.

In my 30 years in the solar thermal business, I've seen collector mounts fabricated from recycled bed frames, lumber, steel wall studs, and electrical metallic conduit—but these materials are not the norm. A simple, durable mount-set can be built with pipe, angle, or square stock. Angle-iron (steel angle stock) is the choice of many installers because of its low cost and ease of use in mounting systems. The common materials are steel, galvanized steel, stainless steel, and aluminum. All of these materials can make durable and strong collector mounts that will last for many decades. Here are some pros and cons of each.

A factory mount-set with a clip that slips into the collector extrusion to transition to Unistrut.

Although it's not pretty, this home-built mount-set has survived for more than two decades and still capably holds the collector.

A pool heating system mounted on a site-built rack fabricated from steel studs.

Steel can be used in arid climates, since the possibility of galvanic corrosion between the steel mounts and aluminum collector frame is almost nil. In areas with higher humidity, steel stock will quickly rust and will require periodic maintenance, such as painting. The minimum dimension for 1/8-inch-thick angle iron or galvanized pipe is 1 inch. Smaller dimensions bend too much in long lengths.

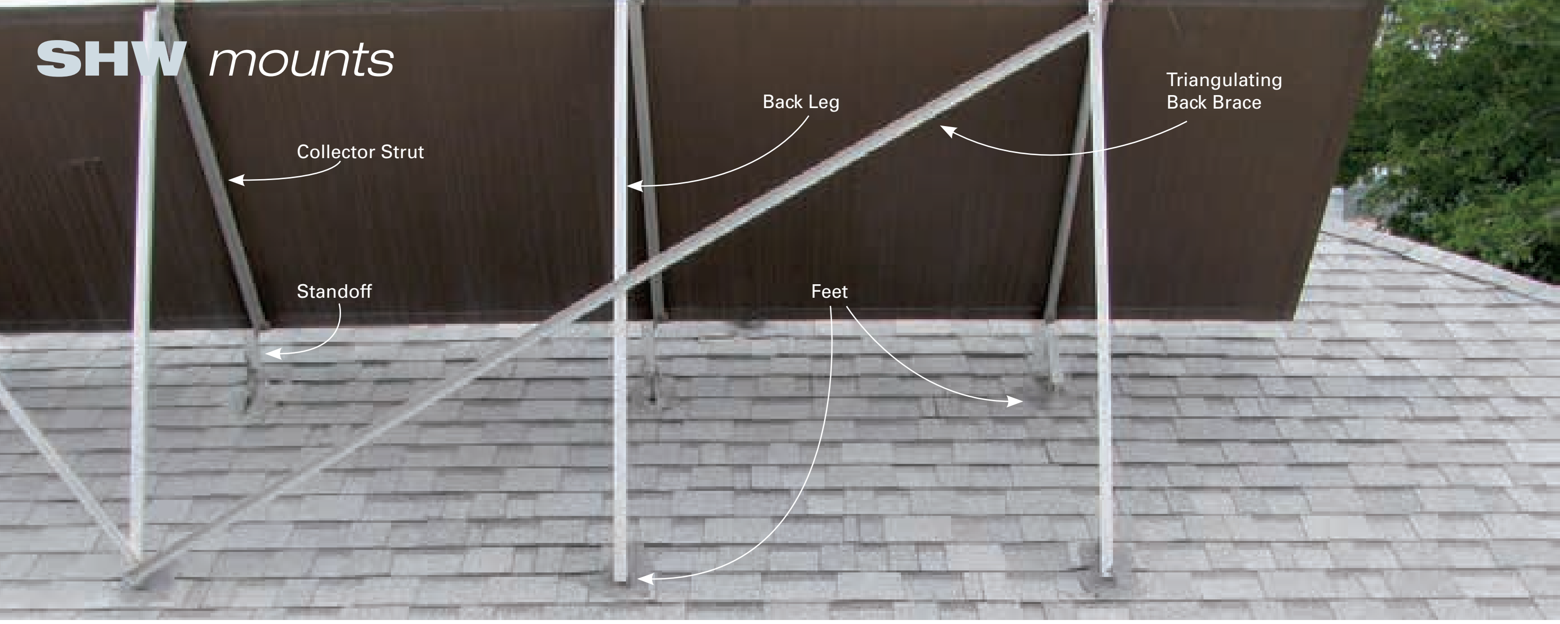
Aluminum is a preferred material for its corrosion-resistance, and is the material of choice for racks and mounts in most of the solar industry. Aluminum extrusions come in a variety of different strengths and properties, and stronger aluminum is usually more brittle. Aluminum is not as strong as steel and needs to be a little larger-sized—the minimum dimension for 1/8-inch-thick extruded aluminum angle is 1 1/4 inches. While aluminum is lighter than steel, it's more expensive, harder to weld, and, unless it is anodized or powder-coated, has a brighter color than the collector frames, so it may stand out more.

Stainless steel (SS) comes in more than 100 grades, designated by numbers that relate to different amounts of alloys. The most common grade for use in collector mounts is 304, but it should not be used in marine environments, since it is vulnerable to chloride corrosion. Instead, 316, an alloy which contains molybdenum to prevent corrosion, is recommended for coastal areas. It is hard to drill and difficult to weld but provides excellent protection from the elements—it's the choice of boat builders for long-term saltwater exposure. If you're planning to weld stainless mounts, 316L (low-carbon) stainless is a bit easier to weld due to the reduced carbon content. The minimum dimension for 1/8-inch-thick SS angle is 1 inch. Stainless stock is similar in cost to aluminum, which has fluctuated in the past few years.

Steel construction studs, steel Unistrut (industrial metal framing), and **galvanized steel** are sometimes used instead of

A wall-mounted collector with a mount-set that is long on function, but short on aesthetic appeal.

Chuck Marken (3)



The pieces of a homemade mount-set on the author's home.

aluminum. The material is stronger than aluminum, but can be more difficult to find. Unistrut is like a giant Erector set: it comes in a variety of angles and channels with holes. Braces, connectors, and slip-in threaded inserts (channel nuts) are available as well. It can be more expensive than other options, and is heavier and harder to cut than aluminum.

Lumber can be used to construct mounts, but it is not recommended. The ongoing maintenance (especially on roofs) is a hassle. Although using treated lumber can reduce the periodic maintenance, screwed connections are prone to weaken over time, and cracks and shrinkage can result in unreliable joints and roof penetrations. Using through-bolts will help strengthen connections to treated wood, and racks and sealed penetrations should be inspected occasionally.

Parts & Pieces

Hardware. Regardless of the mount material, stainless steel hardware (nuts, washers, and bolts) is typically supplied by rack manufacturers and is recommended for most climates. In arid climates, zinc-coated hardware may be acceptable.

These site-built mounts were made from angle stock with prestamped holes. In this case, a factory set would have been more attractive.

Chuck Marken (2)

Mounting Feet. The "mounting foot" is the part of a mount-set that is lag-screwed or through-bolted to the rafters of the roof (or other structure). Angle stock is a good material for feet since it can be drilled for bolting to the roof and the 90-degree face can be bolted to legs or struts. One or two holes are drilled into the foot for attaching to the roof structure. A typical single-collector mount-set of this type will have four feet held to the roof with four to eight lag screws or through-bolts. My company has installed thousands of collectors using plastic roof cement ("pookie") as the roof sealant. Care must be taken to put a bed of pookie under the foot, dip the lag bolt into the pookie prior to screwing it in, and cover the foot with a generous amount of roof cement as the last task before leaving the job. To keep roofing

(continued on page 94)

Wind Loading

Depending on where you live and what type of wind speeds your collectors will be exposed to, wind loading may or may not be an issue. Any side-to-side movement in the mount should be eliminated with additional triangulated support members, since any lateral play will allow strong winds to weaken the mount over time.

For collectors that aren't angled more than 4 feet above the roof, 3/4-inch angle iron or 1-inch aluminum angle have been used repeatedly without failure, since the wind loading is significantly less at lower tilt angles. Square stock and pipe may be used in the same dimensions for each respective material.

If building officials feel uncomfortable with a mounting system, they may require an engineer's stamp on the system drawing. Also, if you live in an area with high winds, having your mount engineered may save you some headaches down the road. Many collector manufacturers will be able to supply you with wind-loading calculations should they be required. For more information on wind and other loads, see "Dealing with the Forces of Nature" on page 77.

High Performance with Off-the-Shelf Parts

Tim Dawson and Luke Frazer of Solar Collection in Talent, Oregon, use off-the-shelf, 1-inch galvanized pipe for their collector mounts. Pipe flanges secure the mounts to the roof rafters or trusses and allow the penetrations to be flashed with ordinary Oatey roof jacks. They use tubular fittings to join the galvanized pipe, and U-bolts to interface with a short piece of aluminum angle that attaches to the collectors.

Here's an example of a neat installation with two Chromagen 4- by 8-foot collectors mounted with standoffs on a composition shingle roof. Note the position of the self-drilling screws attached into the collectors' frames. Whenever screwing into a collector, stay well away from the glass, since even catching an edge of the tempered-glass face with a screw will give you a bucketful of glass chips to clean up—and the expense of replacing the glass. Likewise, make sure that your hardware is not so long that it could penetrate the header pipe when screwing into the sides of the collector frame.

This design is suited for all roof types, ground mounts, and tilt racks. The mounting system can provide a level rack for antifreeze-based systems or a sloped rack for drainback systems (by using progressively shorter standoffs).

Courtesy Solar Collection, Inc. (5)

Flush or Rack Mounts?

Factory mount-sets come in two types: flush- or rack-mounted. Flush, or standoff, mounts are used to mount the collectors at the same pitch as the roof. A rack mount has precut or adjustable legs to tilt the collector at a steeper angle than the roof.

Both flush and rack mounts can be ordered for ground-mounted systems depending on the design and amount of standardized material used. If a ground mount has a structure built from angle, square, or round stock, a low-cost flush-mount kit can be used as an interface between the site-built mounts and the collectors. The flush-mount kits will likely include some sort of channel feet, with clips or mounts that attach to the collector. The channel feet can then be bolted or screwed to the site-built rack.

warranties intact, be sure that the sealant is made to work with the particular roof material.

Collector Struts. Once the feet are in place and spaced correctly, the collector strut and back leg of the mount-set can be bolted together.

There are many adaptations for constructing a basic mount-set. Mount-sets can also be strengthened using horizontal or

Chuck Marken

A factory Novan roof mount-set with more than two decades of leak-free service—the sealant is plastic roof cement.

triangulated angle stock if needed. For a row of collectors, angle stock can be used as top and bottom rails bolted to the collector struts. This configuration makes a "lay-in" mount for a row of collectors, and each collector can be secured to the mounts with self-drilling screws into the collector's top and bottom frame extrusions.

Access

Contributing editor **Chuck Marken** (chuck.marken@homepower.com) is a New Mexico licensed plumber, electrician, and heating and air conditioning contractor. He has been installing and servicing solar thermal systems since 1979. Chuck is a part-time instructor for Solar Energy International and the University of New Mexico.

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A Life in Hydro

Ron MacLeod

Big and small, Ron MacLeod has done it all in his three decades of hydro-electric experience.

by Ian Woofenden, based on interviews with Ron MacLeod

Opposite: Ron's 800 kW site in southern New Hampshire.

Insets (top & bottom): A 1.2-meter propeller turbine; a Nautilus installation.

Right: A Nautilus turbine installed just above the high-water level of the creek.

Below: A 2.5 kW DC installation on 28 inches of head in Lancaster County, Pennsylvania.

Courtesy Ron MacLeod (2)

Ron MacLeod's experiences are rich with lessons on how to harness the amazing potential in falling water. From a 22-megawatt project on the Merrimac River in Massachusetts to a 500-watt residential system on an Amish farm in Pennsylvania, he's at home with water, no matter where it is.

Growing up on a farm in eastern Pennsylvania, Ron started tinkering with mechanical things early in life. He also developed an awareness and respect for nature and natural resources: His parents farmed organically, hunted, fished, and coordinated environmental education programs in their community. It's not surprising, then, that he found his calling in a career that married his mechanical aptitude with natural resources.

In 1976, when visiting his parents in Maine, Ron had his first hydro encounter while trout fishing on the Kennebago River near the Canadian border. Coming around a bend in the river, he spied a former hydro site—complete with dam, powerhouse, and turbines—that had been shut down in the 1960s. Most of the powerhouse was boarded up, but one of the windows was open, so Ron climbed in to look around. The potential of tapping a natural resource with an existing system and the challenge of revitalizing something that had fallen into disuse excited him.

This sparked the start of a long series of explorations into hydro sites and turbines. By his own admission, Ron says he "got obsessed" with commercial hydro projects, and started combing through dam data from state and federal agencies, poring over topography maps, canvassing the countryside, and tapping into the experts—old-time hydro operators, turbine designers, and manufacturers.

He became an expert in the history of the technology. "Energy was so much more valuable 50 years ago. People cared much more about these projects—entire fortunes were made. Hydro is an elitist source of electricity. It's such a good power source, but also, when you control it, you don't have to share it. Power is power; people don't recognize the relationship between horsepower, political power, industrial power, and military power—they are all connected. For instance, in the history of Philadelphia, just about every family that became influential was in one way or another associated with a source of water power."

Although this research was crucial to Ron's professional hydro future—which spanned from turbine and system design to sales, installation, and operation—he says, "During this phase, I learned a lot, but didn't achieve anything in the hydro industry. And I still didn't know enough to know what I didn't know." Until he met Nathan Eberle.

Mennonite Inspiration

In 1980, Ron was living in Chester County, Pennsylvania, just east of Lancaster County, a center of Amish and Mennonite communities. He hadn't had much contact with these groups—also known as "plain people" because of their unadorned dress and simple living tenets. But while working on a building project, he needed a source of inexpensive lumber and found a sawmill run by Mennonites. He was impressed with their honesty, integrity, thriftiness, and determination to eschew material trappings, and focus on their families.

Ron found a font of hydro information in Nathan Eberle, a retired Mennonite millwright in his 90s. As a young man,

Ron's hydro site in southern Vermont.

Nathan would move to a new mill site, supervise the design of the mill, dam, mechanical infrastructure, and electrical transmission, and bring the system into operation. As the Rural Electrification Administration came through the area and the electrical demand exceeded capacity of the existing hydro systems, the communities switched to using gas- and steam-powered engines, and ultimately to a centralized, utility-powered grid. The hydro systems fell into disuse. Ever the conservationist, Nathan pulled out many turbines and stored them in a field, collecting piles of original machinery.

Meeting Nathan was a turning point for Ron, who recognized that new equipment for small hydro sites wasn't available at that time—instead, old equipment had to be refurbished. To do this, you had to be able to identify what equipment you had, and how much power it could produce given a particular head and flow. The specifics of whatever machinery you dug up out of the mud was crucial to success with the projects. As a history buff and researcher, Ron was already acquiring as much information as he could from many manufacturers, but Nathan was a gold mine.

When Nathan died, Ron went to the auction held by the Eberle family with $273—all of his savings. Ron made fast friends with another Mennonite at the auction, and with him bought 14 water turbines, bidding against scrap dealers. At the auction, Ron met Walter, also a Mennonite, for whom he built a 2 kW hydro system.

After Walter's system was up and running, an elder in the Mennonite community saw what Ron had done and leased a dam near Walter's farm, developing a 20 kW system on 8 feet of head. Because it is Mennonite tradition to only use power they produce themselves, these hydro-electric projects became very popular in that community. About a dozen sites along the Conestoga River were developed over the next 15 years, most with Ron's guidance.

Into Big Hydro & Into Business

In 1986, after six years of installing small-scale hydro systems, Ron's moved into the utility-scale arena as an operations manager for a 40 MW system at Lowell & Lawrence on the Merrimac River in Massachusetts. The system at Lowell had one large installation and many smaller (500 kW to 1 MW) systems on the city canal system. Being their hydro-electric operations manager required him to be familiar with both big and small hydro systems.

This work propelled Ron into other hydro-electric projects in New England, as well as equipment brokering, since he had experience evaluating a variety of turbines. His installation and operations management experience eventually led to consulting work in Central America on private and U.S. government-sponsored humanitarian projects through the U.S. Agency for International Development. Among other organizations, the National Rural Electric Cooperative Association hired him to survey the hydro sites that had been destroyed in El Salvador after the revolution and determine if they could be rehabilitated. But he was frustrated by the government bureaucracy, which made it hard to complete projects. Poor planning and not enough funding hamstrung many of the ventures, and Ron decided to take a hydro hiatus.

But like the ebb and flow of rivers, after taking a five-year sabbatical from hydro projects, Ron was drawn back to the field to launch his own business, Nautilus Water Turbines in Pennsylvania. On the day he incorporated the business, he had a massive heart attack, so the business got off to a slow start. But Ron's determination, and the support of his wife, Laura, kept him going. He also called on former colleagues and found that many were open to turning over their turbine designs. Ron was able to add another 20 designs to his turbine collection, giving him the ability to meet a wide range of head and flow requirements. Ron says that "giving a guy a turbine design is not like giving a guy a fish; it's like giving him a fishing rod, because they can be scaled up and down as needed."

Ron started to build his own turbines. The runner, the wheel that receives the water, was based on a design he owned. The scroll case, the conduit directing the water from the intake or penstock to the runner, was Ron's design based on advice he received from his extensive contacts. The product line included 10-inch unregulated, 8-inch unregulated, and 8-inch regulated Francis turbines, used in low- to medium-head situations.

The cover of *HP23* featured one of Ron's systems.

From Manufacturer to Electricity Producer

Even while he was busy building Nautilus turbines, Ron kept pursuing his hydro explorations. Ron and Laura started to think about buying a productive hydro site that would provide income during their golden years. They first purchased a former paper mill in Vermont, but the bureaucratic hurdles of turning this site into a workable hydro-electric system caused them to seek another project. A few phone calls put him in touch with a colleague who

Left: Ron in front of the intake at his New Hampshire hydro site.

Below: The runner sits at the output of the scroll case in one of Ron's Nautilus turbines.

had recently bought a mill site in southern New Hampshire that sold power to the grid. With 18 feet of head and a maximum potential of about 800 kW, it was a feasible scale for an individual to rebuild and operate, and do so profitably.

The site had been online for 15 years but struggled, making about half of the power and money it could have, and had frequent equipment breakdowns. Ron plans to revamp portions of the operation, bringing in new equipment.

Six weeks after he and Laura's purchase of the mill, one 165 kW turbine was up and running: the first of four 300 rpm turbines with 1.2- to 1.7-meter-diameter propellers that Ron will be able to run. He hopes to have the second and third running later this year. Because the water flow varies, the third and fourth turbines may be smaller ones, possibly 50 kW each, to handle lower summer flows without shutting down the site entirely.

Once Ron and his crew have finished overhauling the hydro site, it will take 20 to 40 hours per week to operate and will provide Ron and Laura with a comfortable income. For the electricity they produce, they will be paid a fluctuating wholesale rate for peaking capacity. Plus, they will also earn renewable energy credits. This adds up to a decent income, and the future looks brighter still, with energy prices increasing and supply tight.

Water Power Judgments

As Ron approaches his retirement years, he says he'll be passing the torch to the next generation. "I'd like to find something to do with the turbine designs that I have, to help them be used to do some good in the world."

While Ron sees the benefit of hydro systems, he's not blind to their impacts. He just asks that people consider the alternatives. "Fisherman and kayakers, who are often strongly against hydro installations, seem to overlook that for every dam that is torn down or every project that is stopped, nuclear plants will be developed in their place.

"We're going to have to begin to make judgments, instead of just reacting. It's too late to achieve the very best. Water power has a place," he says. "There was a time when water power was abused, and it still can be. Power and energy can be dangerous and destructive—just like a gun if it is aimed in the wrong direction. But it's not good or bad inherently—it depends on judgment."

Access

Ian Woofenden (ian.woofenden@homepower.com) dreams of a hydro-electric system as he works at his solar and wind-powered home in northwest Washington.

Steca PF166 Refrigerator/Freezer

Application: The PF166 is a high-efficiency 5.9-cubic-foot unit that can be used as either a refrigerator or freezer, and can run on either 12- or 24-volt DC. Last year, I installed one on the north side of my family's off-grid home for frozen storage of our homegrown meat and vegetables.

Off-grid living can present challenges to having modern conveniences, and refrigeration and frozen food storage are high on that list. Conventional upright and chest freezers can be energy hogs because of poor insulation, inefficient compressors, and poor placement and use.

For years, we've kept a standard chest freezer outside a relative's on-grid home, about 3 miles away. In addition to the commuting costs and inconvenience, there was the larger problem of energy use: The older, 23-cubic-foot model used about 2 kilowatt-hours (kWh) per day during the coldest weather, and much more in the summer months. To keep it at our home, such an electric load would require increasing our solar- and wind-generating capacity by at least 20%, and would require more propane generator use on calm, overcast days.

When considering appliances for an off-grid home, it's critical to select for extremely high efficiency, unless your pocketbook can afford a huge renewable energy (RE) system to generate lots of kWh for wasteful appliances. It generally shocks people to hear that we spent almost $3,000 on the fridge in our kitchen, for instance. But if we had purchased a typical fridge, we would have had to spend much more to expand our renewable generating systems—or run our fossil-fuel generator more every winter.

As a middle-class off-gridder without deep pockets, I'll opt for the high-efficiency appliance most every time. So when the Steca PF166 came along, I was happy to add it to our home's collection of appliances. I had worked with Steca's solar charge controllers in simple, off-grid systems in Central America, and was impressed with their quality and the user-friendliness of the interface. Steca is a German company that has been making products for the RE market since 1990. I expected nothing but high quality from them, and their freezer—which hit the market in 2007—delivered just that.

Installation

The installation was pretty straightforward, requiring rudimentary electrical abilities and some heavy lifting (or a good dolly). Note that the PF166 is a 12 or 24 VDC appliance. It will not work on 120 VAC or 48 VDC—though it would be worth considering a DC-to-DC converter if you have a 48 VDC battery bank.

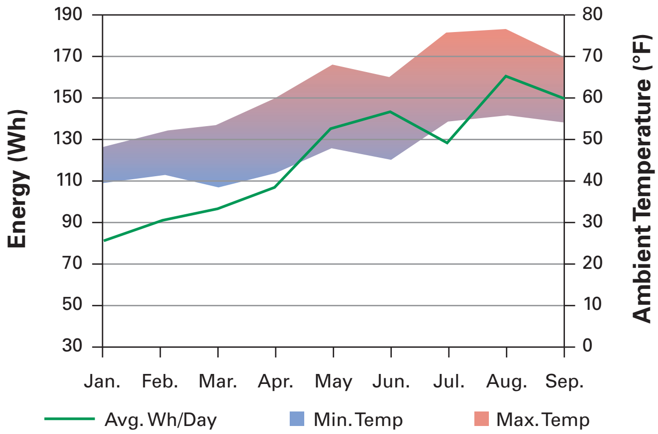
The freezer is hardwired to a 12 or 24 VDC circuit, and be sure to add the appropriate breaker in the circuit. The PF166 comes with a heavy-duty flexible cord. Proper polarity must be observed to operate, though the unit is reverse-polarity protected.

Install it on a flat, level surface, preferably in a cool location. Avoid installing the unit near heat sources or in direct sunlight. Keep at least 8 inches of clearance behind and beside the freezer to keep the ventilation grills unobstructed and ensure optimal cooling.

Features

The Steca freezer is small—at 5.9 cubic feet, it will not hold a full beef or a year's supply of salmon. But small can be beautiful, and it's worth asking yourself how big of a freezer you really need. If you have frozen goods soaking up your electricity for more than six months out of the year, perhaps you should consider cycling produce more quickly and using a smaller unit. In our home, we have two small, off-grid freezers, which gives us the option to run one or both as needed.

Daily Energy Use & Ambient Temperature



The PF166's construction is clean, durable, and modern—inside and out. Two hanging baskets are included, as well as three freezer trays that act as partitions. A chemical ice pack prevents rapid temperature change in the event of a power outage.

A closeable drain allows easy cleaning after defrosting. Steca claims that their patented StopFrost system dehumidifies the incoming air that normally gets sucked into a freezer as the contents cool, significantly reducing the frost inside while increasing overall cooling efficiency.

Because freezers are "always-on" cycling appliances, users can't control these particular energy loads. However, the Steca has a low-voltage disconnect feature to protect a home's battery from ultra-deep discharge. The low settings are only reliable for emergency situations. Be aware of your battery's state of charge, and charge the bank fully on a regular basis.

Programming

The unit has sophisticated controls and monitoring. Its on/off switch makes it handy to shut down the unit without having to unwire the DC feed. The display flashes a symbol to indicate that the unit is off, but that electricity is still connected.

High Points

- Very low energy use
- Modern appearance
- Easy cleaning
- Low-voltage disconnect
- Power loss & maximum temperature alerts

Low Points

- DC only
- No 48 VDC available

Tech Specs

Steca PF166 Refrigerator/Freezer

External Dimensions: 36.1 x 34.3 x 27.9 in.

Weight: 134 lbs.

Nominal Voltage: 12 & 24 VDC (automatic selection)

Input Voltage Range: 10–17 V & 17–31.5 V

Low-Voltage Disconnect: 10.4 V & 22.8 V

Power Draw: 40–100 W

Recommended Fuses: 15 A & 7.5 A

Cooling Method: Danfoss DC compressor

Usable Cooling Volume: 5.9 cu. ft.

Refrigerator Temperature Range: 35.6–53.6°F

Freezer Temperature Range: -4–14°F

Ambient Temperature Range: 50–109°F

List Price: $1,200

Warranty: Two years

While we have only used the Steca as a freezer, it also has a refrigerator mode, with a range of 35.6°F to 53.6°F. The default factory setting is 46.4°F, but a simple menu allows you to change to freezer mode, and another menu allows you to specify the temperature to within 1°. The operating temperature is displayed in either Fahrenheit or Celsius.

A reassuring feature is the power outage display, including an audible alarm and a flashing symbol. The unit also displays the highest temperature reached, so you'll know whether your food has thawed to the point where you should be concerned about its safety.

Performance

Steca's performance predictions suggest that this unit will consume 200 to 1,100 watt-hours (Wh) per day in freezer mode, and 50 to 350 Wh per day in refrigerator mode. These numbers depend on the ambient temperature and the thermostat setting. The manufacturer claims that the unit will run as a refrigerator on the energy from a single 70-watt solar-electric module "in most climates."

The low energy use of this unit is nothing short of remarkable. I thought our previous low-voltage freezer was an energy sipper, but the Steca PF166 takes the prize. While our previous DC freezer is an older model (and the company has made advances since we bought it), compared to it, the Steca uses about half of the energy per cubic foot of freezer area. Compared to our on-grid freezer, the unit uses about one-fifth the energy per cubic foot.

Over our 10-month test period, the Steca averaged 120 Wh total per day. For context, 120 Wh is less than running three

Testing Tools & Method

We relied on two testing tools in evaluating this unit's performance. For energy consumption, we used a Watt's Up Watt Meter & Power Analyzer (www.rc-electronics-usa.com), which logs watt-hours, instantaneous and peak watts, instantaneous and minimum volts, instantaneous and peak amps, and amp-hours. Two meters were tested against each other initially, and a correction factor was applied to attain accuracy.

For logging minimum and maximum temperatures, both ambient and inside the unit, we used a Radio Shack maximum/minimum hygro-thermometer with remote.

15 W compact fluorescent light bulbs for three hours and much less than what it takes to do a load of laundry or dishes using high-efficiency appliances. This freezer is truly an energy sipper!

Our situation is not exactly average, since the unit is installed outside in a shed on the north side of our building. We also live in a moderate climate, with an average summertime high of about 72°F, so our freezer's performance numbers are probably better than if it was installed inside, or outside in warmer climes. Seek out a location for your freezer that minimizes energy use, and then be realistic about your climate and situation.

Chill Out

So how does this freezer achieve its high efficiency? Primarily by using a high-efficiency compressor and heavy insulation. The Danfoss-made compressor has electronic variable speed control and uses a CFC-free coolant (R-134a). The 4-inch-thick foam insulation is seamless, with cooling tubes at the inner surfaces and a heat exchange condenser embedded in the outer surfaces. The door fits and seals well, keeping the coolness in.

This freezer/refrigerator gets high marks from me. It does its job well, using only a fraction of our precious solar and wind electricity. Its modern, clean box is attractive and easy to clean, and the lockable lid provides security. Its intelligent processor and monitoring delivers good temperature regulation and great information. Steca's done a fine job with this machine. If you have an application for a small, low-voltage DC fridge or freezer, check it out.

Access

Reviewer: **Ian Woofenden** (ian.woofenden@homepower.com) enjoys frozen beef, pork, veggies, and berries with his family at their off-grid home.

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EV CONVERSION

Safety First & Foremost

by Ken Koch

An electric vehicle (EV) is as safe and reliable as any vehicle that uses gasoline or diesel fuel. But, as with any vehicle, an ounce of prevention is worth a pound of cure. By being aware of the potential hazards, you can prevent damage to the vehicle as well as injury to yourself and others.

Courtesy www.evenergyfilms.com (2)

No single component is capable of meeting the safety needs of your EV. The full defense comes from safety in numbers—the more components you have to protect your propulsion system, the less vulnerable your vehicle will be in the event of an emergency. Here's a rundown of the main gear to make your EV ride as risk-free as possible.

Motors & Motor Insulation

The motor should be sized appropriately for your application—don't try to use a 10 hp motor when 20 hp is required. An undersized motor can overheat and eventually burn up.

Even with a properly sized motor, you'll still need to be conscious of insulation system ratings—which range from 90°C for low-end commercial motors to more than 300°C for high-end military ones. The higher the insulation's thermal rating, the better the motor can withstand heat and overloading. If the motor's insulation system is compromised, armature and field windings can begin to short out—eventually causing the motor to overheat and possibly ignite. The best commercially available EV motors have insulation systems rated for 180°C (UL Class H rating).

This well-done conversion shows off good cabling practices, well-made battery racks, and an orderly installation.

Emergency Disconnects

Most converted EVs use multiple flooded-cell, lead-acid (FLA) golf cart batteries because they're available, affordable, and durable. But FLAs have very low internal resistance, and some can supply 2,000 amps or more into a short circuit. This magnitude of current can easily cause a fire or explosion if there isn't a quick and reliable way to interrupt it. That's why multiple emergency disconnect devices—such as fuses, circuit breakers, and contactors—are necessary. If one emergency disconnect device should happen to fail, others are there as backups.

Safety Fuses. When too much current flows, a fuse provides an automatic interruption of power by breaking the circuit. In an EV, use at least one safety fuse at the main battery pack to protect system power components from damage due to excessive current. To perform as needed, a fuse must be rated at the voltage, current, and time characteristics appropriate to its application. For example, if a propulsion-pack voltage is 120 V and the motor controller current limit is 500 A, the safety fuse should also be rated to handle these values. "Blowout time" can be slow or fast, depending on your preference: The fuse can blow instantly, or it can be designed with a delay curve. This allows it to tolerate a slight overcurrent for a short time, preventing "nuisance blows" due to a momentary current spike that can be safely ignored.

Several types of safety fuses can be used in an EV. An *enclosed* safety fuse, such as the Ferraz Shawmut A30QS500-4, is best because the fuse element is enclosed in a fire-retardant powder. This powder and its fiberglass or ceramic case can alleviate a fire or explosion in the event of a very high-current overload. With its open construction, a traditional *fuse link* is usable in most applications. It should, however, be enclosed in a piece of high-temperature insulated tubing, such as phenolic, when mounted above a battery. If an unenclosed fuse link should happen to blow, it will spew molten balls of metal that could burn right through a battery case—ruining the battery, or worse yet, causing a fire or explosion. For maximum safety, every implementation or control line that ties into the propulsion system should be protected with a small, high-voltage fuse rated at 1 A or less. Each fuse will protect its small-gauge wire from catching on fire if a short ever occurs within the instrumentation or control circuit. To provide maximum protection, the fuse should be located as close as practical to the propulsion system's tie-in point.

Left: A Ferraz Shawmut enclosed-link fuse—great for use above and near batteries.

Right: A typical open-link fuse, with insulated extensions on the terminal.

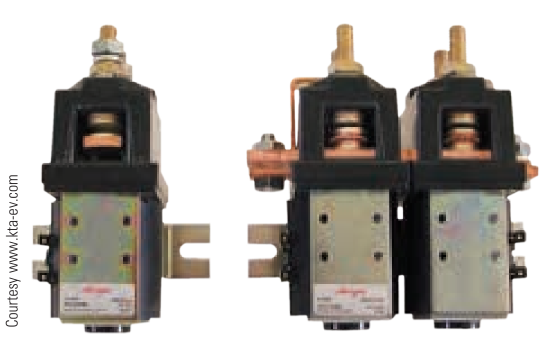
Circuit Breakers. A circuit breaker provides a fail-safe manual and/or automatic interruption of power. It also can be used to shut off battery power during servicing or repairs. As with a fuse, a circuit breaker must be rated for the voltage, current, and time characteristics appropriate to its application.

For maximum safety, a circuit breaker should be mounted within easy reach of the EV driver. This can be accomplished by mounting the unit in the dashboard or console of the vehicle, but requires running the large-diameter battery cables into the vehicle's interior. An alternative is to mount the circuit breaker with the power electronics. Then, it can be activated by a push-pull control cable and knob located on the dashboard or console. This shortens the length of high-current cable used, and keeps high voltage and high current out of the vehicle's interior.

Contactors. In an EV propulsion system, high-voltage inductive loads and extremely high current levels are common. A contactor is an electromechanical device that switches high voltage and current by means of a low-level control voltage. It is similar to a relay, except that it is much more robust and can switch highly inductive loads that might otherwise burn up or weld the contacts of a relay when the circuit is opened.

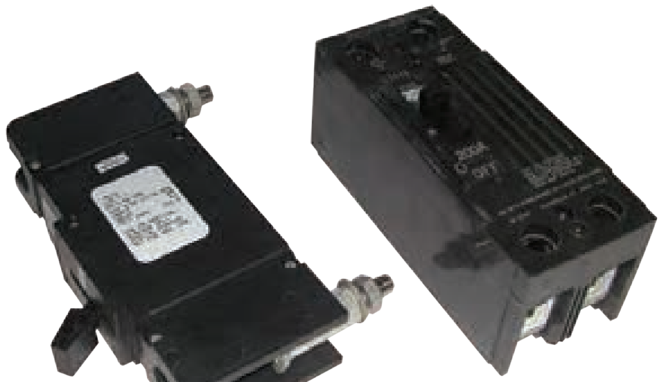
This "main contactor" is installed in the positive or negative line between the propulsion battery pack output and the motor controller input so that battery power can be

Contactors are heavy-duty relays that open and close the high-energy battery circuits in an EV.



Quick Tip

Check and retighten all battery terminal hardware at least once per month, as the vibration experienced in a moving vehicle can cause them to loosen. On a battery terminal, this can cause enough heat to melt a battery post, necessitating expensive battery replacement.



Courtesy www.kta-ev.com

Circuit breakers provide both overcurrent protection and a means of opening the battery-to-controller circuit.

Crimp or Solder?

The debate over whether to crimp or to solder terminal lugs onto heavy-duty cable may go on forever. While some may disagree, the best practice is to crimp all lugs onto wire ends using a proper crimping tool. Should an uncrimped soldered terminal lug secured to a high-current cable ever become loose, it can generate enough heat to melt the solder, causing the lug and cable to separate. A crimped lug will hold to the cable because of its mechanical bond. A crimped and soldered lug will provide maximum mechanical and electrical bonds.

applied or interrupted with the vehicle's key switch. Even though a main contactor's primary function is to *carry* current, the type used should be capable of *breaking* current to an inductive load (i.e., motor) in case of a shorted controller.

The main contactor should be rated for the high voltage and current characteristics appropriate to its application. If a propulsion pack voltage is 120 V and the motor controller current limit is 1,000 A, the Albright Engineering #SW-200B is commonly used. A single #SW-200B contactor is rated only to 120 VDC. When a vehicle's battery system is above 120 V, two #SW-200B contactors may be installed—one in the battery positive line and the other in the battery negative line. Two such main contactors, when activated simultaneously, possess a voltage rating of more than 240 VDC because of their collective interrupting capacity.

Albright contactors include magnetic "blowouts"—small magnets mounted in the switching head of the contactors that have the capability of forcing an electric arc outside of the device, effectively lengthening the path over which the arc must travel. The longer distance an arc travels, the better the opportunity to extinguish it.

Inertia Safety Switch. This device will disconnect the main battery pack from the propulsion drive system in case of an accident. The inertia safety switch is a normally closed, low-voltage/low-current device that switches to open circuit on impact. In an EV, this switch can be wired in series with the 12 V power that activates the main contactor. This switch is rated to perform only low-power switching; the main contactor does the heavy-duty work.

Courtesy www.kta-ev.com

An inertia safety switch provides an automatic disconnect in the event of an accident.

Grounding

A "ground" usually refers to something that is electrically tied to earth ground, but it can also mean being electrically connected to a metallic structure. The high-voltage system in an EV includes the propulsion batteries, contactor, overcurrent protection, disconnects, controller, drive motor, onboard charger, and any lower-current devices that tie into this system. No part of the high-voltage system should be connected to the vehicle frame or metallic body structure. Isolating this system minimizes the possibility of being shocked when touching both a connection point (i.e., a battery terminal) and the body metal. This also minimizes the chance of having a short circuit to the metal body structure or frame if wire insulation becomes frayed or cut and comes in contact with the metal. Some components, including controllers and chargers, are designed not to activate for safety reasons if a high-voltage ground to the chassis is detected.

Wire, Cable, Lugs & Terminals

An EV's wiring should be sized to safely handle the current. Too much current in an undersized wire can cause it to get hot or even catch fire. EVs typically have low-, medium-, and high-

The combination of cable terminal covers, crimped lugs, and heat-shrink tubing make for safe and neat battery cabling.

Courtesy www.evconsultinginc.com

Battery Safety

If properly handled, located, installed, and ventilated, EV batteries can be as safe—if not safer—than gasoline in an internal combustion-powered vehicle. Here's how:

Placement & Containment. Most EV conversions can add as much as 1,200 pounds to the vehicle's stock weight—largely because of the size of the charging system and the weight of the batteries. The first step in a safe conversion is to choose a vehicle with a rust-free, sound body and chassis equipped with good brakes and wheel bearings to handle the additional weight. If possible, try to upgrade any drum brakes to disc for additional stopping power.

Next, it is critical to distribute the battery weight throughout the vehicle and secure the batteries. Too much weight in the back of the vehicle can cause steering sensitivity, making the vehicle too responsive. Yet, too much weight over the front wheels can make every steering-wheel turn an upper-body workout. Distributing the batteries in a way to match the vehicle's original weight over the front wheels should be the goal. The battery weight in the rear will be heavier than stock, and will require the addition of overload springs and/or shock absorbers. Also be sure to mount batteries to maintain the vehicle's low center of gravity.

As a general rule, it's best to keep the batteries out of the passenger compartment for safety reasons. In case of a front or rear collision or a rollover, batteries can leak acid if ruptured or turned upside down. If it's not possible to place them outside of the passenger compartment, you can secure the batteries inside an enclosure.

When it comes to safety, battery containment can't be stressed enough. A plywood or plastic box is not sufficient to hold the batteries in place during a collision—unsecured batteries have the mass and momentum to break this type of enclosure and launch like deadly acid missiles. Batteries should be held firmly in place with metal battery trays and hold-downs, which can be fabricated from steel or aluminum angle stock. All framework should be welded for maximum strength, and the finished cage should be securely bolted to the vehicle floor or frame with bolts, nuts, and large-diameter washers.

Ventilation. Flooded lead-acid (FLA) batteries are the most common propulsion batteries used in EV conversions today. FLAs will begin to produce hydrogen gas at about 2.37 V per cell during the last 20% of the charging cycle. While the possibility of enough hydrogen collecting to explode is low, caution and safety are always recommended. With batteries housed in an enclosure, fans and vents should be used to exhaust any hydrogen gas outside the vehicle.

Handling. When handling or working around batteries, safe practices should be followed:

- Wear heavy-duty shoes and gloves in case a battery slips while being placed or moved, or electrolyte leaks or spills.
- Wear a face shield or goggles to protect your eyes in the event of an explosion or acid spray.
- To prevent shorting, wrap electrical tape around the unused end of any tools used for removing, installing, and/or tightening battery terminal hardware.
- To prevent electrical shock or shorting, place an insulating cover, such as a small piece of plywood or other insulating material, over the tops of batteries adjacent to the one you're working on.

Disc brakes help compensate for extra battery weight.

In this EV, 75% of the batteries are placed in the rear for good weight distribution.

About 25% of the batteries are placed in the front to help match the original weight over the front wheels.

Courtesy www.evconsultinginc.com (3)

current circuits. Low-current circuits, such as instrumentation and control lines, can be wired using #16 to #20, insulated, stranded copper wire. Medium-current circuits, such as to the vacuum system, DC–DC converter, and battery charger, can be wired using #10 to #14 wire.

Most EV conversions use #2/0 welding cable for the high-current propulsion drive system and between the propulsion batteries. With its many strands of very fine wire, flexible welding cable is preferred over stiffer electrical cable types. #2/0 welding cable is suitable for most EV applications of several hundred amps. If the cable lengths are short (as is best) between the motor and controller, #2/0 cable can support up to 1,200 A intermittently. When deciding the proper size of wire or cable to use for an application, consult with the wire manufacturer's ampacity tables. Keep in mind that these tables are for continuous current flow—not intermittent.

Heavy-duty automotive-type posts with crimped clamp-style—not pressure-contact—terminals are the best connections to use with propulsion batteries. The combination of an automotive post and a heavy-duty clamp terminal offers low contact resistance, low maintenance, and high reliability. Once a clamp terminal is crimped onto a cable end, the copper conductors in the cable can be sealed from potential corrosion by using heat-shrink tubing that contains a mastic glue sealer. Another advantage to using clamp-style terminals is that red and black rubber covers are available to further prevent corrosion and also to insulate them from electrical shock hazard. Ring lugs with L-terminals are a good second choice.

In a typical EV conversion, most of the propulsion batteries will be located in the rear of the vehicle, with only a few batteries in the front. This almost always results in running two interconnecting cables beneath the vehicle. To minimize the risk of these cables being scraped or cut by road debris, place them within jacketing, such as flexible or rigid PVC conduit or rubber heater hose, for protection. Likewise, wires of any size that are routed through sheet-metal holes or close to sharp metal edges should be jacketed with plastic wire wrap or grommets to prevent cutting or abrasion.

Access

Ken Koch (amphawg@aol.com) is the former owner of KTA Services Inc., an electric vehicle conversion kit and component supply business that has sold more than 1,200 conversion kits since 1984. His latest business venture—EV Consulting Inc. (www.evconsultinginc.com)—provides consulting, system design, and computer modeling for DC systems.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Combiners to DC Disconnects

by John Wiles

This "dead front" combiner has terminals safely covered.

In *HP128, Code Corner* addressed some code requirements for PV arrays; *Code Corner* in *HP129* covered the math associated with voltage calculations. Now, it's time to safely route that power from the array.

The PV Combiner

PV-source circuits route from the array through combiners (on medium and large systems) and then on to the DC PV disconnect. Normally, two strings of modules can be connected in parallel without requiring a combiner containing overcurrent devices—see *NEC* Section 690.9(A) EX. Batteryless grid-tied PV systems rated above 6 kW may be configured with more than two strings. Since rated voltages range widely and module power ratings can vary from 40 to 300 W, there are no hard-and-fast rules relating the need for a DC combiner to a specific number of modules in an array. If more than two strings are needed, then overcurrent protection on each string may be required and these overcurrent devices are placed in a PV source-circuit combiner (see *Code Corner* in *HP125*).

A combiner may use fuses (typically on high-voltage, utility-interactive systems) or circuit breakers (commonly used on systems operating at 60 volts or below). The *2008 NEC* requires that combiners be listed to UL Standard 1741—the PV inverter standard: 690.4(D). Although listing is required, UL 1741 has not yet been modified to specifically require that combiners be "dead front" (have nonexposed circuit terminals and busbars once opened).

In cold weather, voltages on the exposed terminals and busbars may approach 600 V on many systems. These combiners meet the intent of the *NEC* requirement that a tool be used to access energized surfaces such as terminals and busbars—the combiner shown above has a cover that requires a screwdriver to open.

This combiner has accessible terminals that may be energized when open.

Array to Disconnect

Conductors between modules and those between one end of a string and the other may be single conductor cables in free air. However, as soon as the PV circuits leave the array location, they must transition to a standard *NEC* Chapter 3 wiring method. For roof-mounted systems, that wiring method must be suitable for hot, wet environments and include UV resistance. Electrical metallic tubing (EMT) is frequently used. Conductors are selected based on the short-circuit current being carried in that circuit and must be corrected for the conditions of use, such as on rooftops. In many cases, terminal temperature limitations on combiners or fused disconnects may dictate further ampacity corrections (see *Code Corner* in *HP122* for details).

An equipment-grounding conductor should be run with the circuit conductors in the conduit. In many systems, the equipment-grounding conductors may be as small as #14 between the PV modules. However, in areas where wind, snow, ice, and other environmental factors may introduce mechanical damage, a larger equipment-grounding conductor between modules should be considered (Section 690.46). Where the PV source circuits are unfused, the *2005 NEC* calls for sizing the equipment-grounding conductor based on 125% of the circuit's rated short-circuit current (Isc). In the *2008 NEC,* Isc is used directly in Table 250.122 to select an equipment-grounding conductor. The reduction in size of the DC equipment grounding conductor is due to the *2008 NEC* requirement that nearly all PV systems have ground-fault protection. On systems with PV source or output circuit fuses, the normal procedure is to use the fuse value in Table 250.122 to look up the required equipment-grounding conductor size (690.45).

The DC PV Disconnect

According to Section 690.14 of the *NEC*, the DC PV disconnect should be installed in a readily accessible location, either inside or outside the building at the point of first penetration of the conductors.

Since Section 690.31(E) allows the PV source or output conductors to penetrate the building surface on the roof (if they are routed in a metal raceway inside the building), it appears that the PV disconnect can be mounted inside the building in any readily accessible location. However, this *NEC* allowance may not be the safest option or even very clearly defined in the *Code*.

This parallel wording of 690.14(C)(1) with the requirements for the AC service disconnecting means that 230.70(A)(1) may need further examination. In the world of AC utility power, removal of the AC revenue meter can effectively disable the AC power in a structure, regardless of the AC service disconnect location. With a DC PV disconnect inside a locked structure, the “readily accessible” definition may not be appropriate. On residences, many jurisdictions require that the PV disconnect be located within sight of the AC service disconnect or meter, which typically means on the building’s exterior. On commercial buildings, the PV system may be located far from the AC service disconnect and a directory may be used to show the location of all disconnects, both AC and DC (Section 705.10). When in doubt, consult with the authority having jurisdiction.

The PV disconnect should break all ungrounded conductors but *should not* open a grounded conductor. Grounded conductors in PV systems might be either the negative or positive source-circuit conductors and should have white insulation, or where larger than #6, be marked with a white marking. The type of module determines which circuit conductor should be grounded and the inverter must be compatible with the polarity of the grounded conductor.

If the grounded source-circuit conductor *is* opened by the switch in the disconnect, the marked grounded conductor becomes *ungrounded* and may be energized with respect to ground, up to the open-circuit voltage of the system. This represents an unsafe condition for servicing the PV array. For that reason, the *NEC* prohibits the use of disconnects, breakers, or fuses in grounded PV DC conductors unless they are part of an automatic ground-fault detection/interruption system (Section 690.13).

A properly labeled PV disconnect.

PV disconnects properly installed in a readily accessible location.

Section 690.17 and 690.53 of the *NEC* require labeling on the front of a PV DC disconnect. The 690.17 warning is required because the load terminals of this disconnect are connected to the inverter DC input, which may still be energized for up to five minutes after the disconnect has been opened, as capacitors in the inverter are gradually discharged. The 690.53 label, with the DC voltage and current ratings, allow the AHJ to determine that the correct cables have been installed.

Although insulation partially covers upper line-side terminals on disconnects, the switch blades, fuse holder terminals (if any), and the lower, load-side terminals are exposed and easily touched. In the PV DC disconnect, the PV source or output circuits should always be connected to the line-side terminals. Electricity flows from the PV array through the DC PV disconnect, the inverter, the AC disconnect, and, finally, to the grid, so a general safety rule is that the most dangerous circuits should be connected to the protected line-side terminals. The DC input to the inverter is connected to the load-side terminals, and the 690.17 warning label is required as shown.

Attention to the *NEC* requirements in 690 and other articles, plus an understanding of PV equipment and how electricity flows in a PV system, should enable these systems to be installed and operated in a safe manner.

Access

John Wiles (jwiles@nmsu.edu; 575-646-6105) works at the Institute for Energy and the Environment (IEE) at New Mexico State University. IEE provides engineering support to the PV industry and a focal point for code issues related to PV systems.

Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist, previous *Perspectives on PV* and *Code Corner* articles, and *Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices*, by John Wiles

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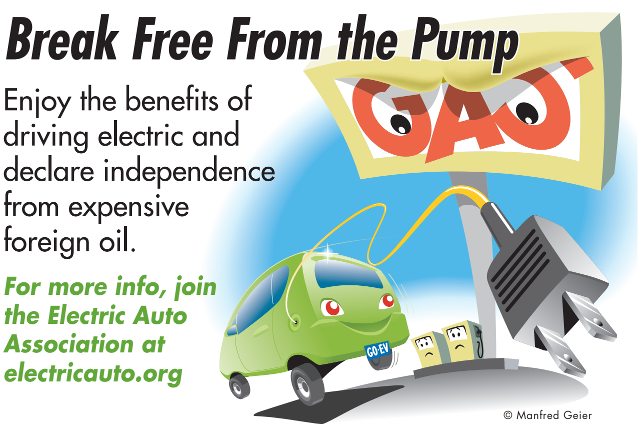

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It Takes An Act of Congress

by Michael Welch

Did you know that U.S. citizens, we taxpayers, actually own a coal-fired power plant? Managed by Congressional vote and administered by the Capitol architect, it sits just blocks away from the Capitol. Long ago, it provided heat and electricity directly to the Capitol itself, but now the power plant makes only steam to heat and cool the structure and 21 other nearby buildings via a maze of underground, asbestos-laden pipes.

The Capitol Power Plant was built nearly a century ago and, as you might imagine, produces pollutants typical of older coal plants. According to a report by the nonprofit Clean Air Task Force, an estimated 515 Washingtonians die each year due to power plant emissions, and the Capitol plant is responsible for 65% of the area's particulate emissions most often associated with ill health effects. Bad, but there are dirtier plants around the nation—so what makes this one special?

Just as Congress has tried to address climate change, they have also tried to deal with this power plant—which literally takes "an act of Congress" for changes to be made. In 2007, House Speaker Nancy Pelosi initiated a project to "green" the Capitol, and switching the Capitol Power Plant to biofuels and natural gas—cleaner-burning fuels—was a proposed part of that effort. Successful in the House, efforts to clean up the power plant have been stymied by powerful Senators Mitch McConnell and Robert Byrd from the coal-bearing states of West Virginia and Kentucky, respectively.

Protesting Coal in Congress

On March 2, the power plant site will have been the target of massive civil disobedience and, as predicted by Greenpeace, "the largest mass mobilization on global warming in the country's history." This power plant is the ultimate and perfect place for a major protest. "This demonstration marks the beginning of a sustained effort to draw a line in the sand against this dirty and dangerous fuel," said Matt Leonard of Greenpeace. "Our leaders cannot promise us a healthy and prosperous future as long as coal is polluting our soil, water, and atmosphere."

Recent news events point out that pollution from burning coal is not the only associated problem. Last December, more than 1 billion gallons of toxic coal combustion waste broke free from coffers at the Tennessee Valley Authority's Kingston Fossil Plant, covering more than 300 acres near Harriman, Tennessee, then flowing into tributaries to the Tennessee River—the source of drinking water for millions living in Tennessee, Kentucky, and Alabama. Then, less than a month later, another TVA waste pond ruptured in Alabama. About 1,300 of these impound ponds are spread across the nation—and, despite toxic materials like lead, arsenic, and mercury that may be leaching into groundwater and soil, they are not yet regulated by the Environmental Protection Agency. According to *The New York Times*, "The lack of uniform regulation stems from the EPA's inaction on the issue, which it has been studying for 28 years. In 2000, the agency came close to designating coal ash a hazardous waste but backpedaled in the face of an industry campaign." Of course, the coal industry and its politicians will continue the fight against such regulation, in part because the waste is used as infill for land and in highway construction, and regulation would make its storage and disposal more difficult and costly.

Besides unearthing toxic metals, mining coal causes other problems. Coal producers have found that the cheapest and easiest way to access coal seams is to simply remove the mountaintops that cover them. *USA Today* quoted an EPA source in reporting that, "More than 700 miles of streams across central Appalachia were buried by valley fills from 1985 to 2001" and that "without further restrictions, 2,200 square miles of Appalachian forests—an area twice the size of Rhode Island—will be eliminated by 2012." Just prior to the end of its era, the Bush administration worked overtime to slacken environmental regulations that applied to its benefactors. One of those efforts resulted in a ruling from the Interior Department's Office of Surface Mining that coal mines may dump the millions of tons blasted from the tops of mountains into valleys within 100 feet of waterways, if they can show cause for why it should be done. Previously, regulations required no dumping within 100 feet of streams.

The laws that deal with mountaintop removal are complex and include the 1972 Clean Water Act and the Surface Mining Control and Reclamation Act of 1977. But loopholes and intent in the laws leave some details to the regulatory agencies, which are appointed by Presidential administrations, making interpretation and enforcement subject to political influence.

Despite President Obama's voter mandate to clean up the environment and stimulate the economy—and accomplishing this with a minimum of legislative pork—the power of entrenched politicians and their own agendas remains. Coal companies and other lobbyists and campaign contributors remain a major stumbling block in our system.

Climate Action through Civil Disobedience

Last September, former Vice President Al Gore said, "I believe we have reached the stage where it is time for civil disobedience to prevent the construction of new coal plants that do not have carbon capture and sequestration."

Nonviolent civil disobedience is the last resort for people who want a more just world and are having troubles getting the job done through legal channels. The dictionary definition of "civil disobedience" is *refusal to obey governmental demands or commands, especially as a nonviolent and usually collective means of forcing concessions from the government.*

Every organized use of nonviolent civil disobedience has a code that it requires participants to follow. Participants in the Capitol Power Plant action are required to adhere to the following:

- We will use no violence (physical or verbal) toward any person.
- We will not destroy or damage property.
- We will promote a tone of respect, honesty, transparency, and accountability in our actions.
- We will not carry anything that can be construed as a weapon, nor possess (or consume) any alcohol or drugs.
- We will all hold each other accountable to respecting these agreements.

The National Lawyers Guild offers handbooks for those interested in protesting or civil disobedience at www.nlg.org/resources/publications_handbooks.php.

Campaign Changes

Although Obama campaign promises included focusing on human-caused climate change and stimulating our faltering economy with increased investment in clean technologies and infrastructure, promises are hard to keep when a huge part of the political machine is set on obstructing the process, just as what happened with trying to clean up the Capitol Power Plant.

When his economic stimulus plan hit the House of Representatives, not a single Republican voted for it, despite overwhelming public support. Enough Democrats were in favor of the bill to make it pass. The Senate is a different story, as the Democrats do not have a large enough majority to break a filibuster if one is mounted by the Republicans. So Obama and the Democrats worked hard to negotiate a bill that would gain a handful of Republican votes—just enough to pass. But powerful coal- and nuclear-supporting Senators managed to squeeze in a provision that added $50 billion in loan guarantees to be available for nuclear and coal power plant construction.

The next step was a conference committee made up of representatives from both legislative bodies and both major political parties to negotiate the final bill, since the House and Senate bills are different. Everything about the stimulus bill was back on the table for discussion. The public response to the dirty-energy threat was phenomenal, with the result that the loan guarantees were axed by the committee.

Optimism over the new administration is running high, but the momentum of the old political machines that favor industry over everything else will be hard to overcome. Certainly, it has been proven effective for the citizenry to take things into their own hands, by vote and direct contact with legislators and regulators or, failing that, the direct action of nonviolent civil disobedience.

Access

Michael Welch (michael.welch@homepower.com)—a firm believer in the power of direct action—missed the Boston Tea Party by a couple hundred years, but has been arrested several times protesting war and nuclear energy in California.

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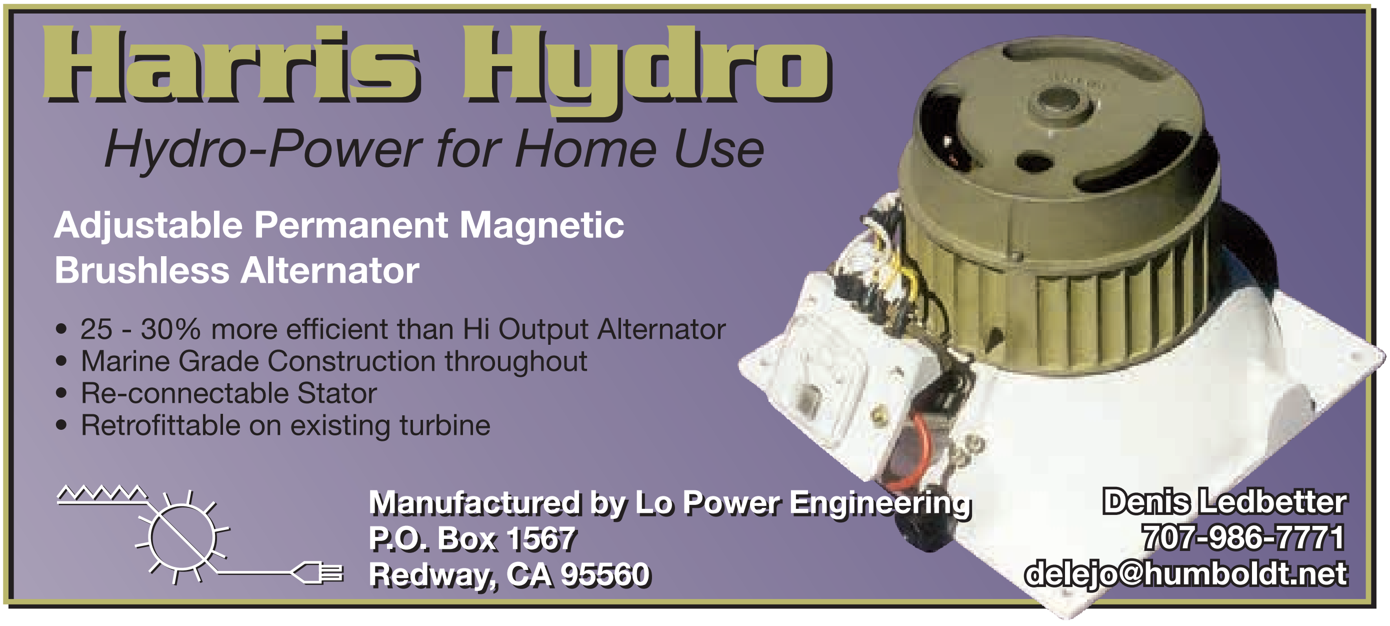

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Re-Cycling

The Jeinkel–Heimer Story

by Kathleen Jarschke-Schultze

My childhood in a big family—two boys and three girls—in the ’50s was rife with bicycles. Ever since they were my two big “bothers” and I was their little “blister,” our resident boy geniuses used our bikes as a starting point of experimentation. Metamorphosed into four-person bikes, and three- and four-wheeled carts, our bikes were like wheeled Erector sets in their hands.

Self-modeled after two of their heroes, Wilbur and Orville Wright, my two older siblings called themselves the Wrong Brothers. The front face of the hill we lived on was dubbed “Kill Devil Hill” in honor of the place the Wrights made their first flight. Our hill was where we performed test runs of the wheeled contraptions the boys built.

One of the boys would pilot the first test run. If he made it to the creek at the bottom without crashing, we would push the cart to the top of the hill again. Then, all of us would climb on, hanging on wherever we could, to make a second run. This is where the cart would show its true mettle (or not). If it hung together and made it to the creek—with or without us still on board—it was deemed a success. If not, the broken hulk was returned to the garage to be cannibalized—emerging at a later date as a newly reincarnated ride.

Through the years, my brothers’ interest in bicycles never waned. Between the two of them, they still own more than 14 assorted styles of bicycles. Over the last decade, they have been working on a fascinating and very practical project together. Today, a blog chronicles their efforts to perfect a bike that’s time has come, a bicycle that answers the question: “Sure, bikes are good for the Earth and good for my health, but how can you go shopping or carry anything on one?”

My brothers assumed nom de plumes for the blog: Ernst “Fritz” Jeinkel and Heinrich “Heinz” Heimer are featured along with our dad, who is referred to as “Gramps.” The Jeinkel–Heimer site does not sell anything—information is power, after all. It’s all about the years they’ve spent designing an ever-better sidecar bike, capable of carrying another person or a load of cargo.

Proto Types

Their first sidecar bike was called Proto I, or “Old Grey.” Fritz took some old bikes and parts to “Victor,” a metalworking friend, and, as he tells it, said, “Could you weld these together so I can put a chair between them?” Victor, in his usual relaxed tone, replied, “Oh, yeah, I could do that, but when I got it done, it would look like crap.” Fritz rephrased his request. "Victor," he said, "would you consider these parts sacrificial and give me a platform beside my bike that is about 5 inches off the ground, 4 feet long and about 26 inches wide?" To that, Victor replied, "Sure, I could do that."

Old Grey worked right out of the gate, but needed fine-tuning. Fritz and Old Grey worked that summer at a large country fair for the alter-abled crew, ferrying people in wheelchairs from the hot, dusty parking lot. He devised a way to secure a wheelchair onto the sidecar platform. If needed, he could attach a chair so he could transport people without wheelchairs.

One of Fritz's passengers that first year was a young quadriplegic. He used a pointer in his mouth to tap out his words on a keyboard. After Fritz brought him into the fairgrounds from the field that served as the parking lot, he tapped out, "Thanks, that was my first bike ride!" In the mornings before the fair opened, Fritz and Old Grey also made supply deliveries to booths within the fair. Fritz quickly became known as the "sidecar guy."

The success of Proto I spawned Proto II, a.k.a. the White Wizard. A close relative under Fritz and Heinz's sphere of influence took some bikes and parts to a welder and had a sidecar bike made. Without the testing, adjusting, and design process used by Fritz and Heinz, Proto II had some issues. For instance, riding the cycle unloaded was very difficult—the bike always wanted to lean to the left. After some consultation and design correction at Jeinkel–Heimer Central, the White Wizard was ready to go to work. Now, two sidecar bikes transport passengers from the fair parking lot.

With the popularity of Old Grey and the White Wizard, Fritz and Heinz realized the importance of their design and redesign experience. They believe that a bicycle capable of carrying in excess of 500 pounds, two passengers, or long, heavy objects has universal appeal and possibilities that we have only begun to imagine. Thus Proto III, the Blue Ferry, was conceived.

Fritz and Heinz learned to bend tubing so they could control the design process and modify the plans. In the first phase, a sidecar model was assembled from coat-hanger wire and trick photography was used to superimpose the wire frame over the bike (my favorite photo on their blog). This gave them a view of the frame compatibility before bending the tubing.

20/20 Heinz Zeit

Their sidecar bikes already generate quite a stir when they're out and about. Mostly, people are enthusiastic about how a bike like that could fit into their lives: "I could haul my dog/groceries/tools/camping gear."

Having used their sidecar bikes over the past 10 years, the boys have now decided to make available as much information as they have discovered, presenting information on the theory, planning, fabrication, and testing required to produce a sidecar bike. Their blog has step-by-step assembly photos and notes on the Blue Ferry.

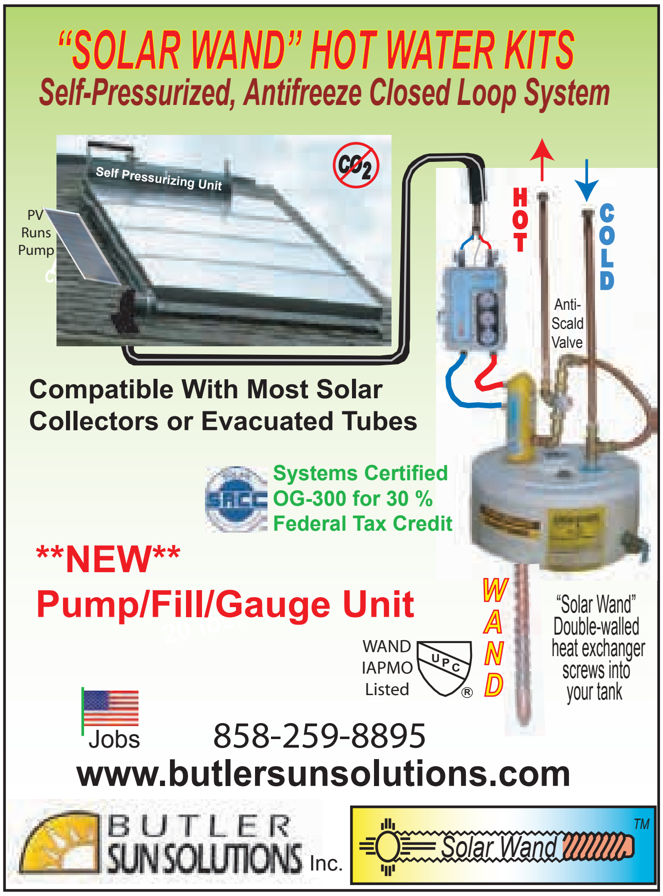
The years of practical, real-life use have revealed specific problems that have been corrected. By welcoming comments, questions, and incorporating other people's ideas and experiences, Fritz and Heinz hope to see more sidecar bikes in daily use. Their theory is that the more people communicate information about this mode of transport, the more viable it will become. Their creations embrace the philosophy of reducing fossil fuel use, reusing parts of one thing to make another—and of re-cycling, for the benefit of ourselves and our world.

I guess they're not such big "bothers" after all.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is reintroducing free-range chickens, under the watchful eyes of Ned, the rooster, to her off-grid home in northernmost California.

Jeinkel–Heimer bicycle sidecars by Lifting Bodies • www.jeinkel-heimer.com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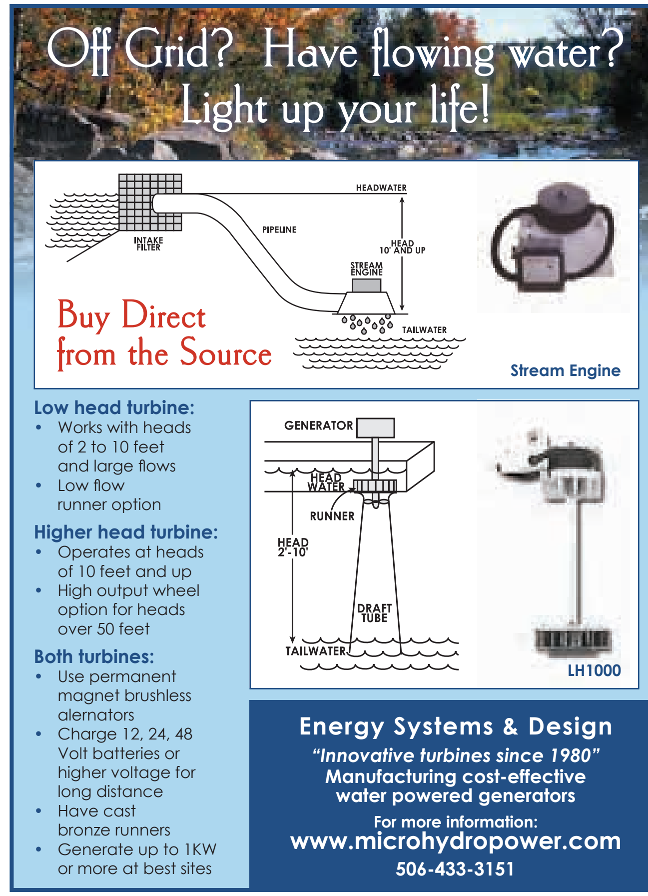
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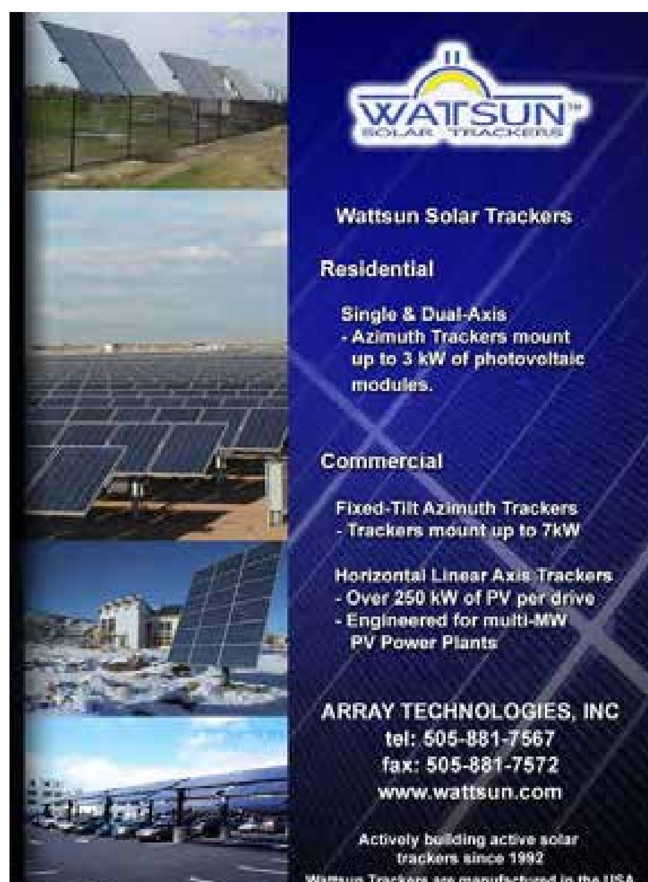
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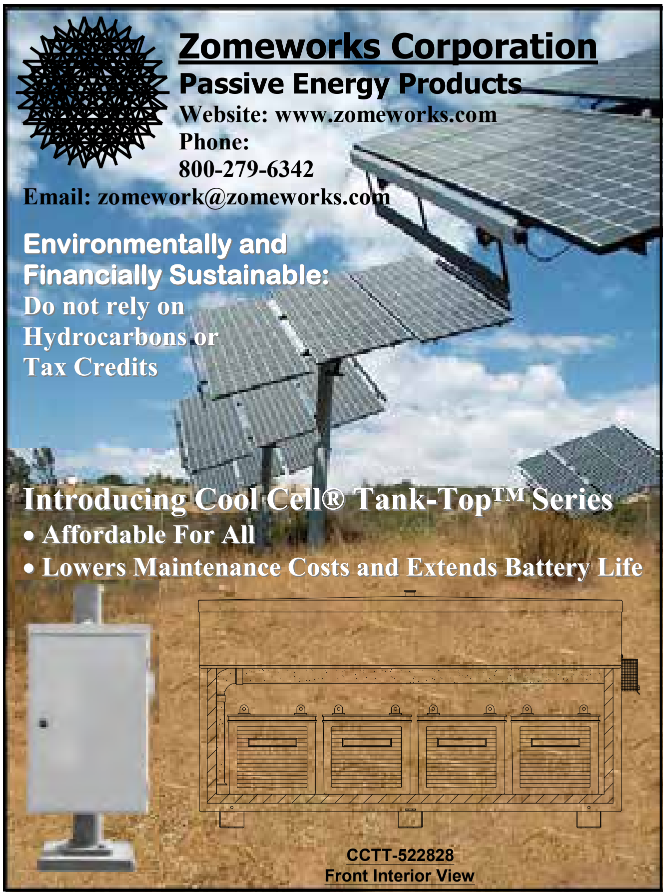
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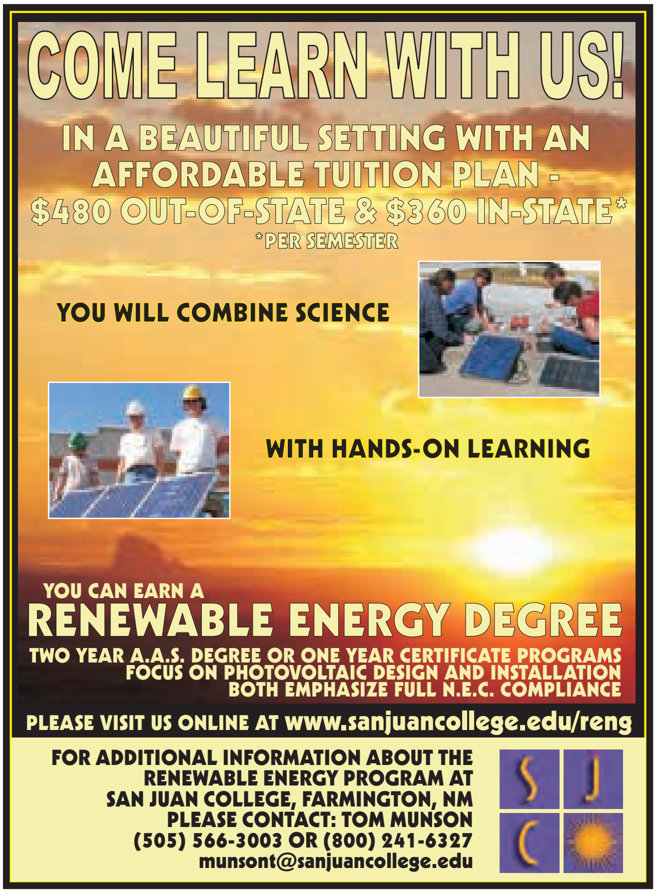
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RE happenings

CALIFORNIA

Jul. 14–16, '09. San Francisco. Intersolar North America. Solar trade exhibition & conference. Market developments & trends, government policies & the latest technology & products. Info: www.intersolar.us

Aug. 8–9, '09. Hopland, CA. SolFest. RE booths, workshops & kids' activities. Food & entertainment. Info: www.solfest.org

Oct. 27–29, '09. Anaheim, CA. Solar Power 2009. Conference & expo. Info: SEIA • 202-296-1688 • www.solarpowerconference.com

Arcata, CA. Workshops & presentations on RE & sustainable living. Info: Campus Center for Appropriate Technology • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Carlsbad, CA. PV installation training for NABCEP certification. Info: www.aptc.edu

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

COLORADO

May 21–24, '09 (Again Jun. 4–7, Jul. 23–26, Aug. 20–23). Solar Heating & Natural Bldg. Design workshop. Info: Crestone Solar School • www.crestonesolarschool.com

Aug. 29–30, '09. Crestone, CO. Crestone Energy & Sustainability Fair. www.joinLAS.com

Sept. 18–20, '09. Fort Collins, CO. Rocky Mt. Sustainable Living Fair. Exhibits, workshops, RE, alternative vehicles & more. Info: • kellie@sustainablelivingfair.org • www.sustainablelivingfair.org

Carbondale, CO. Workshops & online courses on PV, water pumping, wind, RE businesses, microhydro, solar hot water & more. Info: Solar Energy Intl. • 970-963-8855 • sei@solarenergy.org • www.solarenergy.org

FLORIDA

Melbourne, FL. Green Campus Group meets monthly to discuss sustainable living, recycling & RE. Info: fleslie@fit.edu • http://my.fit.edu/~fleslie/GreenCampus/greencampus.htm

ILLINOIS

May 2–3, '09. Carbondale, IL. Shawnee Energy Fest. Energy & home improvement fair. Vendors, workshops, speakers, tours & kids' activities. Info: www.shawneeenergyfest.com

Aug. 8–9, '09. Oregon, IL. IL RE & Sustainable Lifestyle Fair. RE booths, workshops, tours & kids' activities. Food & entertainment. Info: www.illinoisrenew.org

IOWA

Sep. 12–13, '09. Cedar Falls, IA. I-Renew Energy Expo. Workshops, exhibits, food, entertainment. Info: www.irenew.org

Iowa City, IA. Iowa RE Assoc. meetings. Info: 319-341-4372 • irenew@irenew.org • www.irenew.org

MASSACHUSETTS

May 18–20, '09. Boston. Alternative Energy & Building Efficiency '09. For retailers of RE & building efficiency products. Info: www.alternativeenergyshows.com

Hudson, MA. Workshops: PV, wind & solar thermal. Intro to advanced. Info: The Alternative Energy Store • 877-878-4060 • workshops@altestore.com • http://workshops.altenergystore.com

MICHIGAN

Jun. 26–28, '09. Onekama, MI. Michigan Energy Fair. Workshops, exhibits & speakers on solar, wind, alt. transportation & building. Info: www.glrea.org

West Branch, MI. Intro to solar, wind & hydro. 1st Fri. each month. Residential system design & layout. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

MISSOURI

Gerald, MO. Workshops on energy efficiency, PV, wind, solar heating & more. Info: Evergreen Institute • info@evergreeninstitute.org • www.evergreeninstitute.org

New Bloomfield, MO. Workshops, monthly energy fairs & other events. Info: Missouri Renewable Energy • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

MONTANA

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

NEW HAMPSHIRE

Rumney, NH. Green building workshops. Info: D Acres • 603-786-2366 • info@dacres.org • www.dacres.org

NEW MEXICO

Sep. 26–27, '09. Albuquerque. Solar Fiesta. RE & EE exhibits & workshops. Info: (see below)

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

NEW YORK

Apr. 24–26, '09. Canton, NY. North Country Sustainable Energy Fair. Workshops, exhibits, food, kids' area. Info: fair@ncenergy.org • www.ncenergy.org

May 12–16, '09. Buffalo. Solar 2009. Conference & exhibition of ASES. Info: www.solar2009.org

NORTH CAROLINA

Aug. 21–23, '09. Fletcher, NC. Southern Energy & Environment Expo. RE displays, exhibits & presentations. Info: www.seeexpo.com

Saxapahaw, NC. Solar-powered home workshop. Info: Solar Village Inst. • 336-376-9530 • info@solarvillage.com • www.solarvillage.com

OREGON

May 1–3, '09. Portland. Northwest Solar & Clean Tech Expo. Workshops, seminars & exhibits on clean energy. Info: www.nwsolarexpo.com

Jul. 24–26, '09. John Day, OR. SolWest RE Fair. Exhibits, workshops, speakers. Info: EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

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

PENNSYLVANIA

Sep. 18–20, '09. Kempton, PA. PA RE & Sustainable Living Festival. RE, natural building & sustainable ag; workshops, speakers, exhibits. Info: www.paenergyfest.com

Philadelphia Solar Energy Assoc. meetings. Info: 610-667-0412 • rose-bryant@verizon.net • www.phillysolar.org

RHODE ISLAND

Jun. 6–7, '09. Coventry, RI. RI Sustainable Living Festival & Clean Energy Expo. RE, efficiency & building; workshops, music & exhibitors. Info: www.livingfest.org

TENNESSEE

Summertown, TN. Workshops on PV, alternative fuels, green building & more. Info: The Farm • 931-964-4474 • ecovillage@thefarm.org • www.thefarm.org

TEXAS

Sep. 25–27, '09. Fredericksburg, TX. RE Roundup & Green Living Fair. Exhibits, speakers & workshops on RE, green building, green ag & EE. Info: www.theroundup.org

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

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

VERMONT

May 11–16, '09. East Charleston, VT. PV design & installation. Hands-on course, incl. site analysis, design, and a system installation. Info: NorthWoods Stewardship Center • 802-723-6551 x113 • jayson@northwoodscenter.org • www.northwoodscenter.org

Jul. 10–12, '09. Tinmouth, VT. SolarFest. RE workshops, speakers, music, theatre, food & more. Info: www.solarfest.org

WASHINGTON STATE

May 2, '09. Lacey, WA. Lacey Alternative Energy Fair. Info: 360-491-0857 • www.ci.lacey.wa.us/events/updates/lacey_event_b.html

Jul. 18, '09. Shoreline, WA. Shoreline Sustainable Living & RE Fair. Exhibits & speakers. Info: www.shorelinesolar.org

Guemes Island, WA. SEI '09 workshops. Apr. 6–11: Wind-electric systems maintenance & repair; Apr. 13–18: Homebuilt wind generators. Info: See SEI in Colorado listing. Local coordinator: Ian Woofenden • 360-293-5863 • ian.woofenden@homepower.com

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Amherst, WI. Artha '09 workshops: Intro to Solar Water & Space Heating Systems; Installing a Solar Water Heating System; Living Sustainably & more. Info: 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

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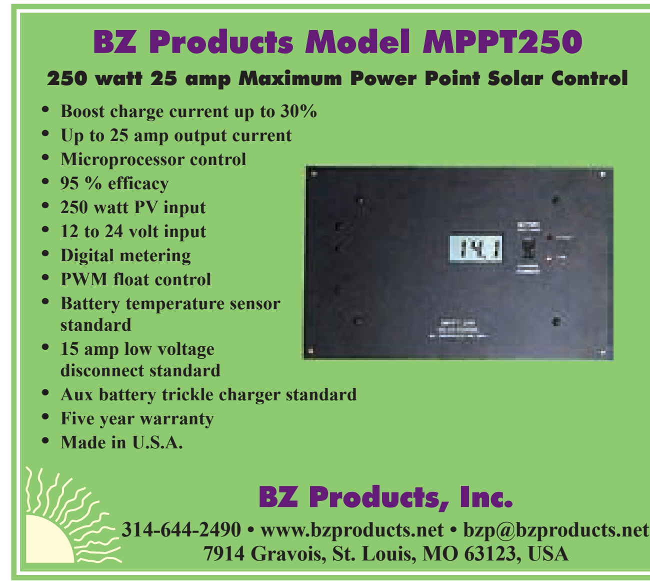
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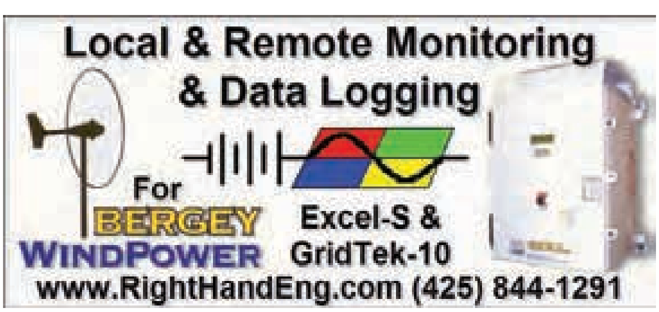
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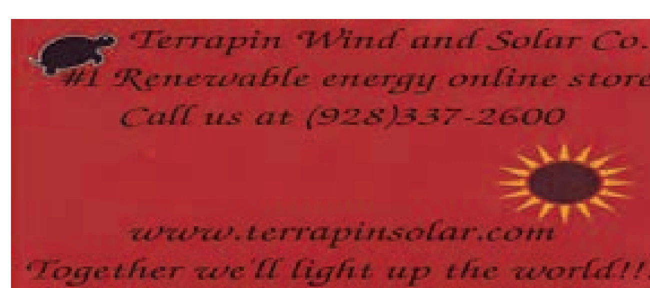
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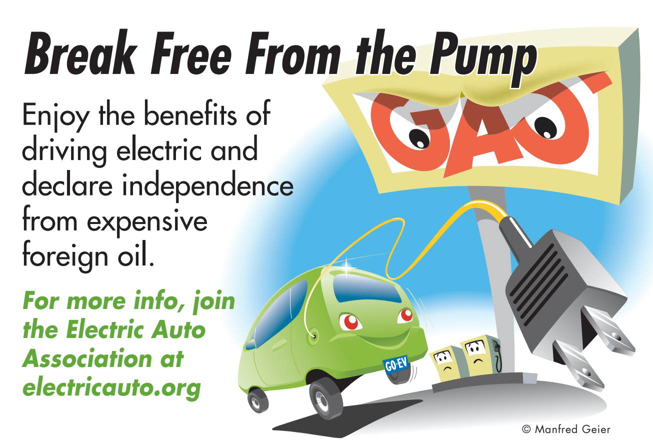
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Choosing a Backup Water Heater

Solar water heating systems usually include some type of conventional water heater as a backup for cloudy weather or for when hot water demand is unusually high. But choosing the most cost- and fuel-efficient backup can be challenging, since the fuel types and efficiencies are like apples and oranges. Here's an easy method for figuring out your best choice.

Electric water heaters are easy to compare since they all use the same fuel source. **Tank-style electric water heaters** have an efficiency of about 90% because of the standby loss through the tank insulation, while **on-demand (tankless) electric water heaters** are rated at 100% efficiency—they convert all the energy to hot water. Electrical efficiency estimates are derived from heat energy transferred to the water and do not include utility or home generation and transmission inefficiencies.

Because of heat loss through the uninsulated flue pipe, **tank-style fossil-fuel water heaters** have lower efficiencies, ranging from 60% to 65%. **On-demand gas water heaters** offer more efficiency (at about 80%), and **high-efficiency (HE) condensing tank-type gas water heaters** are the most efficient at about 86%. (Note: At high altitudes, fossil-fuel water heaters lose some efficiency due to decreased oxygen levels in the air.)

An electric on-demand (tankless) water heater.

But comparing one fuel source against another can be difficult—like figuring out whether you should replace your old natural-gas-fired tank-style unit with an on-demand electric heater. To accurately compare fuel costs, it is easiest to convert the Btu content of each therm or gallon of fossil fuel into kWh (electric energy unit) equivalents—1 kWh is equivalent to 3,412 Btu. Then you can factor in the efficiencies of the water heaters (see the table below). The second part of the table shows the fuel costs in dollars per kWh for each water heater type and for a range of fossil fuel costs. This allows a comparison of the fossil-fuel cost to the cost per kWh.

For example, the table indicates that the cost to operate a propane tank-style water heater is equal to about 17.2 cents per kWh at a propane cost of $3 per gallon. In this case, an electric tank-style water heater would be a better value if electricity cost 15 cents per kWh or less. At 90% efficiency, the electric tank will cost the equivalent of 16.6 cents per kWh.

A typical tank-type gas water heater.

Dollars aside, electric water heaters can also be supplied by renewable energy generated by PV modules, wind-electric systems, or hydro-electric turbines for pollution-free water heating—whereas fossil-fuel heaters cannot. Another possibility is heat-pump water heaters. They boast "efficiencies" of about 200%, delivering twice as much heat energy as the electricity they consume, but are expensive and require greater infrastructure (ground or water source) to attain those efficiencies.

—Chuck Marken

Kilowatt-Hour Conversions & Heater Fuel Costs

						kWh Equivalent Heater Fuel Costs @ Cost Per Unit, Fuel Cost Per Gallon or Therm					
Fuel	**Heater Type**	**Fuel Unit**	**Btu Content Per Unit**	**Heater Efficiency**	**kWh Per Unit @ Efficiency**	**$1.00**	**$1.50**	**$2.00**	**$2.50**	**$3.00**	**$3.50**
Heating oil	Tank	Gal.	139,000	60%	24.4	$0.041	$0.061	$0.082	$0.102	$0.123	$0.143
Natural gas	HE tank	Therm	100,000	86%	25.2	0.040	0.060	0.079	0.099	0.119	0.139
	Tank	Therm	100,000	65%	19.1	0.052	0.079	0.105	0.131	0.157	0.184
	Tankless	Therm	100,000	80%	23.4	0.043	0.064	0.085	0.107	0.128	0.149
Propane	HE tank	Gal.	91,600	86%	23.1	0.043	0.065	0.087	0.108	0.130	0.152
	Tank	Gal.	91,600	65%	17.5	0.057	0.086	0.115	0.143	0.172	0.201
	Tankless	Gal.	91,600	80%	21.5	0.047	0.070	0.093	0.116	0.140	0.163