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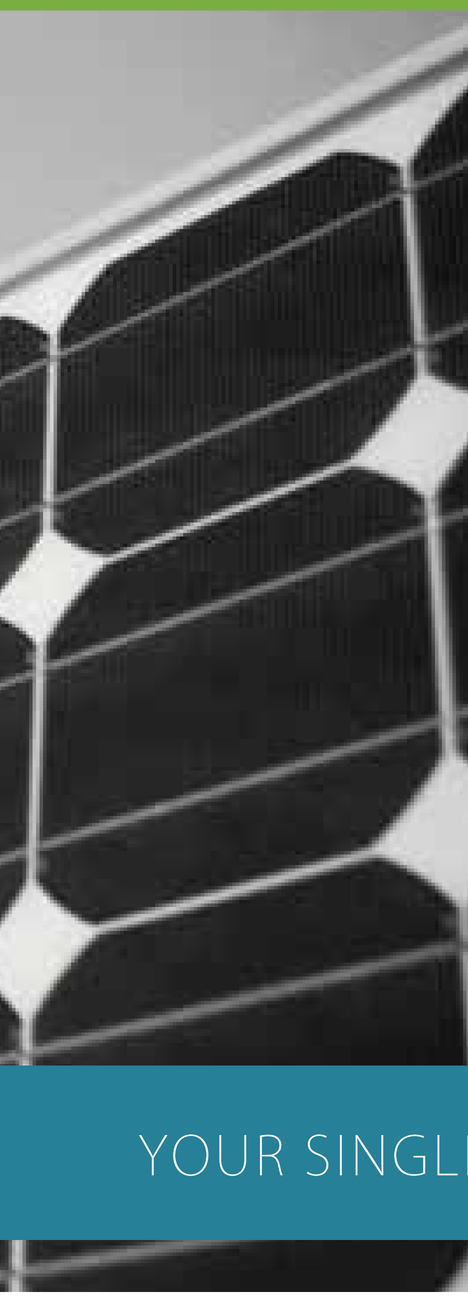

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Main Features

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Jacob Wood of True South Solar on Brammo's Empulse electric motorcycle.

Photo: Shawn Schreiner

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Solar Equity

Home Power puts the spotlight on the implications of our everyday energy choices—and, more importantly, gives you practical ways to reduce the use of conventional energy. In every issue, you will find ways to reduce your dependence on fossil fuel and move toward clean, renewable solutions.

We talk about equalizing the energy playing field so that the full costs—economic, social, and environmental—of all fuel sources are considered, and ground-breaking reports that are assessing these costs are now starting to surface. In a study released earlier this year, the New York Academy of Sciences quantified the per kWh external costs of electricity produced from burning coal. Worldwide, about 40% of electricity comes from coal and, here in the United States, it's about 50%, making it the predominant fuel for electricity.

There are annual and cumulative costs that stem from all of the pollutants (airborne, solid, and liquid) emitted from mining, processing, transporting, and burning coal that impact our public health and the environment. This study states that these costs average 17.8 cents per kWh—a cost that is *in addition* to existing electricity rates. With these numbers, when you're comparing conventional coal-based electricity to solar- or wind-generated electricity, the reality is that renewables increasingly make good economic sense for society as a whole.

With an average electricity rate of 10 cents per kWh, that adds up to 27.8 cents per kWh. This adjustment makes investing in renewable energy a bargain by comparison, and this is *without* including the impact of renewable energy incentives, such as local, state, or federal tax credits; rebates; or production-based incentives.

Remarkably, the study states that "still these figures do not represent the full societal and environmental burden of coal." In quantifying the impacts, the authors omitted several costs, including the impacts of toxic chemicals and heavy metals on ecological systems and diverse plants and animals; the direct risks and hazards posed by sludge, slurry, and fly ash impoundments; the full contributions of nitrogen deposition into fresh and coastal sea water; the prolonged impacts of acid rain and acid mine drainage; many of the long-term impacts on the physical and mental health of those living in coal-field regions and nearby mountaintop removal sites; and the full assessment of impacts due to an increasingly unstable climate.

When we consider the true cost of energy, we need to look at the big picture, not just the rate on the utility bill. Conventional fuels have real social, environmental, and economic impacts. So, be sure to figure in the cost of your *Home Power* subscription when you order your home-scale RE system—you will still be coming out far, far ahead on the deal.

—Justine Sanchez, for the *Home Power* crew

Think About It...

"...reducing harmful emissions, abating our dependence on foreign oil, and developing alternative renewable energy sources have benefits that go beyond environmental health—they improve personal health, enhance national security, and encourage our nation's economic viability."

—Jim Clyburn, U.S. representative, South Carolina

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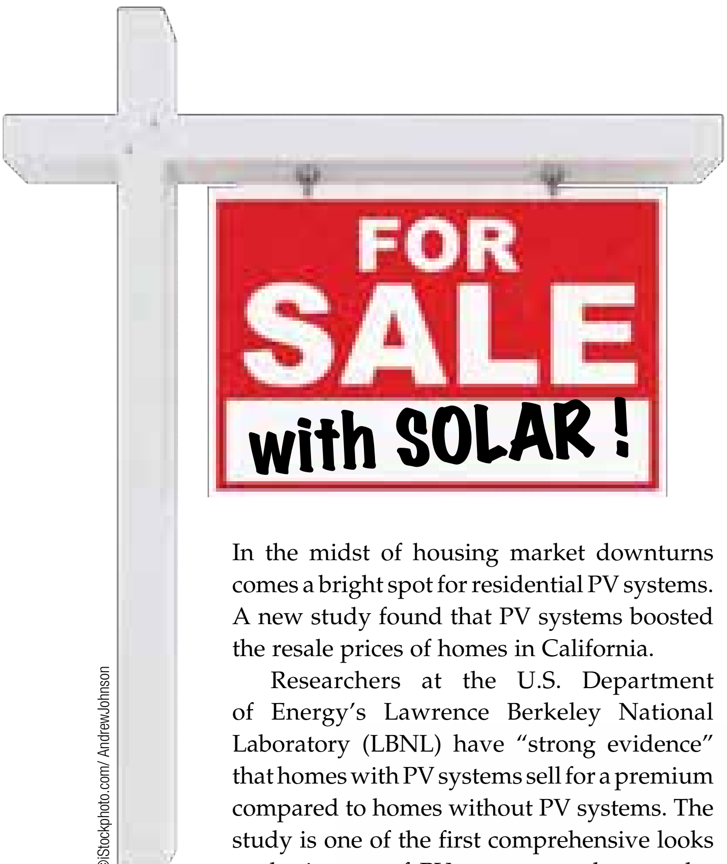
PV Boosts Home Resale Prices in California



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In the midst of housing market downturns comes a bright spot for residential PV systems. A new study found that PV systems boosted the resale prices of homes in California.

Researchers at the U.S. Department of Energy's Lawrence Berkeley National Laboratory (LBNL) have "strong evidence" that homes with PV systems sell for a premium compared to homes without PV systems. The study is one of the first comprehensive looks at the impact of PV systems on home sales prices.

Sales premiums ranged from $3.90 to $6.40 per installed watt, with most near $5.50 per watt and premiums at the time of sale decreasing as systems aged. The study notes that the premiums are comparable to the $5-per-watt average investment that homeowners made to install PV systems in California during the same time period. The study interprets this dollar-per-watt additional price to an average home sales price premium of approximately $17,000 for a relatively new 3,100 W system—the average size of the PV systems in the data.

"Relatively little research exists that estimates the impacts of PV systems on home sales prices," says Ben Hoen, the study's lead author and a researcher at LBNL. "This research could have a considerable impact on the industry. It might influence the decisions of homeowners who are considering installing PV on their home or who are selling their home with PV already installed."

The study looked at approximately 72,000 homes sold throughout California from 2000 through mid-2009. Of those,

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nearly 2,000 homes had PV systems. To create a level playing field between homes, researchers used a variety of models and tests to control for variables, such as square footage, lot size, neighborhood effects, and the home's age. The analysis also adjusted for inflation and market fluctuations.

The findings also show that existing homes retrofitted with PV commanded larger sales premiums than new homes with similarly sized PV systems and notes that further research is necessary to explore the disparity. The average premium for new homes ranged between $2.30 and $2.60 per watt, while the average premium for existing homes was more than $6 per watt.

One possible reason for the gap is that many new home builders offer PV systems as a standard sales option at lower premiums to help close sales. "Builders are struggling to sell new homes and doing all sorts of things to entice buyers. Some are giving out new cars. It is the same thing with PV," Hoen says. "The study might give builders something to think about." Another rationale, Hoen explains, is that homeowners are more familiar with their PV systems than new-home brokers, and therefore better able to highlight the systems' attributes.

If extrapolated nationally, the findings might suggest that all homes with PV would command some level of premium at resale. But Al Medina, director of the National Association of Realtors' green designation program, cautions homeowners from making any generalizations about what's going on nationwide based on the study.

"Behaviors are different across the country. California has a population that understands and appreciates the benefits of solar," Medina says. "There is clear evidence that certified green homes command a premium in markets across the country, but whether PV alone would command a premium remains to be seen. There are a lot of factors to consider in each market, and the data does not exist yet."

Taylor Watkins, a real estate appraiser in Oregon who specializes in green buildings, said the study will make a good secondary source for appraisers in California to consult, but it will have little value for appraisers in other markets, where local data is needed.

—Kelly Davidson

Green Real Estate Market

Comprehensive statistics on residential PV and home sales have been hard to come by, but the National Association of Realtors (NAR) is making an effort to collect better data with the launch of its Green MLS tool kit. The program aims to help real estate agents expand the entry forms on their multiple listing services (MLS) to address a home's green construction attributes, such as renewable energy systems and efficiency features.

Home buyers, sellers, and appraisers depend on the MLS to track home sales, search for properties, and ensure fair appraisals of homes. The MLS is a searchable database of properties that are for sale or have sold. The detail of each often varies by region, and while the NAR makes suggestions, there are no requirements as to how many searchable fields—green or otherwise—each service includes.

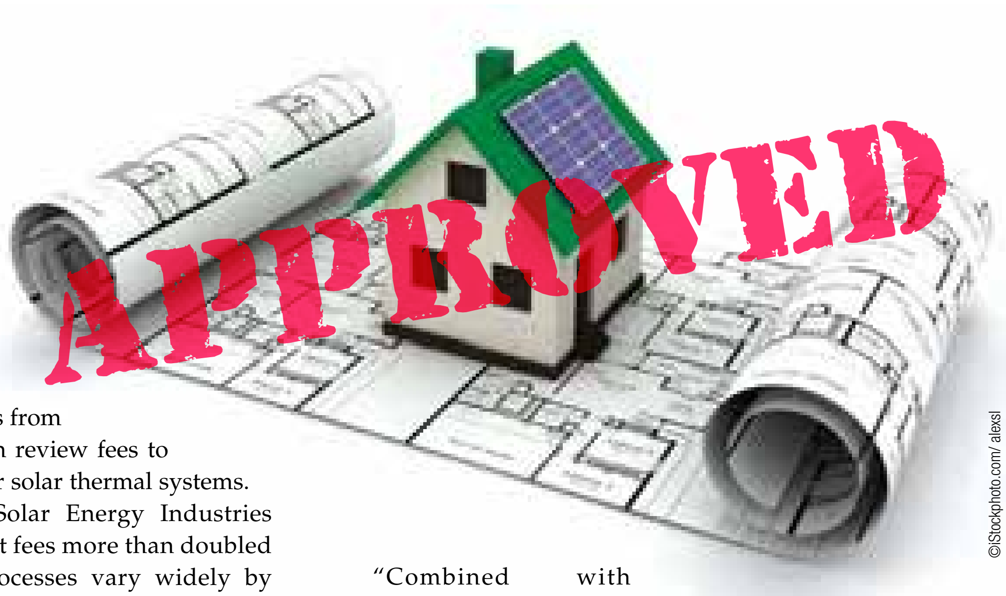
"Appraisers use the MLS to find comparable properties when performing appraisals of homes. Expanding the MLS to identify more green features will make it easier to identify specific attributes and compare apples to apples," says Michael H. Evans, an appraiser with the Reston, Virginia-based American Society of Appraisers.

"Depending on the area, it isn't always easy to find comparable properties when appraising a home with a renewable energy system. That's why it is important to work with an appraiser that is willing to go the extra mile and do the research necessary to make the most accurate assessment," says Evans .

Until recently, only a minority of services tracked green construction features, according to Al Medina, director of the NAR's green designation program. "This is a step in the right direction, but it will take time," Medina says. "Five years down the road, we hope we'll have green 'fields' in every MLS across the country and be able to aggregate the data to get a clearer picture of how green features impact home values."

There are nearly 900 MLS in the United States; about 80 are live with searchable "green" fields. To learn more, see www.greenthemls.org.

New Laws Cut Solar Permit Fees



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Costs to install solar technology are set to decrease in Colorado and Vermont under new laws that will make permitting processes more streamlined and consistent.

In Colorado, Governor Hickenlooper signed the Fair Permit Act into law in June. The new legislation prevents state and local government agencies from charging excessive permit and plan review fees to customers installing solar-electric or solar thermal systems.

According to the Colorado Solar Energy Industries Association (COSEIA), state permit fees more than doubled last year, and local fees and processes vary widely by region. In some communities, government permit costs were so high that they exceeded the labor costs to install a PV system.

"While solar costs continue to decrease through innovation and efficiency, permit costs have actually increased over the past few years," says Neal Lurie, COSEIA executive director. "By keeping government fees low, this legislation helps promote economic development and save consumers money."

The Fair Permit Act limits solar permit and related fees to a local government's actual costs in issuing the permit. Fees cannot exceed $500 for a residential installation or $1,000 for a commercial system. The legislation also closes loopholes and improves transparency in the permit process.

In Vermont, new legislation (H.56) established a first-of-its-kind registration process for solar installations that are 5 kW and smaller. Under the new process, a system may be installed within 10 days of the owner completing a registration form and certificate of compliance with interconnection requirements. Unless the utility raises interconnection issues within those 10 days, the project receives a "Certificate of Public Good" to proceed with installation.

"Solar registration is an innovative way to address the high costs and long time frames that are often associated with installing small-scale renewable energy systems," says Mark Sinclair, executive director of the nonprofit Clean Energy States Alliance in Montpelier, Vermont.

In addition, H.56 expands the state's net-metering program with a financial incentive that requires utilities to offer customers with net-metered PV systems a 20-cent production credit for the energy their systems produce. It also increases the allowable size of net-metered projects from 250 to 500 kW and raises the per-utility net-metering cap from 2% to 4%.

"Combined with expansions to the state's net-metering law, this new provision will make it easier and more viable for homeowners and businesses to go solar, and give a boost to Vermont's economy by spurring job growth in the renewable energy sector," says Martha Staskus, chair of Renewable Energy Vermont, the state's nonprofit RE trade association.

At the federal level, the U.S. Department of Energy recently designated $27 million in new funding for its SunShot Initiative, which aims to reduce permit and inspection costs associated with solar energy projects. The funding will support a $12.5 million Rooftop Solar Challenge, where local and regional government teams can compete for funds to help eliminate administrative barriers to residential and small commercial PV installations. In addition, $15 million will be allocated to create tools that will help local governments develop information technology systems to streamline local processes and reduce unnecessary fees.

"Innovations in IT and local business processes, such as online permit applications, can deliver significant savings for solar energy systems and will help America to compete globally in this growing market," said U.S. Department of Energy Secretary Steven Chu, in a statement released in June.

All of these legislative changes come on the heels of a national study that concluded the total installed cost of residential PV systems is falling more slowly because of inconsistent local permitting and inspection processes. The report—produced by San Francisco-based PV integration company SunRun—found that wide variations in permitting processes and practices add $0.50 per watt, or about $2,500 per 5 kW installation.


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Enphase Energy M215 Microinverter

Courtesy Enphase Energy

In June, Enphase Energy (www.enphase.com) released its M215 series microinverter. With a 215 W output and a DC input operating voltage range of 16 to 36 V, the microinverters are compatible with 60-cell modules (which is common with new higher-wattage modules, but they are not compatible with 72-cell modules). The M215 series has a CEC weighted efficiency of 96% and comes with a 25-year limited warranty. (The company's M190, M210, and D380 models carry a 15-year warranty.) For a better fit underneath the module, the box height has been reduced to 1 inch. These lighter-weight units can be mounted with a single bolt.

Enphase has also released a new cabling system. The Engage system creates an "AC bus," a continuous length of cable with built-in connectors. For residential system applications, the Engage has four individual 12 AWG conductors, and allows connection with up to 17 microinverters on a single 20-amp branch 240 V circuit. Installers can cut cable to the needed length, running one end into a junction box and terminating the other end with a termination cap. Each microinverter is simply plugged into the built-in connectors spaced along the "AC bus."

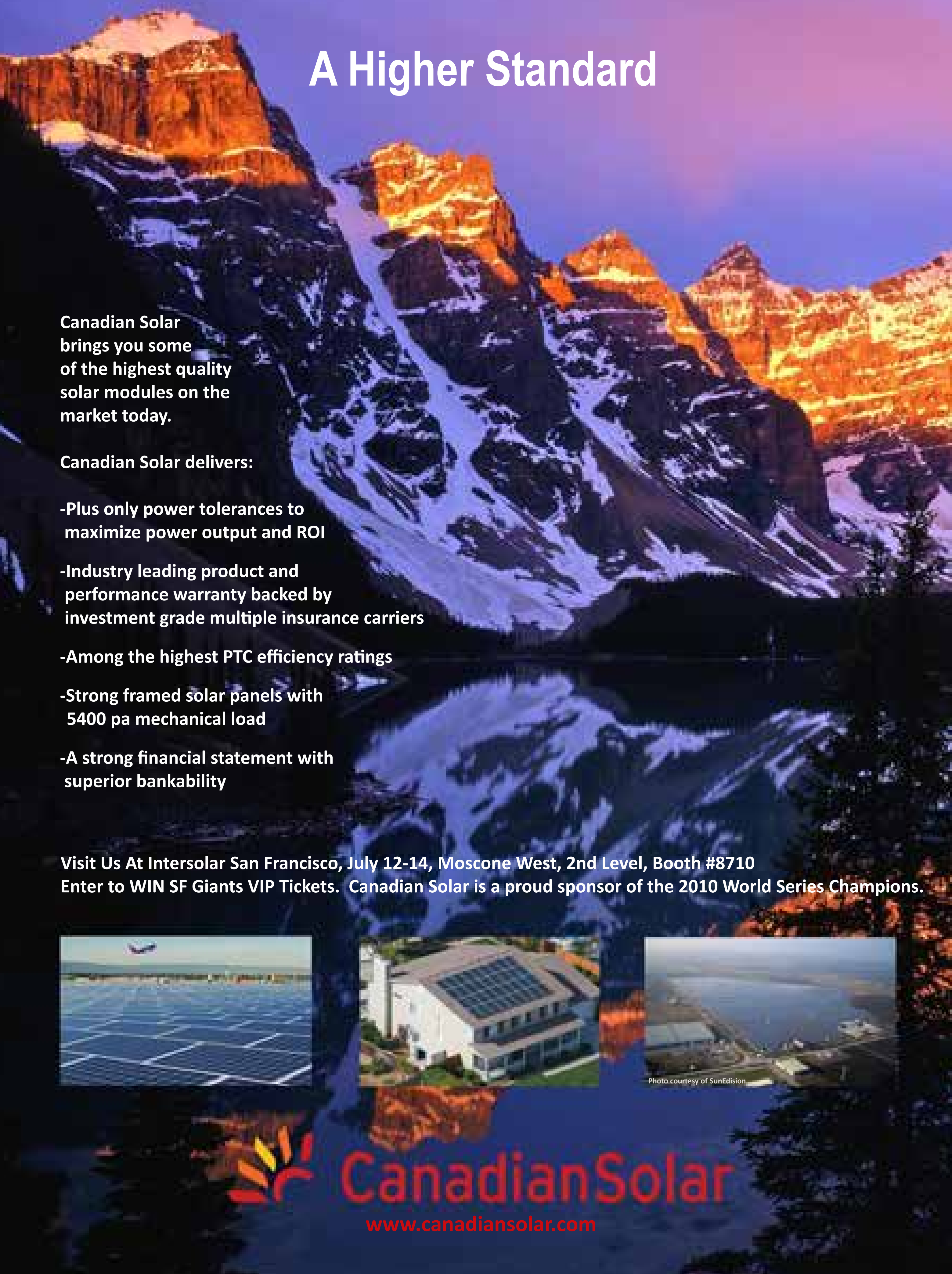
—Justine Sanchez

Trojan Battery U1- & 22-AGM Batteries

Trojan Battery (www.trojanbattery.com) has recently released two more models in its absorbed glass mat (AGM) battery line: the U1-AGM & 22-AGM. With amp-hour capacities of 33 Ah and 50 Ah respectively (at a 20-hour rate), these 12 V batteries are intended for applications having smaller energy storage requirements, such as for roadway and security lighting. Like all AGM batteries, there is no electrolyte to spill (handy in transporting the batteries or for mobile applications). These batteries can also tolerate low temperatures. Because they do not require the addition of distilled water, they are considered “maintenance-free” (vital for small, remote applications). For larger renewable energy applications, such as a grid-tied system with battery backup, Trojan offers several larger-capacity AGM batteries.

—Justine Sanchez

Courtesy Trojan Battery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A New School of Solar Thinking

Courtesy Midland School (2)

Midland School's 2011 solar installation team with the newest 3 kW photovoltaic array.

High school students at Midland School in Los Olivos, California, are not afraid to get their hands dirty. For a week each spring, they participate in hands-on learning activities that supplement their classroom lessons. For the eighth consecutive year, sophomore chemistry students have worked alongside a professional electrician to install a PV system for the school.

"Students learn this is something *they* can do rather than simply watching the professionals do it," says Lise Goddard, Midland's chemistry teacher and director of environmental programs. "Students do not work with any live wires or high voltage. The electrician makes the final connections and closely supervises all work, but the students do everything else."

Over the course of three days, roughly 25 students dig the post holes by hand, mix and pour the concrete for the post footings, cut the rails for the rack, and bolt down the PV modules.

In 2011, students installed a 3 kW grid-tied PV array to offset the energy use of two well pumps that supply potable water for the more than 100 school residents. The array joins another 3 kW PV array that the students installed last year to provide energy for about 50% of the school's water-pumping needs.

"Setting up the array from scratch gave me a whole new understanding of solar energy and the ways it can be used. I would like to work with water quality issues in the future, and I'm curious to see how renewable energy can be used to clean and preserve our water sources," says Miguel Provencio, 16, a sophomore who helped dig the post holes and mount the PV modules for the installation.

Installer Gary Gordon, of Santa Ynez Valley Solar, didn't know what to expect when he signed on to work with the school last year. "I must admit I thought there would be some grumbling about all the work. But the kids surprised me," he says. "There was such camaraderie and enthusiasm from

Contribute

To meet their goal of being powered 100% by solar energy, Midland School continues to seek grant and donor support. Learn more at www.midland-school.org.

them: 'What can I do next? What can I do now?' We had a tractor auger to dig the post holes last year, but the kids chose to dig all the holes themselves this year. That is impressive, given the state of the rocky ground."

Gordon has worked with Midland for the past two years and plans to continue working with the school in the future. Like other installers of years past, he donates his time to the projects.

Solar energy is a natural fit at Midland, where self-reliance and environmental responsibility are core to the curricula. Since 1932, the boarding and day school, which serves grades nine through 12, has taken an distinctive "close-to-nature" approach to education.

Students are relatively unplugged from outside influences and live in basic cabins on the 2,800-acre campus—a large percentage of which is untouched wilderness. Among other chores, students chop the wood used to fire the boilers, which provide domestic water heating, and raise organic vegetables served in their dining hall.

The PV program got its start in 2003 when Goddard moved on campus to head the school's environmental programs and donated a 150 W system previously used on her off-grid yurt in the Santa Barbara hills. Following two weeks of classroom lessons in solar electricity, chemistry students worked with a local electrician to assemble and wire the pilot system to power the lights in the student commons room.

Students gain valuable knowledge of renewable energy systems by working with them directly.

New Federal Program Promotes High-Performance Schools

Energy is an enormous expense for schools—approximately $6 to $8 billion each year—and sadly, much of that energy is wasted. The U.S. Department of Education's Green Ribbon Schools program encourages schools to cut expenses through energy efficiency and green building measures. The voluntary program will provide incentives to and recognize K-12 schools for taking steps toward greener spaces and education.

The final criteria are still in development, but emphasis will be put on new strategies in environmental curriculum development, teacher training, facilities management, operations, and community engagement. A key component will be that schools use green innovations to educate students about science, technology, and the environment.

"In a time when budgets are tight, the Department of Education is encouraging schools to engage in a creative win-win scenario—cutting expenses while using the school facilities as dynamic learning labs for students," says Larry Schweiger, president and CEO of the National Wildlife Federation.

The U.S. Department of Energy estimates that smarter energy management in schools could reduce energy consumption by as much as 25% and cut school energy costs nationally by more than $1 billion annually.

"No other building type speaks more profoundly to the benefits of green building than the places where our children learn," says Rick Fedrizzi, president, CEO and founding chair of the U.S. Green Building Council. "Green schools reduce energy consumption, save money, and foster healthier learning environments for our children."

The Department of Education will manage the program with support from the U.S. Environmental Protection Agency and the White House Council on Environmental Quality. Additional details and applications will be released later this year. The program is open to public and private schools. See www.ed.gov for more information.

Since then, students have installed roughly 3 kW of PV annually. Two $10,000 grants from BP Solar's A+ For Energy program covered a portion of the tab. Discounted and used modules, with donated labor from area installers, helps keep costs down. The arrays installed by students over the years now meet about 20% of the campus electricity needs.

Midland aims to install enough PV each year to offset 3% of the campus electricity needs—and keep going until solar electricity meets all of the school's needs. "If we do it right, we will produce more than just clean kilowatt-hours," Goddard says. "We will produce kids with skill sets to continue building, scaling up, and evolving the infrastructure for our renewable energy future. We will produce kids who 'get' it."

Mariah Chen, 18, worked on the system installed in 2009 and credits the experience for motivating her to study environmental policy at Barnard College in New York next year. "You definitely rise to the occasion and recognize that you are a part of something bigger—something that will have a life of 25 years or more, something that will help sustain Midland," says Chen. "It is an experience that I will keep with me for the rest of my life and remember every time I make energy choices."

Goddard hopes the school's initiative will demonstrate that small steps make a difference. "We need to take courageous steps out of the spiral of procrastination. We may not be able to solve the climate change problem in one day, but we can move in the direction of sustainability, in increments."

"The campus mindset is that we will install an array next year, and another the year after that," Goddard says. "We will keep doing this because this is what we do. Just like brushing our teeth or doing our laundry or taking final exams. This is what we do."

—Kelly Davidson

Referrals

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Solyndra PV Modules for Flat Roofs

Courtesy Ken Gardner

PV modules need to be perpendicular to the sun's rays for maximum performance, and arrays are typically tilted accordingly. For aesthetic reasons, however, homeowners and installers may choose to mount PV systems parallel to the roof plane.

This doesn't result in much of a performance hit on pitched roofs but can pose problems on houses with flat roofs. In Salt Lake City, Utah, where a regulation requires mounting PV systems parallel to a roof, a resident wanted PV modules installed on a flat section of his home's roof. In this climate, standard crystalline PV modules would have been covered by snow for nearly four months of the year. Instead, Solyndra cylindrical modules—thin-film cells spread across a 360-degree, curved surface—were used.

Solyndra modules include 40 tubes per module, with each tube parallel with other tubes. Because of this unique layout, shading on one or more tubes only affects those tubes—not the entire module. And, since dirt, dust, and snow don't have a flat surface to build upon, production losses from soiling or snow also are reduced.

We found some additional benefits gained from the Solyndra system as well. The modules used here provide 8.2 watts per square foot of horizontal roof space. (A standard mono- or polycrystalline module placed in a ballasted racking system will provide 5 to 7 watts per square foot when tilted to the optimum angle.) The Solyndra system comes with mounting hardware and feet, requiring no roof penetrations. The overall weight of the system, including modules and mounting, is 3.3 pounds per square foot (psf), which is often less than framed crystalline module setups (commonly around 3 to 4 psf). We also found that Solyndra modules can be installed in half the time, compared to standard modules. However, more wiring considerations are necessary when rooftop module layout does not follow regular geometric patterns.

—Ken Gardner • Gardner Engineering

Project Specs

Project name: Silloway residence

System type: Residential grid-direct PV

Installer: Ken Gardner, Gardner Engineering Alternative Energy Services (www.gardner-energy.com)

Date commissioned: March 2010

Location: Salt Lake City, Utah; 40.77° latitude

Solar resource: 5.35 average daily peak sun-hours

Array capacity: 7.8 kW STC

Average annual production: 10,891 AC kWh

Average annual utility bill offset: 88%

Equipment Specifications

Modules: Solyndra Series 150, 45 total modules rated at 173 W each

Inverter/s: SMA America 8,000 W, 240 V inverter

Array installation: Mounted on flat roof with modules approximately 11.8 in. off roof; Solyndra modules include mounting structure


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Configuring a PV Array
Series & Parallel Wiring

Previous articles have shown how to size a PV array for both off-grid and on-grid systems ("Designing a Stand-Alone PV System" in *HP136* & "Sizing Batteryless Grid-Tied PV Arrays" in *HP138*). Those articles can help establish the array size, but how are PV modules wired together to form an array that will produce the required voltage for your particular system design? This is where understanding array voltage and series and parallel wiring comes into play.

Array Voltage

In batteryless on-grid systems, array voltage will be dictated by your inverter choice and its input voltage requirement. For central-string inverter-based systems, the array will be configured for a high voltage range (up to 600 VDC). For microinverter-based residential systems, each module will be wired to its own inverter and the microinverters will be wired together so the voltage of the array will be 240 VAC.

In battery-based systems (off-grid and grid-tied with battery backup), the array voltage will usually be lower, and dictated by several factors, including inverter choice, battery bank voltage, and the charge controller input and output voltage. In the case of a smaller off-grid PV system, for example, a designer may choose a 24 V inverter. This will require a 24 V battery bank, which, in turn, will require a charge controller that offers a 24 V output. Depending on which charge controller is chosen, its input may require a 24 V PV array. However, if a step-down MPPT charge controller is used, you have options to wire the array at a higher voltage, such as 48 V, 60 V, and higher. (The voltage limit will depend on the charge controller's make and specifications.)

Series Wiring

A series connection is formed by one connection between each module—connecting the positive terminal on one module to the negative terminal of another module (and so on). Two or more modules wired together in series are called a "series string." In the past, creating a series string meant attaching a piece of flexible conduit between each module's junction box (J-box), pulling a wire through that conduit, stripping the wire ends, and landing them on the appropriate terminals in each J-box. These days, most modules come pre-wired with negative and positive leads that simply plug together. The unused positive and negative leads (one will be on each side of the string) provide a way to connect the output wiring for that series string. (Note: It can be helpful to think of a series string as simply one large module with one positive lead and one negative lead.)

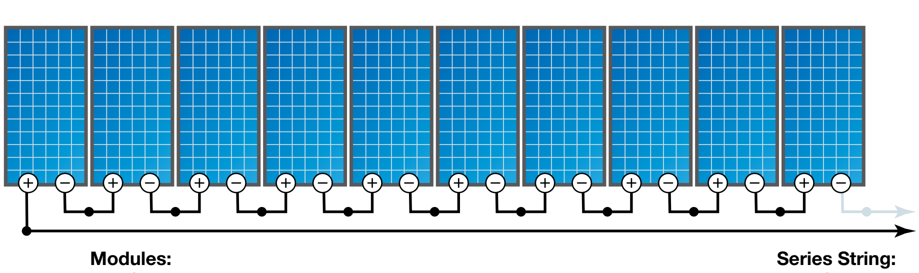
When we wire modules in series, the voltage of each module is additive, while the array amperage is the same as for a single module. For example, let's say we have 10, 35-volt, 5-amp modules and our grid-tied, 1,750-watt array design calls for a 350-volt output. We must wire these 10 modules in series so that each module's voltage will add to the other for a 350 V, 5 A array output.

Parallel Wiring

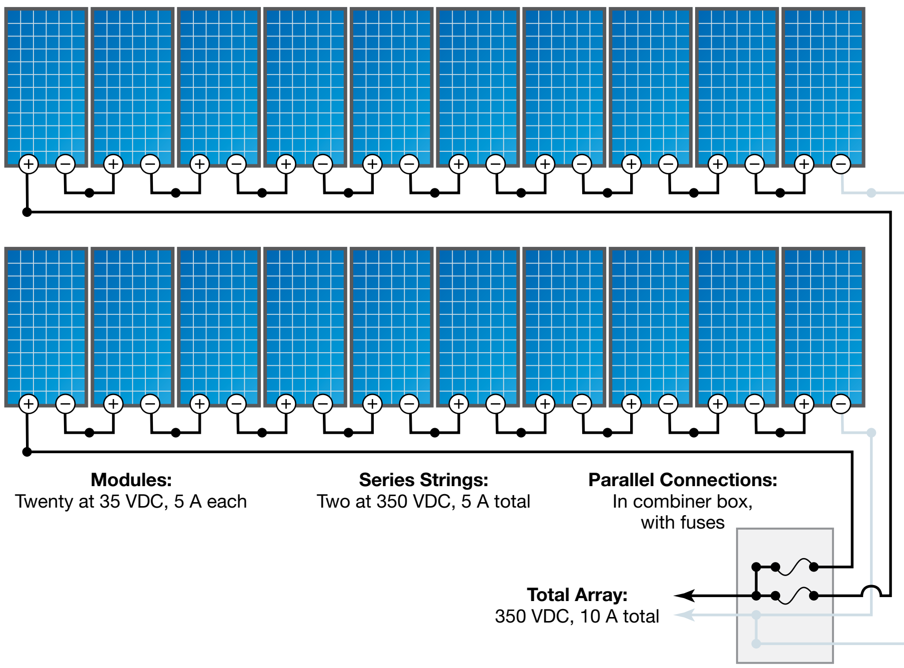
A parallel connection is made by providing *two* connections between modules: wiring the positive terminal of one module to the positive terminal of the another module *and* by wiring the negative terminals together. Parallel connections are typically made at a positive bus and negative bus inside a combiner box, rather than with module interconnects. This is so that there's a way to connect array output wires and a place to house array overcurrent protection (fuses or breakers).

When modules (or series strings) are wired in parallel, the voltage remains constant (i.e., the voltage of one module, or the voltage of one series string) and the amperage of each module (or series string) is additive. If our design called for a 3,500-watt array wired for 350 V at 10 A, given the same 35 V, 5 A modules, we would need to

PV Modules Wired in Series



PV Modules Wired in Series & Parallel



add another 10-module series string and wire these two strings in parallel, with a resulting 350 V, 10 A array.

There are many different combinations of series and parallel wiring, and the requirements will vary for each system. For practice, check out some of the past *Home Power* system diagrams and trace out the wires—you will be able to identify series and parallel wiring examples in each system, and all those little lines that can make a system diagram look complicated will start to make more sense.

—Justine Sanchez


Courtesy Tom Simko

World's Tallest Pole-Mounted PV Array?

I'll claim the title until proven otherwise! My latest project for a customer with too many trees uses 24 SunTech 215 W modules for a 5 kW+ grid-tied system in Idaho. It is 60 feet tall to the highest point, using all "pre-owned" (bought cheap from a salvage yard) steel pipe. A 6 kW Fronius Plus inverter was used.

I have my own crane service in addition to doing renewable energy work, and often the two combine! Both arrays were pre-fabbed in my shop; modules were installed and wired, and then trucked to the site. I built the racks myself, and designed them so they can easily be rigged for a crane lift.

Tom Simko, Skyline Solar
• Inkom, Idaho

Another Perspective on Ethanol

I enjoyed reading "The Big Picture for Biofuels" by Brad Berman in *HP143*, but I'm surprised the author did not mention the logical alternative to industrial-scale corn-based ethanol—small-scale ethanol sourced from culled and damaged crops, beverage and bakery waste, and discarded food that comprises, by some accounts, nearly 30% of the food stream in the United States. He aptly applies "think small and local" to biodiesel, where home-brew buffs have made viable inroads, but seems to have overlooked the fact that small-scale private and cooperative distillation has produced clean, high-octane alcohol fuel since the 1920s, albeit not so much on our shores.

You could have reviewed my book, *Alcohol Fuel: Making and Using Ethanol as a Renewable Fuel*, which sheds considerable light on practical, small-scale biofuel production. Mr. Berman hit the nail on the head when he mentioned the influence of the corn–lobby states in influencing policy, particularly the E85 program (7.5 million flex-fuel vehicles on the road) and a waiver of the Clean Air Act (to raise the national ethanol-blending percentage from 10% to 15%).

But what is being left unsaid is significant: Unlike Europe, where diesel passenger cars represent 50% of the market, we have far more gasoline-powered cars on the road than diesels (at less than 2%), so developing a replacement for unleaded gasoline would seem to take priority. Also, the automotive industry in general and automotive engineers in particular show little interest in optimizing spark-ignition engines for ethanol. With an octane rating of 106, only basic modifications to existing engines are required to markedly improve the combustion efficiency of ethanol fuel; that done, the fuel-mileage differential goes away. In ethanol-rich Brazil, Fiat markets a Siena TetraFuel sedan, developed as a joint venture between Fiat Group and electronics developer Magneti Marelli. It burns gasoline, ethanol, or CNG (motorists compare prices at the pump before they fill up) and has the ability to switch between fuels automatically, adjusting ignition timing and fuel pulse width without compromising emissions control.

For some reason, we seem to equate ethanol exclusively with corn, with the result that the only good ethanol is no ethanol. This is one case in which size matters, because the flexibility of a small-scale ethanol fuel operation allows it to adapt to a variety of available non-food feedstocks far more easily and with less economic penalty than an industrial-scale ethanol plant could.

Richard Freudenberger • Hendersonville, North Carolina

RE Peaks

I was disappointed in the "From the Crew—A Better Base Load" in *HP143*, as the author seemed to say that solar energy systems fall short because they have no storage. That is a golden teaching moment to explain that the dumb old fossil-fuel base loads make the same energy day and night, yet we humans have peak load needs with 90% needed just when solar is at its peak. A fossil-fuel base load makes way too much off-peak and it even gets dumped.

My 4 kW grid-tied PV system makes more than we use to run our home and Leaf plug-in, which runs 100% on electricity. We still help the utility with clean, renewable energy during the peak hours, and we help again by using their excess off-peak, with a timer in our car that charges it from 11 p.m. to 1 a.m.

We also help by not making an ounce of pollution, use no water for energy, and make all of our energy right where it's needed, so we reduce transmission lines and transformer loads.

Solar is the perfect base load, as it adjusts to the human peak loads and the environment. Other good base loads are hydro—even in Arizona, we get 8% from hydro. It doesn't make too much at off-peak times, so we don't have to dump it. They can even slow the flow or pump it back uphill during off-peak times so it's available on-peak.

Fossil-fuel plants can't ramp down and up to adjust to human loads. Even nuclear (which uses 90% imported uranium and makes tons of deadly waste, while using lots of water) can't ramp up or down. Refueling every 18 months also makes it a very poor base load.

Jim and Elaine Stack • via e-mail

Battery Charging Advice

I was reading Dan Fink's advice regarding battery revival ("Ask the Experts" in *HP143*). The system has eight Trojan T105 batteries connected in four 12-volt pairs, so I suppose you could equalize them with the generator, separating out one string at a time. But I cannot understand the need to equalize with a generator if the batteries are "fully charged before noon." The solar energy is there to do the job in the afternoon. Doesn't the SB controller have an equalize function? Could they equalize one string each afternoon if the solar can't kick out enough to equalize the whole lot given time?

Alternatively, if the whole 900 Ah bank were given a gentle overcharge on a daily basis, this would dramatically reduce the need for equalization. It seems to me that the charge controller is actually getting in the way of looking after the battery if it is throwing away energy adhering to an arbitrary standard absorption voltage while the batteries gradually die. Where the battery capacity is large compared to the charge rate, then the absorption voltage ought to be set higher for the health of the battery. And the absorb time should be set much longer. This would save a lot of gasoline and probably also a lot of batteries.

I guess the charge controller is set to 14.4 volts or similar. Setting it to 15 volts for a few weeks while checking electrolyte levels weekly might do wonders for the battery. A setting of 14.8 might be better in the long term to reduce maintenance. I just cannot see the reasoning for running a generator for several hours when the sun can do the job in its own way. The only reason I can see for using a generator to do equalization is if there is not enough sun to fully charge the battery every day.

Generator-based systems (without significant renewables) typically manage batteries on an incomplete charge for several cycles and then periodically give a full charge for the health of the battery. The full charge is much less energy efficient but it needs to be done periodically. With renewable electric systems, you don't have to worry about efficiency since the energy is free. Why not charge them fully every time? Weather permitting, of course.

Hugh Piggott • Scoraig, Scotland

Thanks for your valuable input. That charge controller does indeed have an equalize function built in, and the PV array appears ample for proper equalization without splitting the parallel battery strings—but the homeowners simply were not using this feature.

I too am suspicious that the controller may have been installed with an absorption voltage and time that were set too low. Many battery manufacturers are now recommending higher voltages (including for equalization) than they did 10 years ago. Other factors, such as loose connections, high battery box temperatures, and electrolyte levels below the plate tops, may also be at play here.

If the homeowners are unable to rescue these batteries and end up buying a new set, I would highly recommend that they hire a PV professional to thoroughly test the PV array, program the controller, and install the new bank—and purchase a simple battery monitoring system and annual battery service plan. It's always preferable to equalize using solar energy, and this particular PV system is capable of it.

Dan Fink • Buckville Energy Consulting

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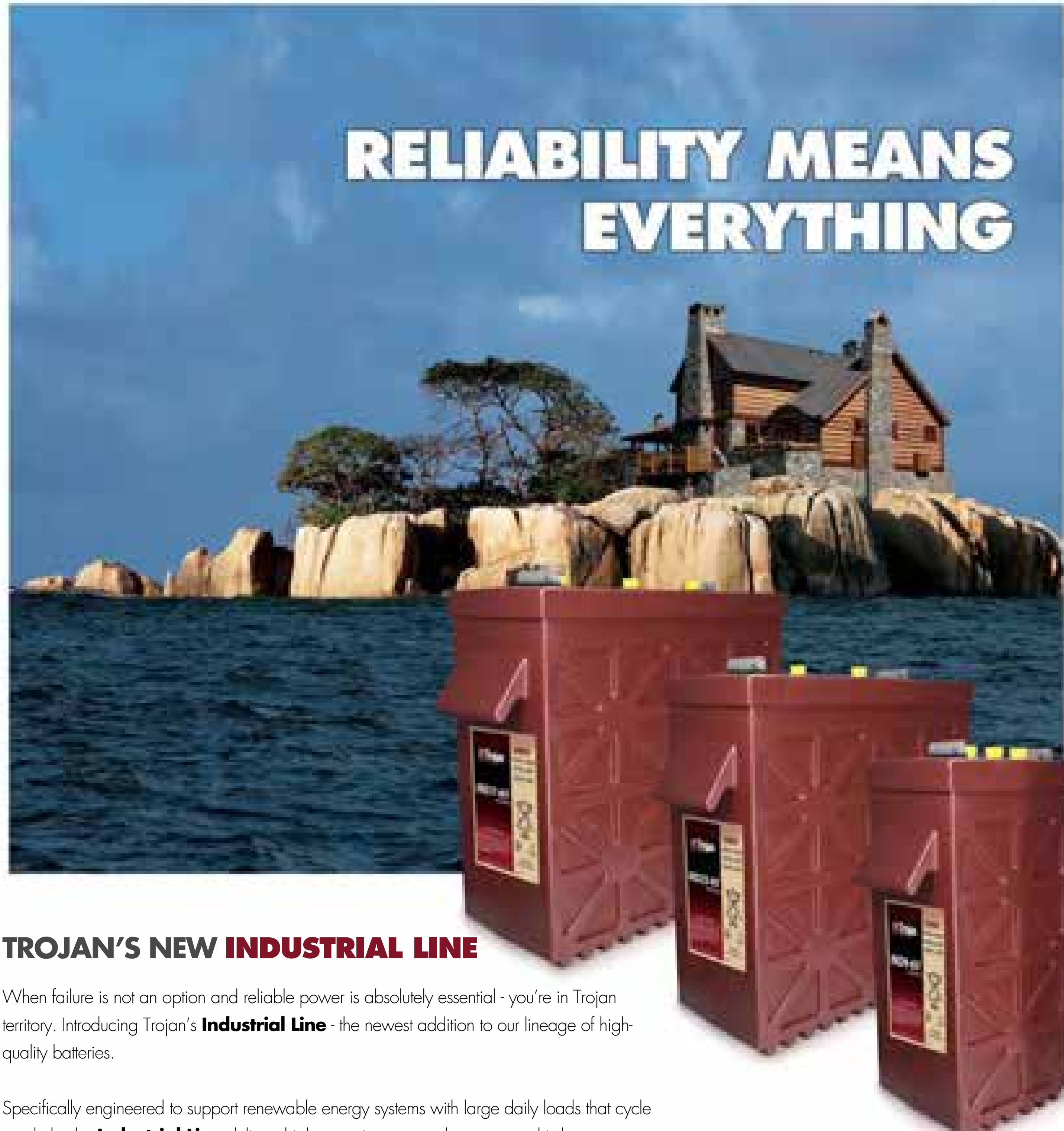

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Solar Thermal Ground Mounts

I am having trouble finding detailed instructions on ground mounts for solar thermal systems. Can anyone recommend a good book or article on the basics of placing Sonotubes, racking, and the like? I have contacted some rack manufacturers, but they mostly have roof-mount instructions for their respective systems. I'm getting ready to install a system, and could use the help.

Thomas LaPointe • via e-mail

Courtesy Tom Hardisky

I generally design ground mounts on site. I just have plenty of angle stock on the truck and my crew can change the design if we hit a snag. See the solar thermal installation article in *HP94*, which has a small section on ground mounts near the end. In addition, the Uniform Solar Energy Code requires that ground-mounted collectors be at least 6 inches above grade, but in snow country, I would put them a minimum of 18 inches (perhaps more to ensure accumulated snow doesn't shade the collectors and allows them to shed snow). I have always used 6-inch-diameter tubes for a form and, as mentioned in the article, made sure the concrete sat below the frost line. A 6-inch-diameter works well because you can use a hand post-hole digger to dig the holes.

There is little difference in a flat-roof installation and a ground-mounted one after you have a substantial (2 x 2 x 1/4-inch) angle joining the piers. I rarely use the factory mounts for ground mounts, but if this is your first installation, they might work better for you. Since so much of the prep work on a ground mount is custom, I have always just built mounts out of aluminum or steel angle, like 1 1/4- or 1 1/2-inch stock depending on the collector size, orientation, and stock material.

Most systems that are ground-mounted are antifreeze-based. The piping doesn't need to be buried, though most people do bury it a few inches. Buried or aboveground piping should be insulated with 3/4- or 1-inch closed-cell, high-temperature insulation (*not* home center hot water pipe insulation) and then encased in PVC or ABS pipe to keep it from being crushed.

Chuck Marken • *Home Power* solar thermal editor

Multiple Wind Turbines

Under what conditions, if any, would it be desirable to install multiple smaller turbines instead of one larger turbine? In particular, I was thinking about two 10 kW units versus one 20 kW unit; and two 50 kW units versus one 100 kW. How far apart should multiple turbines be spaced?

Mark Malcolm • via e-mail

While it is certainly more cost-effective to install one larger turbine instead of several smaller turbines, there are a variety of reasons why someone might want to install multiple turbines. My company has a number of multiple turbine installations in Wisconsin, as well as a variety of reasons why they were installed:

- Different uses on the same property. At a home and business that occupied one property, the installer put up two Bergey Excels on 120-foot towers. One powers the home and the other powers the owner's office.
- Usually, there is an economy of scale with wind where the larger you go, the more cost-effective it is. But this is not always the case. The Prehn Cranberry Farm installed two Endurance E3120s because they were more cost-effective than one Northern Power 100. The Endurance turbines were better suited to the site's lower wind speed.
- No larger turbines are available that fit the load. Two Northwind 100s power the Village of Cascade Waste Water Treatment Plant.
- Often, it is easier to get permits for multiple small turbines rather than one large one. Wisconsin turbine manufacturer Renewegy pioneered this very clever business model. There are at least five such installations in Wisconsin, including five turbines at the Menasha Corp., four turbines at SCA Tissue, three turbines at JJ Keller, and two turbines at Kaukauna High School. You can see these at www.renewegy.com.

dreamstime.com/Beanvader

- As a teaching tool, Lakeshore Technical College has a Vestas V-15, Endurance E3120, Entegrity 15-50, and a Proven 7.
- For the fun of it and to gain experience. Lake Michigan Wind & Sun has four turbines and towers. I have three. The reason? John Hippensteel and I are both wind weenies—we like to play with multiple turbines, learning more for our businesses. In addition, we both installed these incrementally, as time and money allowed.

For horizontal spacing, 10 times the rotor diameter is a reasonable distance. The utility wind industry uses 7 to 10 times if the turbines are downwind of each other in the prevailing wind direction, or 3 to 5 times if perpendicular to the prevailing wind direction. These are minimums that allow as many rotors as possible to be located on a piece of land. There may still be significant disruption of wind with these minimum distances, as has been noted recently in several papers on array layout and performance.

Another thing to consider is that wind farms are typically on ridges or locations were there is a predominant prevailing wind direction. It's not the same with small turbines, which tend to be sited in locales where the wind comes from all directions over the course of the year, even with a prevailing wind direction. Because of this, a minimum spacing of 10 times the rotor diameter is a prudent distance to separate small turbines.

Mick Sagrillo • Sagrillo Power & Light

Battery SOC

How do I calculate the percentage of battery charge remaining? I have a simple 12-volt system, two 50-watt PV modules connected to a 180 Ah standard auto battery, via a MPPT charge controller. My loads are both 12 VDC and 220 VAC. The charge controller has a display in volts, amps, and watts. From this, I've sort of worked out that 14.8 volts means the battery has reached a fully charged state. It drops to 13.2 volts when the charging ceases.

How can I use the display to calculate what happens when the battery is under a load? Is there a simple mathematical formula to work this out, and expressing it as a percentage? I only use a load when the battery is fully charged, and then only until it drops to 12.6 volts. This seems to work, but it would be great to know what percentage this represents.

I've been asking this question of anyone remotely interested in alternative energy, for the last 10 years, and no one has been able to give me an answer.

Phil • via e-mail

Used amp-hour meters like this venerable Cruising Equipment E-Meter can often be found super cheap on the Web.

Without special instrumentation, getting a handle on battery state of charge (SOC) is not easy. In fact, it is nearly impossible to figure out the SOC during or soon after a lead-acid battery has been under charge or discharge. Even after the battery has been at rest for awhile, calculating SOC is still difficult because you cannot be fully aware of the battery's condition or any differences in condition between its individual cells.

These factors turn the computation into a very complex one (do a Web search on Peukert's Law, for starters), which is generally why people need a good amp-hour meter. These units constantly monitor the battery's health, count the amp-hours into and out of it, and take into account the battery capacity, which changes with use. I highly recommend getting one. (I occasionally see older, inexpensive Ah meters for sale online—and the older ones work just fine. Just make sure to get the shunt, cabling, and instructions with them.)

See "Managing Your Batteries" in *HP142* about battery monitoring—including information on using specific gravity, which is probably the cheapest way to understand your battery's state of charge.

In the meantime, you can probably feel somewhat comfy with your current methodology. But as the battery ages, you will find yourself reaching that 12.6 V earlier and earlier. Bottom line? Get an amp-hour meter.

Michael Welch • *Home Power* senior editor

PV Fire Safety

I am a licensed electrician with IBEW local 300 in Vermont and have taken PV systems and installation training, but am wondering about a fire safety issue. In the event of a house fire, what's the proper way for firemen to safely vent (cut open) roofs with PV modules installed?

Ed Bonoyer • via e-mail

PV arrays can produce voltage up to 600 VDC. Because there is no easy way for firefighters to determine a system's actual voltage during an emergency response, there is really no safe way to ventilate a roof by cutting through PV modules. Even at night, doing so would bring on a hazardous situation as soon as the sun came up.

"Smart arrays," in which individual modules can be monitored and shut down from the system control center, are safer, but at a chaotic fire scene, locating the controls, operating them, and confirming shutdown could be extremely difficult for firefighters.

New codes addressing firefighter safety and PV systems are coming soon, including required access pathways for roof ventilation around PV arrays; the routing of DC source conductors near structural members to avoid contact during ventilation; and appropriate warning signage. But firefighters will always have to deal with grandfathered-in arrays that don't meet any of the new standards.

Ventilation through the roof face opposite a solar array is sometimes possible, but if winds are blowing from an unfavorable direction, that technique could be both ineffective and dangerous. For such situations, fire departments should prepare and train for using alternative ventilation techniques, such as ventilating through gable ends, positive-pressure ventilation using high-power portable fans, and compressed-air foam systems.

Stay safe!

Dan Fink • Buckville Energy Consulting LLC

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kick started

ELECTRIC MOTORCYCLES GAIN TRACTION

"It's fun to ride, that's for sure. How often do you wake up looking forward to your morning commute?"

BRAMMO ENERTIA

Courtesy Brammo

by Brad Berman

Three short years ago, the notion that everyday consumers could easily buy a mass-produced electric car seemed hopeful, if not slightly delusional. The only battery-powered cars available were the exotic $109,000 Tesla Roadster coupes or neighborhood electric vehicles (golf-cart-like buggies not legally permitted to drive more than 25 mph). Fast-forward to today, and electric cars like the Nissan LEAF, Chevy Volt, and Tesla Motors Roadster—and dozens more like them, expected to hit showrooms in the next few years—have entered the mainstream market.

But what about options for those of us who want to hit the highway on two wheels instead of four? Motorcyclists who want to go electric must feel much like electric car fans in the mid-2000s. The number of choices can be counted with fingers on one hand. Hefty price tags, lack of a distribution network, and market challenges for electric motorcycles make electric cars seem like a slam dunk by comparison.

Motorcycle Motivations

Harry Mallin, a Kansas City-based attorney, set out to buy a motorcycle in spring 2009. His motivation? SUV guilt. Not feeling so hot about his 19-mpg Honda Pilot (which he bought to pull his camper trailer, but ended up using for his daily 25-mile commute), he dreamed about riding a motorcycle again after hanging up his helmet and leather jacket more than 30 years earlier.

"I was waiting for something to happen to make my amends to the environment," Mallin says. Although ditching his SUV for a gasoline-powered motorcycle would have meant a jump in fuel efficiency, Mallin found a disquieting June 2008 article in *The Los Angeles Times* that made him reconsider his decision. The article reported that "the average motorbike is about 10 times more polluting per mile than a passenger car, light truck, or SUV," according to the California Air Resources Board.

While gasoline-powered motorcycles and scooters can use fuel twice as efficiently as cars, wringing more energy from the fuel produces more nitrous oxide emissions—gases that contribute to air pollution. Although technologies such as catalytic converters exist for reducing emissions on cars, there's no requirement for stringent pollution strategies for motorcycles.

Financial Incentives for E-Motorcycles

The feds are kicking back some bucks to reward consumers for their electric two-wheelers: As part of the American Recovery and Reinvestment Act, two new tax incentives apply.

A tax credit allows two-wheeled EVs to qualify for the 10% plug-in vehicle tax credit, capped at $2,500. To qualify for the federal tax credit, these vehicles have to be highway-capable. A tax credit is directly subtracted from your tax bill.

The second incentive is a federal tax deduction that allows taxpayers to deduct state and local taxes paid for a new electric motorcycle. (Note that this deduction is subject to a phase-out for taxpayers with adjusted gross income of more than $125,000; $250,000 for joint returns.) As a federal tax deduction, the amount is subtracted from your adjusted gross income, reducing your taxable income.

First Timers Get to Kick the Tires

It was Mallin's motivation to find a more responsible ride that led him to investigate electric motorcycles and to Brammo, an Oregon-based company that is currently one of the few outfits in the United States offering all-electric, highway-capable motorcycles. At the time, two other U.S. companies, Zero and Quantya, sold street-legal electric dirt bikes—and California-based Vectrix makes and sells "personal electric vehicles"—but Mallin was looking for a daily commuter. (More recently, Zero has started selling electric motorcycles suitable for riding on the road.)

When Brammo lowered the price of its first product, the Enertia, to $7,995, Mallin decided to make his move. The Enertia was only available in California and Oregon at the time, but in a stroke of luck, Mallin managed to win an Enertia in a contest sponsored by Brammo.

Mallin says that his motorcycle, which was delivered to him in a crate in June 2010, has exceeded his expectations. Not only is it a greener transportation option, but most of all, it's a daily thrill. "It's fun to ride, that's for sure," Mallin says. "How often do you wake up looking forward to your morning commute?"

> "Gearheads in it for the raw horsepower might not be impressed, but those who want to hit turns and curves with smoothness and speed are going to have a blast."

"The dearth of established distribution channels is one reason why electric motorcycles face an uphill battle in the U.S. market."

A Quiet, Powerful Ride

Two primary attributes make riding an electric motorcycle exciting. The first is the raw acceleration of an electric-drive vehicle—100% torque at 0 rpm. "One of the things that a motorcycle manufacturer has to do when making an electric motorcycle is make sure it doesn't shoot out from between the rider's legs when they just barely turn the throttle," Mallin explains.

The other benefit is the vehicle's silent operation. "The only thing I hear when I ride my motorcycle is the wind inside my helmet, a little bit of chain noise, and the tires on the road," Mallin says. "It's much more of a visceral experience and closer to nature, compared to the rumble, rumble, rumble of a gas bike. On an electric bike, you can hear the crickets in the summer."

Mallin's awakening about the joys of electric motorcycle riding is not uncommon. "Every opportunity we've had to put motorcyclists on our bikes, they come away with smiles on their faces," says Brian Wismann, director of product development at Brammo.

Wismann says the only rare complaints come from customers who don't fully understand the range limitations of electric vehicles. That's why Brammo has focused on expanding the driving range of the Enertia, which provides 40 miles on a full charge, on its next products. Brammo intends to offer the Enertia Plus for an additional $1,000. This model bumps up battery storage from 3 kWh to 6 kWh, doubling the range to 80 miles, while keeping the top speed to 60 miles per hour.

Courtesy Mission Motors

MISSION MOTORS MISSIONR

Getting the Green Goods

The distinction of bringing the first electric motorcycle goes to Electric Motorsport, an Oakland, California-based company that sold a limited number of its GPR-S model in 2008. The company sold that model for between $6,500 and $8,500, but has since shifted its business strategy. "Motorcycle usage in the United States is more for amusement or as a toy, but not as a serious form of transportation," says Raul Aguilar, chief operating officer at Electric Motorsport.

The company is now focusing its efforts on Europe, Asia, and Latin America, primarily selling its core technology rather than finished products. Nonetheless, the company still hopes to return to the U.S. market bringing its Native brand to consumers. For Electric Motorsport, the unformed nature of the electric motorcycle market presents commercial challenges. "If we don't get a big enough purchase order, we can't make anything," says Aguilar. "There's way too much money at stake."

Courtesy Brammo

BRAMMO ENERTIA PLUS

Other players, like Mission Motors, similarly shift between selling technology and products. Mission had sold its high-end, 150 mph, 150-mile range Mission One electric "superbike," which debuted in 2009 for just under $70,000, before turning its focus to selling electric powertrains.

Meanwhile, Brammo marches on with plans to offer its second model, the Empulse, in the future. The Empulse will be available with three choices of battery pack: the 6 kWh pack for $9,995; the 8 kWh pack for $11,995; and the 10 kWh pack for $13,995. That means driving ranges of 60, 80, and 100 miles, respectively—with a similar spread of full recharge times of six, eight, and 10 hours via 120 V household current.

While Brammo has made great strides with its technology, it continues to face challenges with marketing and distribution.

That means dedicated specialty shops like Hollywood Electrics—which sells electric motorcycles, bicycles, and scooters, including Brammo and Zero products—are the key distribution channel.

"I have a store full of electric motorcycles," said Harlan Flagg, owner of Hollywood Electrics, who rides an electric bike daily. "If I'm just cruising around town, Brammo is great for that," he says. "But if I'm carving up the canyons, I'd prefer riding the Zero." Flagg praises both manufacturers for high quality, but according to Harlan, Santa Cruz, California-based Zero makes the higher-performance bike with the greater foot-peg clearance needed for taking corners at a sharper lean angle.

While Zero's heritage is in off-road electric bikes, Flagg says that all of its products can be ordered direct from the factory as street legal. Zero's $8,000 XU bike, its newest product specifically designed for urban use,

"While gasoline-powered motorcycles and scooters can use fuel twice as efficiently as cars, wringing more energy from the fuel produces more nitrous oxide emissions—gases that contribute to air pollution."

"There's an inevitability about electric transportation because it's, in the long term, a much better way of doing things. You can't keep burning a very precious commodity just to get around. That's stupid."

has features targeted to city riders. "XU has a removable battery. That's advantageous for a lot of people who live in the city, like apartment dwellers; people who don't necessarily have a place to plug in their bikes," says Flagg. "They take out the battery, carry it upstairs, and plug it in."

Flagg's shop does not carry bikes from Quantya, because the Swiss company has limited availability in the United States.

The dearth of established distribution channels is one reason why electric motorcycles face an uphill battle in the U.S. market, says Dave Hurst, senior analyst at Pike Research, a Colorado-based clean tech market research firm. (Like Aguilar, Hurst and many other observers believe that electric motorcycles have better prospects in Europe, where more compact urban environments, wider acceptance of two-wheel commuting, and generous incentives are more common.)

"Unlike the automotive industry, there isn't a good distribution channel for electric motorcycles. They don't really fit with the current power-sports networks, which for the most part are independent dealers," Hurst says. "You don't know where to buy them. And even if you do buy one, you don't know where you're going to get it serviced."

ZERO S

Courtesy Zero (2)

ZERO XU

VECTRIX VX-1


Courtesy Vectrix

Hurst believes that limited range—which restricts use to local riding—is also holding back electric motorcycles. "The economics do pencil out for an electric motorcycle. But it's much tougher on the emotional side to say, 'Here's a bike you can only use as a commuter,'" Hurst says. The Brammo Enertia "can only go 40 miles and do 60 mph, so you can't take your bike out and go cruising for the weekend."

Despite these restrictions, Pike Research's forecast calls for electric motorcycle sales to grow from 3,600 units in 2011 to 47,000 in 2016. In about five years, that could represent between 5% and 7% of the total motorcycle market in the United States.

Going for Greens, Gearheads—& Geeks?

Hurst doesn't believe that incentives—like the current 10% federal tax credit—will make much of a difference in driving the market for electric motorcycles. But what about their environmental appeal?

"I wish I could say it's a major driver, because it's a primary interest to me and a lot of the people who work at Brammo," Wismann says. "But sales, and talking to customers, have suggested otherwise. People will take green, and they don't have a problem with it, but they don't go out of their way to buy it."

John Adamo, an IT professional in the Chicago area and a motorcycle rider for nearly 20 years, is keenly interested in electric motorcycles, but not necessarily for their eco-grooviness.

"What caught my attention is they are almost completely silent, and you can ride them in areas where noise is a concern," Adamo says. Based on his short test-rides of the Zero S, he was fascinated by the sensation of accelerating without shifting gears, and coming to a stop without pulling a clutch lever. Gearheads in it for the raw horsepower might not be impressed, but those who want to hit turns and curves with smoothness and speed are going to have a blast.

A self-defined computer geek, Adamo started thinking about the high-tech capability of electric bikes, and imagines being able to tune them from a personal computer, or customize their power delivery maps and regenerative braking.

Azhar Hussain, a London-based consumer electronics entrepreneur and the founder of the TTXGP electric motorcycle racing series (see "Paving the Way"), perceives an even stronger correlation between electric motorcycles and computers.

As huge as the global automotive industry is, there's a much bigger industrial base for electronic devices, from computers to smart phones. "Tesla Motors couldn't exist if laptops hadn't evolved to a point where it could get 6,000 laptop cells for its Roadster," Hussain says. "Look at every

"What caught my attention is they are almost completely silent, and you can ride them in areas where noise is a concern."

"Look at every electronic device out there that needs a battery. That is what's driving electric mobility."

electronic device out there that needs a battery. That is what's driving electric mobility."

Hussain is on a mission to educate the public about the myriad benefits of petroleum-free transportation—and to help the world break the shackles of oil addiction. "There's an inevitability about electric transportation because it's, in the long term, a much better way of doing things," Hussain says. "You can't keep burning a very precious commodity just to get around. That's stupid."

Hussain believes it's only a matter of time before an entirely new type of motorcycle company emerges, with a new, electric-based platform and new business model. Hurst foresees major manufacturers entering the electric motorcycle market, much the way Nissan, General Motors, and Ford, among others, have made big investments in electric cars when Tesla used to be the only game in town. "It wouldn't surprise me to see BMW move in that direction," Hurst says. "Honda is another one."

Until that day comes, Brammo is trying to get as much traction in the market as possible. "There's not a lot of competition out there right now," Brammo's Wismann says. "For us, the biggest competition will come when the large OEMs decide to get into the market." He believes the major companies are waiting until the market is proven before jumping in.

With only a handful of U.S. companies offering electric motorcycles designed for daily transportation, you could describe the market as nascent. TTXGP's Hussain disagrees."Clearly, it's relatively early compared to petrol, but I don't know if that's the fair measure. A better way to look at it is that it's a technology that's prime for those people who are able and wanting to engage with it. I don't think it's nascent. I'd rather say it's undiscovered."

Paving the Way for Electric Racing

The world's first sanctioned, zero-carbon motorsport event, TTXGP—also known as the eGrandPrix—is an international race series that provides a high-profile platform for electric vehicle innovation and development. In 2009, TTXGP was launched as part of the annual Isle of Man Tourist Trophy races—a prestigious and decades-old motorcycle event in the United Kingdom.

In 2011, there will be about 15 races on three different continents—including North America (see www.egrandprix.com). "Anybody who has been to one of our races has come away changed, heart and mind," says TTXGP founder and consumer electronics entrepreneur Azhar Hussain. "I have a waiting list of tracks wanting to join us."

Access

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Motorcycle Manufacturers:

Brammo • www.brammo.com

Mission Motors • www.ridemission.com

Vectrix • www.vectrix.com

Zero • www.zeromotorcycles.com

Lightning Arrestor

(Surge Protective Device)

The MidNite Solar Surge Protective Device (MNSPD) is a Type 1 device, designed for indoor and outdoor applications. Engineered for both AC and DC electric systems, it provides protection to service panels, load centers or where the SPD is directly connected to the electronic device requiring protection.

The SPD is offered in three different voltages to maximize the protection level. Protection is achieved by reducing the clamping voltage to a safe level that your system can sustain without damaging any electronics in the system.

The MidNite SPD is a welcome replacement for less sophisticated arrestors that have been the mainstay of the industry for many years.

Due to the growing solar industry, there are numerous listed SPD's entering the market. These new din rail mount SPD's, like the MidNite versions, are much better at clamping surges to a safe voltage level than previously available lightning arrestors. Din rail SPD's are physically small and typically can only provide 1/8th the protection of the MidNite product.

When exposed to transients above their capability, permanent damage occurs. Din rail SPD's are always mounted inside of a box such as a PV combiner up on a roof top. When the din rail SPD fails from a near lightning strike, it just quits working. This means that it also quits protecting. Since it is locked away inside of a box, you have no way of knowing it has failed until your next lightning storm! The MidNite SPD's are mounted on the outside of a PV combiner and have blue LED's viewable from a distance that show your system is still protected. The MidNite SPD's are built to last. Each MNSPD is capable of clamping a 115,000 amp surge. In the event that the MNSPD does eventually wear out, they can easily be repaired. No planned obsolescence here.

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personal electric vehicles

GET MORE PERSONAL

by Ted Dillard

When the term was coined, "personal electric vehicle" (PEV) meant almost exclusively electric cars. A decade later, we're seeing the resurrection of the electric car—almost every major automobile manufacturer has something in development. With the electric car movement behind them, a parade of PEVs—from something you can sling over your shoulder to a 100 mph-plus electric racing motorcycle—is coming down the pike.

The price range for these vehicles is almost as extreme as the vehicles themselves. A few hundred dollars will buy you an around-town scooter. A whole lot more will get you a custom-built, full-on race motorcycle.

Even a year ago, many of these products were pipe dreams—pretty online prototypes, but not in actual production. Today, there are products that are available, affordable, and sitting on a showroom floor for you to see, touch, and ride.

Stand-up Scooters

We'll start the tour with two extremes in the stand-up scooter market: Segway's Personal Transporter and one of the ubiquitous Razor-type scooters. Both of these can be used for just about the same thing—getting around the city.

At a retail price of about $8,000, the Segway is a premium product, commonly in use by police and security details. It weighs a little more than 100 pounds, and has a top speed of about 12.5 mph with a maximum range of 24 miles. A marvel of gyro-servo robotic technology, the Segway is controlled by the rider's shifting weight.

SEGWAY X2

Courtesy Segway

Courtesy Razor

RAZOR ECOSMART METRO

Courtesy E-Glide

E-GLIDE 48

Courtesy Crystalyte

CRYSTALYTE

On the other end of the scale is the simple, light, and inexpensive electric Razor scooters. Originally a kid's toy, Razor now offers the EcoSmart Metro, with larger wheels and more power, which means some propulsion oomph. At about $400, with an 18 mph top end and a range of 15 miles, these scooters can get you everywhere a Segway can, plus you can carry it up the stairs and park it in your office.

A little more exciting is the E-Glide GI Powerboard. This 1,000-watt, 36-volt electric skateboard is not for the meek. At $1,400, with a handheld controller and an estimated top speed of 24 mph, this is an affordable option for the commuter/adrenaline junkie.

Electric Bicycles

The electric bicycle market ranges from DIY kits for converting your standard bike with hub motors for bike wheels to purpose-built electric bicycles. There are several DIY kits, including Crystalyte and Golden Motor that come as individual parts or as complete packages with batteries and controllers. You can get an idea of acceleration by the motor's power rating, and electric bikes generally fall within the low 250 to 800 W range. Higher wattage gives you more speed and acceleration.

The Ultra Motor A2B is one of the more striking purpose-built bikes available. It weighs 72 pounds, can pull you (unassisted) at 20 mph, and has a range of about 20 miles (unassisted). The electric components are completely integrated and the bike includes disc brakes and tires that look more intended for a light motorcycle than a bicycle. These, as well as the kits, have pedals and even multispeed shifting, just as a standard bike. At $2,700, they're not out of the range of what many die-hard bikers would pay for a racing bike.

ULTRA MOTOR A2B

Courtesy Ultra Motor

Courtesy Trek

Courtesy Schwinn

TREK RIDE+

SCHWINN SEARCHER E8

Two mainstream bicycle manufacturers also have entries in the electric bike market—Trek and Schwinn both have electric models in the $2,000 to $3,000 range. Typically billed as "electric assist," these bikes are aimed at the bicycle enthusiast who, for one reason or another, needs some help with the pedaling. At 250 to 350 W, these are at the lower end of the power spectrum, but are lighter and look and feel more like a standard bicycle. These bikes are very popular with people who want to get outside, ride with younger friends, or like bike touring and sightseeing—but have trouble staying out too long, going too far, climbing hills, or keeping up with the group.

Mopeds

Somewhere in the mix between electric bicycles and scooters is the "electric moped," the most popular product sold in some stores, according to Harlan Flagg of Hollywood Electrics. Their Bumble Bee offers speeds of up to 20 mph, power ratings of about 800 W, and a range of 25 to 30 miles. At $1,195, they are an attractive option for urban commuters. In most states, mopeds do not require a driver's license or motor vehicle registration, an added bonus.

BUMBLE BEE

Courtesy Bumble Bee

Riding an electric bicycle, whether electric-assist or high-powered moped, gives an interesting sensation from the electric motor. When pedaling one of the lower-powered bicycles you can, at will, simply turn up the power and you get the impression of being pulled forward, as if by some invisible force. With higher-powered bikes, the vehicle itself is heavier and pedaling becomes less feasible. Some of the bigger mopeds/scooters can't be comfortably pedaled, and have pedals more as legal vestiges than for practical purposes.

Motor Scooters

The design of a motor scooter is great for an electric powertrain—smaller, fatter tires and wheels provide a good fit for the integrated hub motors (motors that are built into the wheels). A low deck doubles as a great place to put batteries. There's plenty of room, the weight of the batteries is kept low, and the result is stability. As a result, there's a huge array of very affordable electric scooters available—they are a common sight in Asian markets, and catching on in Europe and the United States.

One of the more popular brands is the Native Scooter from Electric Motorsport in Oakland, California, assembled from parts manufactured largely in Thailand. The Native Z1.5 has a 40-mile range, a 30 mph top speed, and sells for about $2,200. The larger Z6(Li) increases the top speed to 60 mph and retails for $4,800.

Some U.S. manufacturers are entering the market, with products available now or by order. Massachusetts-based Vectrix offers a small, lower-priced scooter, the VX-2, but also has the VX-1 Li—a near-motorcycle level machine with lithium battery technology and performance to match. The VX-1 Li has a top speed of 68 mph, a range of 40 to 60 miles,

Courtesy Vectrix

Vectrix VX-1

Courtesy Current Motor Company

Current Motor Co. Deluxe

and a 0-to-50 mph acceleration of 6 seconds, you're looking at a product that starts to blur the lines between a scooter and a motorcycle. At $14,000 for the premium Li version, you clearly are paying the price for the performance you're getting.

Another new U.S.-based company is Current Motor Company, with three models ranging from $6,500 (30-mile range and a 55 mph top speed) to $8,000 (50-mile range and 65 mph top speed).

These scooters are a much tougher sell in the U.S. market than in Europe and Asia because of road systems and rider habits. They are marginally "highway capable," but even at a 70 mph top end, they won't give you a margin of speed and feeling of security on an interstate. Where posted speeds are lower and roads are narrower, they're a great fit, and a workable solution for more rural, village, or country errand-running and commuting. The high cost makes them much less attractive in the city, though, where the acceleration and top speed aren't going to be as usable.

Whether you're jumping on for a grocery store run, using it to commute to work, or taking a sightseeing tour of local attractions, riding these scooters is as effortless as strapping on your shorty helmet and turning the key. Once you've

Electro Motorsport Native Z1500

Courtesy Electric Motorsport

Two-Wheeled Rides

What are these PEVs like to ride? They all have a few things in common. First, they're virtually silent. Scooting around on the street or sidewalk takes a little patience and defensive driving where pedestrians, and even cars, are concerned. People aren't going to hear you, and they may see you, but it may take a few moments for them to really understand that what they're seeing is a person moving along at a fairly good clip, but not riding a bicycle.

Second, they're also clean—they don't have all the grease and oil that their gas-powered counterparts have. Plus, they have no tailpipe emissions. And if you recharge them with renewable energy, they're an all-around green transportation option.

The power from the electric motors is also very different—even the small scooters have a great deal of acceleration from a dead stop. They spin up without the use of a transmission, so there's no shifting needed—you just get smooth power.

Solar-Charging an EV


Courtesy Brammo

Since one of the reasons you invested in an EV or PEV was to give fossil fuels the boot, the last thing you'll want is to continue powering it with dirty fossil fuel and nuclear-made electricity—common grid sources in nearly all parts of the United States. How about a PV system to charge your EV or PEV?

The type and size of PV system that can provide charging for a PEV or EV varies widely. Typically, a PV system for PEV charging is much smaller than one designed to serve an EV's needs. You'll need to consider battery capacity and your daily commute, among other things, to arrive at a system to meet your PEV or EV needs. For example, a Razor scooter will be running 36 V with maybe 20 Ah, requiring about 720 Wh. A Native scooter may have 48 V with 40 to 60 Ah (1,920-2,880 Wh), and the Roehr runs at 7.7 kWh. If you figure the estimated ranges of the bikes based on the manufacturers' numbers, compared with the U.S. average daily commute of 16 miles, and consider battery capacity, you can design and size your system accordingly.

depleted the battery, you simply plug it into a standard 120 VAC outlet to recharge. Most of these products will typically come to a full charge within a 4 to 5 hours. There's no gas or oil; nothing to mix, drip, or smell; and the ride is silent. Riding around a campground in Maine in the wee morning hours, I've sneaked up on more than a few deer and other critters—a birdwatcher's dream. Stopped at a traffic light, you're aware of wind rustling in the trees, chirping crickets, and even conversations in neighboring cars.

QUANTYA EVO1


Courtesy Quantya

Motorcycles

Electric motorcycles range from small, light, off-road dirt bikes like the Swiss-made Quantya, U.S.-made Zero, and the 6-speed transmission-equipped Brammo (also U.S.), up to "superbikes" like the Mission R, the Motoczysz E1pc, and the Roehr eSuperSport.

In the middle of this field are light street/commuter bikes like the Brammo Enertia and the Zero XU. Both companies are struggling to meet the challenges of offering production, consumer-ready Department of Transportation-approved products—looking like a business-school study of what faces a start-up company.

Both Brammo and Zero struggle with finding workable distribution. Brammo has tried to work outside the typical motorsports industry, originally offering their bikes through a national electronics retailer, on the premise that the bike fits into the "consumer electronics" market. Now, Brammo is looking to sign up independent dealers. Zero, currently able to deliver bikes, uses a combination of independent sales reps and a conventional dealer network. If you want to see a Zero, you may be able to go to a dealer or you may get a personal visit from your area rep, depending on where you live.

There are two basic issues with the standard motorsports-dealer model. First, the cost—a range of $7,000 for smaller bikes to more than $20,000 for some of the production superbikes. The ideology behind an electric motorcycle makes

Full-size electric cars, with their higher- voltage, higher-capacity battery banks, will require much larger PV systems for charging. Typically, they'll need a system that can provide about 12 kWh of daily charging energy.

EV owners might think about putting in a simple PV array to directly charge the EV batteries, since PV-direct applications can be the most efficient and least costly of all system types. But that kind of system would charge the vehicle only when the sun is shining—requiring you to drive only early and late in the day, and not being anywhere but at home during solar-charging hours—and the system may have to be oversized to deal with decreased sun-hours in winter and cloudy weather.

Another option for a dedicated EV solar-charging system might be a PV system with a stand-alone inverter and a battery bank. A battery bank would allow you to charge the EV at times other than when the sun is shining. However, the size of the battery bank depends on the EV's charging requirements—with electric cars requiring a large battery bank, that could become a very expensive proposition. Off-grid, battery-based systems for smaller PEVs can be more economical.

With a batteryless grid-tied system, you can use the grid as a battery substitute. You can pump your PV-made energy into it year-round, and "draw" it out again whenever you need it: night or day, cloudy or sunny. Eliminating the batteries and other battery-related equipment removes substantial system cost, as does not needing to size a PV array to provide enough energy even on poor solar days.

A grid-tied system is even more attractive for its design flexibility. You can spend what you can afford, and expand your system later on. On the other hand, if you oversize the grid-tied PV system, you can also offset some of your household use in addition to the EV use. Or do what Kevin Johnson and Lisa Brown did with their oversized solar EV charging system, and get an electric yard tractor (see "Solar Electricity: At Home...and on the Road" in *HP117*).

Beyond the home, solar charging stations are under development across the nation. SolarCity, in cooperation with Tesla Motors, has planned a "solar corridor," allowing all-electric cars to charge at four locations between San Francisco and Los Angeles using solar energy. At the University of Central Florida, a PV-powered carport provides energy to charge electric vehicles by plugging them into an electrical outlet at the station. And in Plainville, Connecticut, General Electric's EV Solar Carport produces enough solar energy to charge about 13 cars per day through six charging stations, as well as power the location's overhead lighting. In addition to providing power or cars, the carport is also connected to the electrical grid, allowing it to send solar surplus power to the grid. Of course, to take advantage of these solar-charging opportunities, your daily commute destination will need to be close to a charging station.

—Michael Welch

Courtesy Motoczysz

MOTOCZYSZ

it a tough sell sitting on a sales floor next to a significantly cheaper gasoline-powered motorcycle. Second, dealers look to make money on after-sale service, and there's very little service required on an electric bike. No tune-ups; no oil changes. In some cases, the electronics on electric bikes can be serviced and updated with downloads from a website, and installed by the owner with a standard USB memory stick.

Although a few models in each line are squarely aimed at the commuter and a lot of the language on the sites is

BRAMMO ENERTIA

Courtesy Brammo

all about the green aspect of the bikes, they're really part of the enthusiast market. Even commuter bikes like the Enertia and the Zero S are designed to be fun to ride, handle well, and give you a little thrill, but when you look at the dirt bikes that Quantya, Zero, and Brammo offer, and then the street/sport bikes that Mission, Roehr, Mavizen, and Brammo have, you're looking at much more than just practical or environmentally responsible. A few of the dirt bikes have innovations like removable battery packs so you can show up at the pit with a few packs in the truck, run them hard, and switch them out—all without having to carry the extra weight on the bike. Some of the superbikes are barely street-legal replicas of all-out race bikes.

Riding the Zero and the Brammo provide different experiences. The Zero S is a more standard, lightweight sport-bike configuration, with the footpegs directly under the rider's center of gravity, allowing more control under fast or bumpy riding conditions.

The Brammo/cruiser/scooter position is more like sitting in a chair, while the Zero/sport position is more like riding a horse. Both bikes are nimble and quick, but the Brammo seems aimed at a more consumer-based crowd and new riders, while the Zero is pointed at the enthusiast market.

At the other extreme is Roehr's eSuperSport, a motorcycle that, for $18,000, measures up to most gas-powered supersport bikes. Its lithium batteries are capable of a 75-mile range and the top speed is more than 100 mph. It has all of the features sport riders expect from a new model: 41 mm inverted, adjustable rebound and compression-dampening front forks; single shock with rising rate linkage rear suspension with adjustable preload; and double 300 mm disc, four-piston caliper front brakes and single-disc, two-piston caliper rear brakes; all in an oval-tube steel-beam frame.

The electric specs are equally impressive: a 50 kW (67 hp) peak AC induction motor that pumps out 80 foot-pounds of torque, with 7.7 kWh of lithium-iron phosphate high-discharge batteries, running at 96 V/80 Ah and 650 amps (peak). It's a bike you could take to the track. After riding a bike like this, you'll have no doubt you're living in the twenty-first century.

Courtesy Roehr

Roehr eSuperSport

The "rider triangle," showing the relationships of the rider's seat, hand, and foot positions. The Zero shows a more forward position, with the rider's center of gravity squarely over the feet, allowing greater control. The Brammo shows a weight-back position, allowing more comfort, but less ability to shift weight to the footpegs.

Courtesy Zero

Courtesy Brammo

PEVs Compared

PEV	Weight (Lbs.)	Range (Miles)	Top Speed (mph)	Acceleration	Price	Comments
Razor EcoSmart Metro	75	15	18	Low*	$400	Kid's toy for grown-up commuters
Bumble Bee	n/a	25	20	Low*	1,195	Electric moped
E-Glide GI Powerboard	57	10	24	High*	1,400	Extreme sports PEV
Native Z1.5	n/a	40	30	Moderate*	2,200	U.S. assembled
Schwinn Searcher E8	40	20	20	Low*	2,679	Standard bike design, incorporated drivetrain
Trek Fx+	45	20	20	Low*	2,679	Standard bike design, incorporated drivetrain
Ultra Motor A2B	72	20	20	Low*	2,700	Futuristic purpose-built design
Native Z6 (Li)	n/a	40	60	High*	4,800	U.S. assembled
Current Motors Deluxe	425	50	65	not published	8,000	U.S. assembled
Segway i2	100	24	12.5	Low*	8,000	High-tech gyro direction & speed control
Zero XU	218	30	50	5 sec. (0-60)	8,000	Commuter/sport
Brammo Enertia+	324	80	60	not published	9,000	Commuter/first-time rider
Quantya EV01 Strada	195	25	45	not published	11,000	Off-road/sport-derived design
Brammo Empulse 10.0	420	100	100	not published	14,000	Purpose-built chassis from U.S.
Vectrix VX-1 Li	425	60	68	6 sec. (0-50)	14,000	U.S./European manufacture
Roehr eSuperSport	470	75	100	4.2 sec. (0-60)	18,000	Based on Hyosung Motors U.S.A GT650R chassis

*Estimated from watt/weight specs

All specifications are as per the manufacturer's claims or, where absent, estimates based on the best available information. *Home Power* magazine accepts no liability for errors or omissions.

Courtesy Quantya

QUANTYA EV01 STRADA

With 141 hp and 115 foot-pounds of torque, the MissionEVT powertrain, with its liquid-cooled AC induction motor, is capable of 0 to 160 mph in one gear.

For anyone who's been at a dirt track and heard the "angry horde of bees" din, the simple mechanical sound of the shocks and chain, along with a quiet whir of the motor, is a little disarming. It is, however, one of the attractive things for riders who live and ride in populated areas—the ability to go for a hard ride without raising the neighbors' ire.

The street bike ride is like nothing you've ever experienced. An electric bike with a 350 W motor is one thing, but a motorcycle with a 10 kW or greater motor is something else entirely. Electric motors give 100% of their torque—that head-snapping, teeth-rattling jolt of wheel-turning adrenaline—as soon as you crack the throttle. A gasoline-powered motor gives you almost no power until it gets its revs up. From there, an electric motor continues to dish out power as it spins up; if you want to go faster, you just give it more voltage and spin the motor faster. Gas motors have very narrow bands of power, which is why a transmission is needed to spread that power over all the speeds. Most electric motorcycles don't use or need a transmission.

Riding one of these, even one of the smaller bikes, is like having instant power at your fingertips. Riding the big bikes can only be described as holding yourself hooked to the end of a big, long bungee cord and then letting go. From 0 to the motorcycle's top speed, it's a simple twist of the throttle and you're gone. There's nothing to think about, except negotiating the road—no concentrating on engine speed or when to shift. This is a new experience and a new way to understand motorcycling.

Are electric cycles as fast as gas bikes? Yes, they can be. Electric bikes have competed, and sometimes won, against a field of gasoline-powered bikes. In racing, there's the "class" issue—you've got to determine the proper weight and power class to ensure a fair match. But clearly, they can hold their own. As the technology develops, they will no doubt surpass gas performance—the all-electric Grand Prix (the TTXGP) is only entering its third year.

What's Next?

The main development in electric vehicles is the battery system. Lithium-ion battery technology continues to progress and, as the supply and technology ramps up, prices are dropping dramatically. We may soon see even lighter, less-expensive batteries with greater capacity. But the lead-acid battery technology that is more than a century old remains a viable option for low-cost, reliable, and long-lasting systems.

As the all-electric car market ramps up and starts to drive demand, the charging infrastructure grows, and much of the prejudice about electric vehicles fades away, the personal electric vehicle, in whatever form you're looking for, is here to stay.

Access

Ted Dillard (ted@evmc2.com) is the author of www.ElectricChronicles.com, a website devoted to two-wheel electric vehicles of all descriptions, renewable energy and EV technology, and of "…from Fossils to Flux," a basic guide to building an electric motorcycle. He's had an unhealthy obsession with EVs since his first ride in a Renault Mars II in 1968.

Manufacturers:

Brammo • www.brammo.com • Electric motorcycle

Crystalyte • www.crystalyte.com • Electric bike conversion kit

Current Motor Co. • www.currentmotor.com • Electric scooter

E-Glide • www.e-glide.com • Electric scooter

Electric Motorsport • www.electricmotorsport.com • Electric scooter

Golden Motor • www.goldenmotor.com • Electric bike conversion kit

Hollywood Electrics • www.hollywoodelectrics.com • Electric scooter

Mission • www.ridemission.com • Electric motorcycle

Motoczysz • www.motoczysz.com • Electric motorcycle

Quantya • www.quantyausa.com • Electric motorcycle

Razor • www.razor.com • Electric scooter

Roehr Motorcycles • www.roehrmotorcycles.com • Electric motorcycle

Schwinn • www.schwinnbikes.com • Electric bike

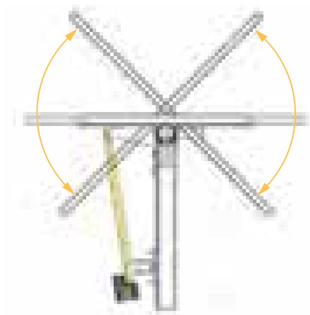
Segway • www.segway.com • Electric transporter

Trek • www.trekbikes.com • Electric bike

Ultra Motor • www.ultramotor.com • Electric bike

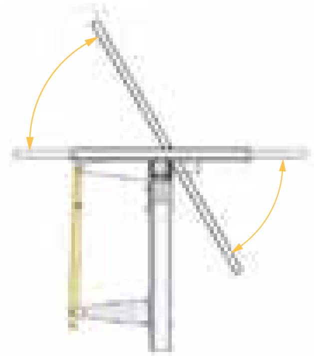
Vectrix • www.vectrix.com • Electric scooter

Zero Motorcycles • www.zeromotorcycles.com • Electric motorcycle



HORIZONTAL LINEAR AXIS

Get 25% more power from your system with this extremely durable, low-profile horizontal tracker. Not only can it blend into the environment, but it's also easy to assemble. The HZLA tracks from 45° to 45° and can produce up to 4 kW per tracker.



SEASONAL ADJUSTABLE RACK

This low-cost alternative to a tracker or fixed ground mount gives you the ability to quickly and easily optimize your array's tilt to compensate for the sun's seasonal changes. With up to 4 kW capacity, it is adjustable from flat to 60°.

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Solar trackers are never a "one-design-fits-all" solution. For more than 20 years, Array Technologies has been designing high quality, low maintenance tracking and racking systems for residential, commercial and utility-scale projects. From our popular Wattsun and HZLA single-axis, dual-axis and horizontal linear-axis trackers, to our innovative, low-cost seasonal adjustable racks, we have the perfect solution for your project.

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PV SYSTEMS Simplified

by Justine Sanchez &
Ian Woofenden

Photovoltaic (PV) modules make electricity from sunlight, and are marvelously simple, effective, and durable. They sit in the sun and, with no moving parts, can run your appliances, charge your batteries, or make energy for the utility grid. It's difficult to find a product that combines the longevity *and* productivity of PV modules. When you buy them, you're buying 40-plus years of electricity for a one-time cost.

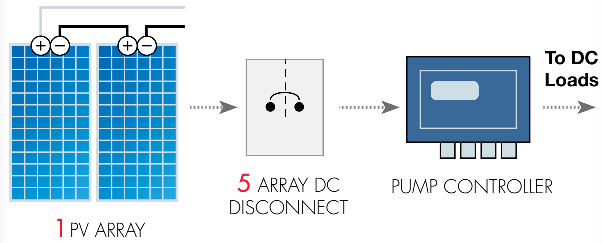
A PV array is the energy collector—the solar "generator." To use the energy from the array, you also need other components which make up a solar-electric *system*, and you need to design the whole system for the purpose desired. This article explains the basic components and configurations for the four most common system options in solar electricity:

- PV-DIRECT
- STAND-ALONE (OFF-GRID)
- GRID-TIED WITH BATTERY BACKUP
- BATTERYLESS GRID-TIED

Specific systems will vary—not all equipment is necessary for every system type. In the diagrams, the numbers in red correspond to the major components needed.

PV-DIRECT SYSTEMS

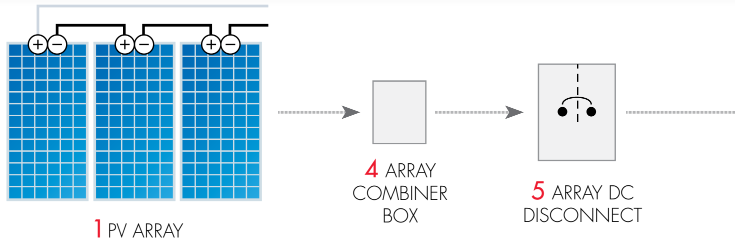
These are the simplest of solar-electric systems, with the fewest components. Because they don't have batteries and are not hooked up to the utility, they only power the loads when the sun is shining. This means that they are only appropriate for a few select applications, notably water pumping and ventilation—when the sun shines, the fan or pump runs. At night these systems do not provide energy. These systems require a match between the PV modules and the load, and may also have electronics between the array and load to facilitate start-up and maximize energy production.



OFF-GRID SYSTEMS

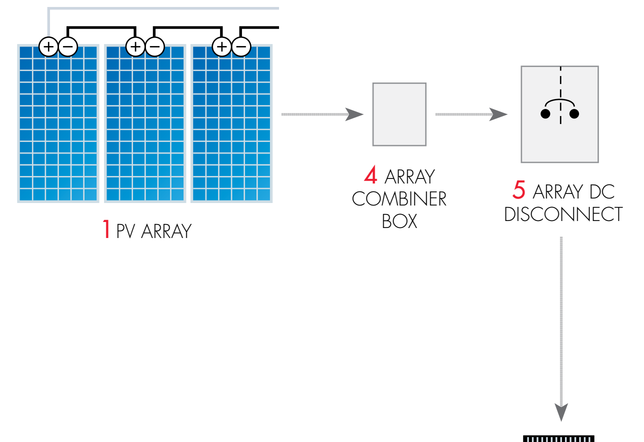
Although they are most common in remote locations without utility service, off-grid solar-electric systems can work anywhere. These systems operate independently from the grid to provide all of a household's electricity. That means no electric bills and no blackouts. People choose to live off-grid for a variety of reasons, including the prohibitive cost of bringing utility lines to remote home sites, the appeal of an independent lifestyle, or the general reliability a solar-electric system provides. Two key components are batteries to store energy and an engine-generator which can provide energy during periods of cloudy weather.

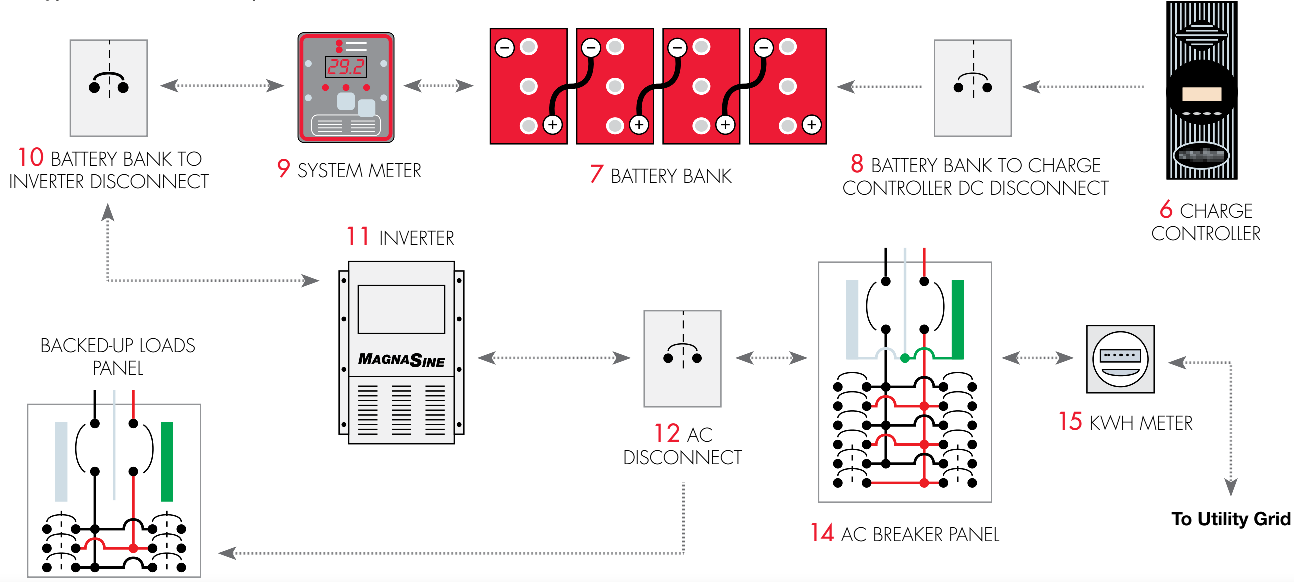
Those who live off-grid often make adjustments to when and how they use electricity, so they can live within the limitations of the energy available. This doesn't necessarily imply doing without, but rather is a shift to a more conscientious use of electricity.

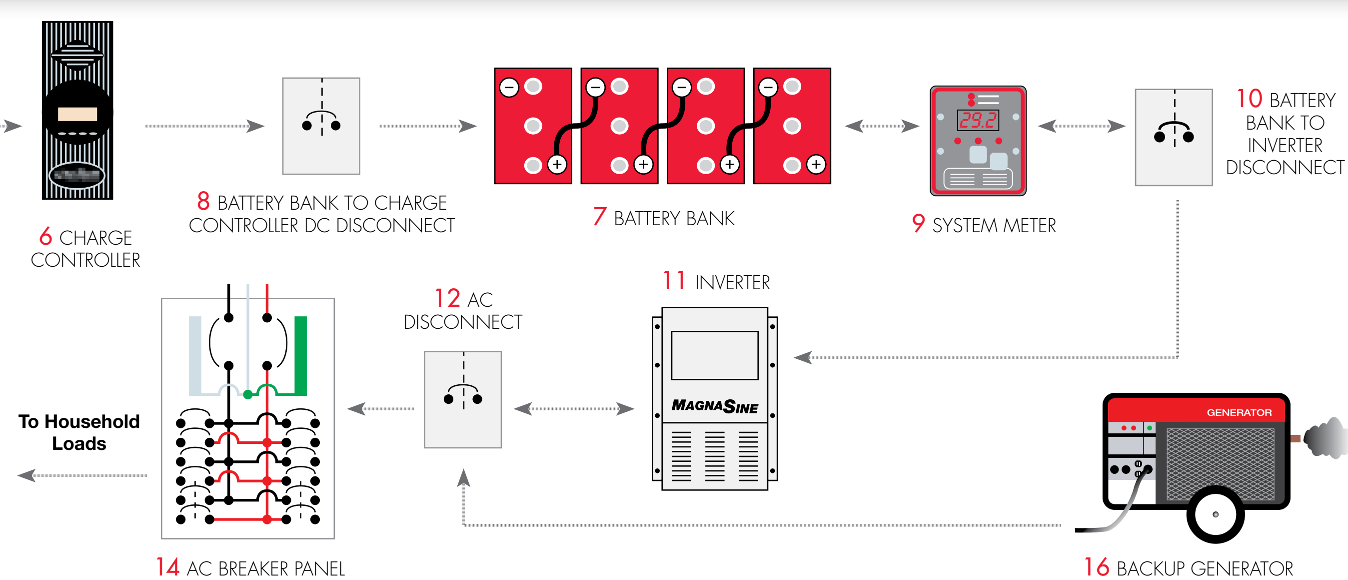


GRID-TIED SYSTEMS WITH BATTERY BACKUP

This type is very similar to an off-grid system in design and components, but adds the utility grid, which reduces the need for the system to provide all the energy all the time. The battery bank provides backup to some or all loads during utility outages. Battery backup can be provided for any household circuit, but common backup loads include refrigeration, a well pump, or a computer. Including batteries in a grid-tied system requires more components, is more expensive, and lowers the system's overall efficiency compared to a batteryless grid-tied system. But for homeowners who regularly experience utility outages or have critical electrical loads, having a backup energy source can be important.



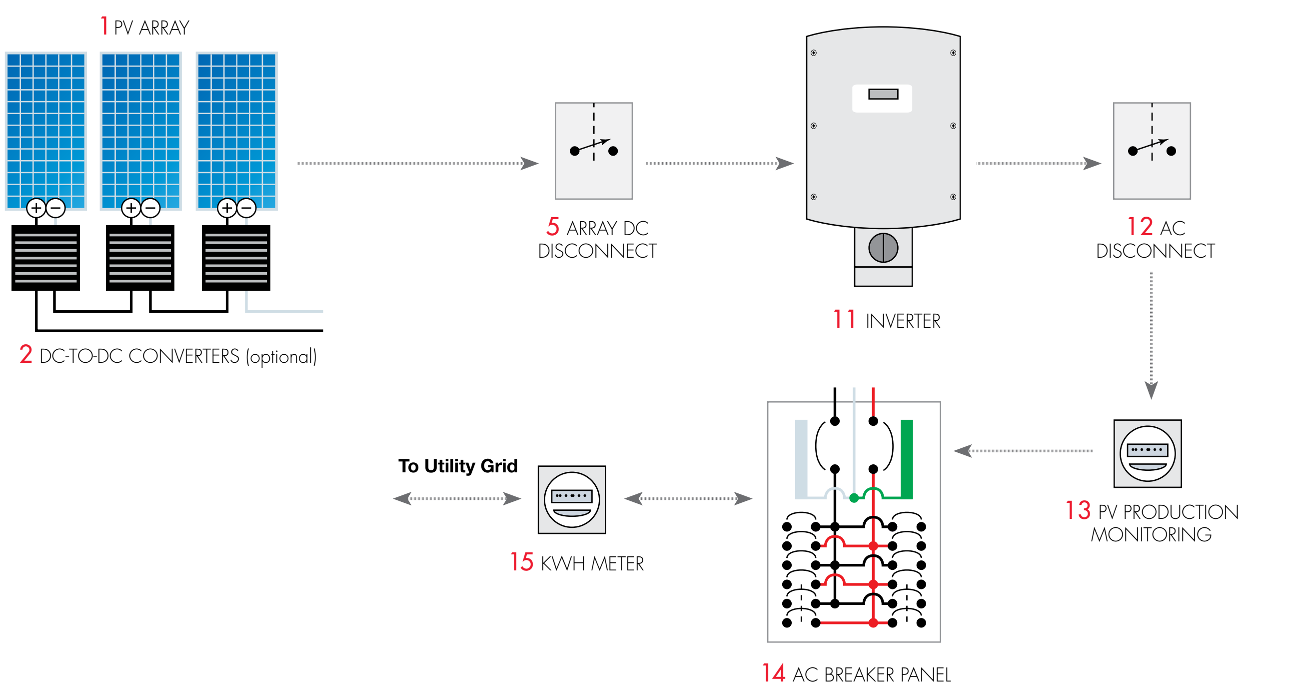




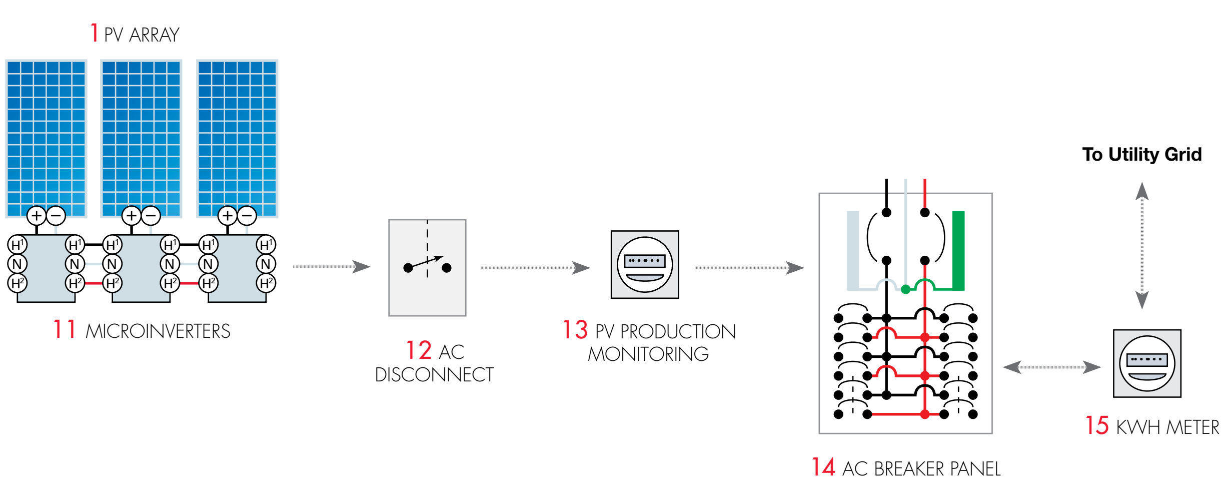
BATTERYLESS GRID-TIED SYSTEMS

These most common PV systems are also known as on-grid, grid-tied, utility-interactive, grid-intertied, or grid-direct. They generate solar electricity and route it to the loads and to the electric utility grid, offsetting a home's or business's electricity usage. Living with a grid-connected solar-electric system is no different than living with utility electricity, except that some or all of the electricity you use comes from the sun. The drawback of these batteryless systems is that they provide no outage protection—when the utility grid fails, these systems cannot operate.

In many states, the utility credits a grid-tied customer's account for solar electricity produced during each billing cycle, which is then applied to periods when the system produces less or electrical consumption is greater. This arrangement is called net-metering or net billing. The specific terms of net-metering laws and regulations vary from state to state and utility to utility. In some states, a production incentive may pay the system owner a premium for PV system production. (See www.dsireusa.org for states' incentives details.)



MICROINVERTER SYSTEMS



1 PV MODULES (AKA: solar-electric modules)

PV modules are a solar-electric system's defining component, where sunlight is used to make direct current (DC) electricity. Behind a PV module's shimmering face, semiconductor materials work their magic, using light (photons) to move electrons in a circuit—what's known as the photovoltaic effect.

PV modules are rated in watts, based on the maximum power they can produce under ideal sun and temperature conditions. You can use the rated output (along with a figure representing your local solar resource and an efficiency factor) to determine how many modules it will take to meet your electrical needs. Multiple modules combined together are called an array. Although framed modules are most common, PV technology also has been integrated into roofing shingles and tiles, and even peel-and-stick laminates for standing-seam metal roofs.

PV modules are very durable and long-lasting—most carry 25-year warranties. They can withstand severe weather, including extreme heat, cold, and hail.

Solar World

2 DC-TO-DC CONVERTERS (AKA: distributed power harvesters, power boxes, module maximizers)

A new component that's showing up on some batteryless grid-tied PV systems is DC-to-DC converters. These units can maximize the output of each module and reduce losses due to variances between modules' outputs. They are directly wired to each module and are bolted to either the module frame or the PV rack. The output of each power box is combined (either in series or parallel) to the other power boxes and the final output is wired to the PV disconnect.

SolarEdge

3 ARRAY MOUNTING SYSTEM (AKA: mounts, racks)

Sungevity

Mounts provide a secure platform on which to anchor your PV modules, keeping them in place and oriented correctly. Modules are generally mounted on a rooftop, atop a steel pole set in concrete, or at ground level. The specific pieces, parts, and materials of your mounting system will vary considerably depending on which method you choose.

Usually, arrays in urban or suburban areas are mounted on a south-facing roof (although east- and west-facing roofs can also be used), parallel to the roof's slope. This approach is sometimes considered most aesthetically pleasing, and may be a local requirement. In areas with a lot of space or if your roof is not ideal because of orientation or shading, pole- or ground-mounted arrays are options.

Pole-mounted PV arrays can incorporate tracking, automatically following the sun across the sky from east to west each day. Tracked PV arrays can increase the system's daily energy output by 25% to 40%, but come with more cost, complexity, maintenance, and potential failure than fixed arrays.

4 COMBINER BOX
(AKA: series string combiner)

The array combiner box is used to wire and combine parallel strings of PV modules. These are most commonly found in off-grid systems, although larger on-grid systems will have combiner boxes as well. Coming into the input side of a combiner box will be the positive and negative wire for individual module strings, each with its own terminal. Each positive terminal is internally connected to a series circuit breaker (or fuse) for that string. The output of each breaker/fuse is connected together on a common bus bar to which a positive output wire is connected. The strings' negative wires are simply connected to a common bus bar along with the negative output wire. Some batteryless grid-tied inverters integrate a combiner box on the input side of the inverter, eliminating a separate combiner box. And some grid-tied systems only have a few PV module strings (3 or less), and do not need a combiner box at all.

MidNite Solar

5 DC DISCONNECT

The DC disconnect is used to safely interrupt the flow of electricity from the PV array. It's an essential component when system maintenance or troubleshooting is required, and may be mandated by local inspectors. The disconnect enclosure (sometimes a part of the inverter package), houses an electrical switch rated for use in DC circuits. It also may integrate either circuit breakers or fuses, if needed.

Siemens

6 CHARGE CONTROLLER (AKA: controller, regulator)

OutBack Power Systems

A charge controller's primary function is to protect the battery bank from over-charging. As a battery becomes charged, the controller moderates the flow of electricity from the PV modules. Batteries are expensive and need careful treatment. To maximize their life, avoid overcharging or undercharging them. Most modern charge controllers incorporate maximum power point tracking (MPPT), which optimizes the PV array's output to maximize energy production. Some battery-based charge controllers also include a low-voltage disconnect for the DC loads to help prevent over-discharging, which can permanently damage the battery bank.

7 BATTERY BANK (AKA: storage battery)

PV modules produce electricity only when the sun shines on them. If your system is designed to provide energy without the utility grid, you'll need a battery bank—a group of batteries wired together—to store energy so you can have electricity at night or on cloudy days. For off-grid systems, battery banks are typically sized to keep household electricity running for up to three cloudy days. Grid-tied systems also can include battery banks, which provide emergency backup power during grid outages to keep critical electric loads operating until grid power is restored.

Although similar to car batteries, the deep cycle batteries used in solar-electric systems are specialized for the type of charging and discharging they'll need to endure. Flooded lead-acid batteries are most commonly used in solar-electric systems, are the least expensive, but require adding distilled water occasionally to replenish water lost during the charging process. Sealed batteries, absorbed glass mat (AGM) and gel-cell, do not require adding water and often used for grid-tied systems where the battery bank is usually small (as compared to off-grid banks), and the batteries are typically kept at a full state of charge.

Surrette

8 BATTERY BANK TO CHARGE CONTROLLER DISCONNECT

Because all electrical components may need to be serviced periodically, it is necessary, and required by the National Electric Code (NEC) to place disconnects between all sources of power and the other components. Because of this, a disconnect (usually a circuit breaker to also protect the wire) is placed between the battery bank and charge controller, which enables isolating the charge controller from the battery bank for servicing.

MidNite Solar

9 SYSTEM METER (AKA: battery monitor, amp-hour meter)

System meters measure and display several different aspects of a PV system's performance and status—tracking how full your battery bank is; how much electricity your solar-electric array is producing or has produced; and how much electricity is being used. Web-based monitoring is offered in some metering packages and is extremely handy to keep tabs and potentially troubleshoot the system. Operating your solar-electric system without metering is like running your car without any gauges—although it's possible to do, it's always better to know how much fuel is in the tank.

Bogart Engineering

10 BATTERY TO INVERTER DISCONNECT (AKA: main DC disconnect)

In battery-based systems, a disconnect between the batteries and inverter is typically a large, DC-rated breaker mounted in a sheet-metal enclosure. This breaker allows the inverter to be quickly disconnected from the batteries for service, and protects the inverter-to-battery wiring against too-high current.

Carling Technologies

Siemens

12 INVERTER AC DISCONNECT

Utilities usually require an AC disconnect between the inverter and the grid. Some grid-tied inverters have integrated AC disconnects, but these may or may not meet local requirements, calling for a separate PV system AC disconnect box, usually located near the utility kWh meter. In battery-based systems an AC disconnect is also required between the inverter, the AC breaker panel and any other AC power source. It is usually incorporated into an inverter bypass breaker assembly, allowing the AC loads to be fed by either the inverter, or if power from the inverter is unavailable, by another AC power source such as a backup generator.

11 INVERTER (AKA: DC-TO-AC CONVERTER)

Inverters transform the DC electricity produced by the PV modules or from the batteries into the alternating current (AC) electricity commonly used for lights, pumps, and other electrical appliances. Grid-tied inverters synchronize the electricity they produce with the grid's AC electricity, allowing the system to feed any unused solar-made electricity to the utility grid.

Most grid-tied inverters are designed to operate without batteries, either tying to one or more strings (series grouping) of modules, or using a "microinverter" for each module. Similar to systems using DC-to-DC converters, microinverters offer module-level monitoring and maximize array output with module-level MPPT, enabling each module to operate independently of the others.

Battery-based inverters for off-grid or grid-tied use often include a battery charger, which is capable of charging a battery bank from either the grid or a backup generator during cloudy weather. Most batteryless inverters can be installed outdoors, but most battery-based inverters are not weatherproof and should be mounted indoors, close to the battery bank.

SMA

Magnum

Enphase Energy

13 PV PRODUCTION MONITORING

An additional meter to measure solar production is useful for tracking system performance, and is needed for production-based (per kWh) incentives. This can be a dedicated kWh meter that counts the kWh coming out of the inverter, or can be a full revenue-grade or Web-based data monitoring package.

Power-One

Benjamin Root

15 KILOWATT-HOUR METER (AKA: kWh meter, utility meter)

Most homes with a grid-tied solar-electric system will have AC electricity coming from and going to the grid. A bidirectional kWh meter can cumulatively track the flow in both directions. The utility company often provides these special meters at no cost.

14 AC BREAKER PANEL (AKA: mains panel, AC load center, breaker box, fuse box)

The AC breaker panel is where a building's electrical wiring connects to the source of the electricity, whether that's the grid or a solar-electric system. This wall-mounted panel or box is usually installed in a utility room, basement, garage, or on the building's exterior. It contains a number of labeled circuit breakers that route electricity to the various rooms or household circuits. These breakers allow electricity to be disconnected for servicing, and also protect the building's wiring against overcurrent, which may cause electrical fires.

Just like other electrical circuits, an inverter's electrical output needs to be routed through an AC circuit breaker. This breaker is usually mounted inside the building's mains panel, which enables the inverter to be turned off and isolated if servicing is necessary, and also safeguards the circuit's electrical wiring.

Benjamin Root

16 BACKUP GENERATOR (AKA: gas guzzler, the racket)

Honda Power Equipment

Off-grid PV systems can be sized to provide electricity during cloudy periods when the sun doesn't shine. But sizing a system to cover a worst-case scenario, like several cloudy weeks during the winter, can result in a very large, expensive system that will rarely get used to its capacity. To spare your pocketbook, size the system moderately, but include a backup generator to get through those occasional sunless stretches. Generators are also used to provide battery equalizing charging—occasional, high-voltage, prolonged charging that brings the weaker battery cells up to the charge level of the stronger cells.

Engine generators can be fueled with biodiesel, petroleum diesel, gasoline, or propane. These generators produce AC electricity that a battery charger (either stand-alone or incorporated into an inverter) converts to direct current, which is stored in batteries. Like most internal combustion engines, generators tend to be loud and polluting, and require maintenance. A well-designed PV system will require running a generator only 50 to 200 hours a year.

SOLAR-ELECTRIC SYSTEMS DEMYSTIFIED

As you can see, the anatomy of a solar-electric system isn't that complicated. All of the parts have a purpose, and once you understand the individual tasks that each part performs, the whole system makes more sense. Now you're ready to look at the system articles and schematics in *Home Power* without your eyes glazing over, and you'll have a clearer understanding of what is going on. To solidify your understanding, your next task could be to examine a solar-electric system in person, going on a local solar tour, or getting on the solar grapevine to visit folks ahead of you on the solar curve.

ACCESS

Justine Sanchez (justine.sanchez@homepower.com) is Technical Editor at *Home Power*, a Solar Energy International instructor, a NABCEP-certified PV installer, and is certified by ISPQ as a PV Affiliated Master Trainer.

Home Power Senior Editor Ian Woofenden (ian.woofenden@homepower.com) has been living with solar-electric systems since the early 1980s. His systems include a wide range of applications, including solar flashlights, vent fans, hybrid wind-PV systems for home and shop, a PV-powered waterslide, electric fence chargers, an iPhone backup charger, and more.

Making Energy-Efficient Lighting Work in Your Home

by Brian Clark Howard & Julia Rezek

Low-voltage track and recessed, adjustable down-lights are used to accent artwork, using 37 W IR MR16 lamps. Lighting is controlled by a Lutron Homeworks Series 8 whole-house automated dimming system, in which all lights are programmed to be dimmed 10% even at full "on" mode. This helps to extend lamp life, save energy, and reduce maintenance costs.

Lighting a home is not as cheap as you might think. The average American household spends 9% to 20% of its electric bill on lighting, according to the U.S. Department of Energy (DOE). That's $90 to $180 a year for home lighting, depending on where you live. Americans also spend $11.9 billion a year on lighting equipment, with $2.7 billion of that on lightbulbs.

In the United States, about two-thirds of our electrical energy is produced by fossil fuels, meaning that lighting has a significant environmental impact from greenhouse gas emissions, particulate pollution, spills, and other damages from extraction of coal, oil, and natural gas. With nuclear, there's also the potential for widespread deadly contamination, and the important issue of disposing of radioactive waste.

Beyond the environmental benefits of improving a home's lighting efficiency, it is cost effective as well. An analysis by the Energy Cost Savings Council estimates the average payback period for an investment in efficient lighting at 2.2 years, with an average return on investment (ROI) of 45%. That's a better return than almost any other change you could make to your home.

In 2007, by switching to compact fluorescent (CF) lamps, Americans saved an estimated $1.5 billion and enough energy to light all of the households in Washington, D.C., for 30 years, according to the DOE. That's like planting 2.85 million acres of trees or taking 2 million cars off the road in greenhouse gas reduction. If every American household replaced one incandescent with a CF, we would save enough energy to light 3 million homes and make greenhouse gas cuts equivalent to removing 800,000 cars from the road.

Lighting Legalities

America lags behind much of the rest of the world in adopting efficient lighting. In Europe, Australia, Israel, East Asia, or Latin America, you'll see almost exclusively CFs. Before the United States passed the new efficiency standards, most lighting companies already had plans to discontinue mass production of incandescents, and switch to more efficient technologies.

Congress passed the Energy Independence and Security Act of 2007, which requires new general-purpose bulbs to be 30% more efficient than standard incandescents by 2014. By 2020, additional standards require general-purpose bulbs to produce at least 45 lumens per watt (W), about the same as current CFs. Many other countries have similar standards.

Specific Lighting Semantics

Shoppers should familiarize themselves with the correct terminology when they're looking for lighting. "Lightbulbs" are "lamps"—mechanisms that consume energy and deliver light. Lamps are typically a part of another device, which controls the way the light is distributed into the space. This device is called a "light fixture" or "luminaire." The term "light source" may refer to either a lamp or a light fixture.

There are several other terms to become familiar with when evaluating and comparing lamps and light fixtures. Many reputable manufacturers publish data in product specification sheets (usually available online). Sometimes, this information can be found on the product packaging. Look for the following specifics:

Watts: A measurement of the amount of power a light source consumes.

Lumens: A measurement of the amount of light a light source produces.

Efficacy: A measurement of lumens produced per watt consumed (LPW). For example, if you have a 100 W lamp that produces 1,800 lumens, divide the lumens by the watts and you will get the measured "efficacy"—18 LPW.

Correlated Color Temperature ("CCT"; measured in degrees Kelvin): A measurement of the "warmth" of a light source. For example, the yellow warmth of a candle measures 1,500 Kelvin. A standard household incandescent A-lamp measures about 2,700 K. Halogen sources measure approximately 3,000 K, while fluorescent sources can range between 2,700 K and 5,000 K. White LED sources have an even greater range, spanning 2,700 K to 8,000 K. For a comparison, noon sunlight measures 5,500 K. North light (under a blue sky) measures 8,000 K. The bulb's Kelvin rating, however, does not tell you anything about how accurately the light source renders colors in the environment (see CRI, below).

Color Rendering Index ("CRI"): A measurement of how well a light source renders colors in the environment. CRI is not a perfect measuring system, but in general, the higher the number, the better the color rendition. Select lamps with a CRI between 80 and 100 to make people and things look their best. Note that incandescent and halogen sources are always rated at 100, even though incandescent sources are deficient in the blue end of the spectrum.

Beam Spread: If the light source you are considering is a "point source" (meaning the light is directed primarily in one direction) like an outdoor floodlight (PAR lamp) or an MR16 halogen lamp, then you want to carefully select the appropriate beam spread for your application. Typically, you will find the following options: spot—10°; narrow flood—25°; flood—40°; and wide flood—60°. This means the primary intensity of the beam will fall within this conical field of measurement.

Lamp Life: A measurement of how long the lamp will operate in hours before it either extinguishes, shifts to an undesirable color, or produces less than 70% of its rated lumen output.

Dimming: It's important to consider whether a light source is dimmable and if there are added costs to dim the product. Also consider that some LED and CF sources have limited dimming ranges and do not shift to a warm tone when dimmed.

—Julia Rezek

Lightbulb Comparison

A-Lamp Types	Power (Watts)	Brightness (Lumens)	Avg. Life (Hrs.)	Correlated Color Temp. (Kelvin)	Color Rendering Index	Lumens per Watt	Dimmable
Incandescent (general purpose)	60.0	850	1,000	2,850	100	14.2	Yes; full-range dimming
Halogen	60.0	965	3,000	2,850	100	16.1	Yes; full-range dimming
Compact fluorescent	14.0	800	8,000	2,700	82	57.1	Some; consult packaging and use appropriate dimmer
LED	12.5	800	25,000	2,700	80	64.0	Yes; see manufacturer's dimming requirements & limitations

Courtesy Juno Lighting

Courtesy Juno Lighting

Courtesy Tech Lighting

Consider Design First

Before selecting any lighting, follow a couple of design recommendations. First, keep interior finishes light in color to reflect as much light as possible. Avoid gloss paints or wood finishes with semi-gloss or gloss treatments, particularly for ceilings because the reflective surface can act as a mirror, making an up-lighting application look uneven, with hot spots. Maximize the use of daylight with thoughtfully placed windows, and light wells or solar tubes. Use lighting controls (dimmers and occupancy sensors) where appropriate. (Note that dimming some lightbulb types can be tricky—follow the manufacturer's recommendations to select the correct dimmer.)

Brighter Lighting Technologies

Incandescents are inefficient and short-lived compared to other technologies. They turn only 2% to 10% of the energy they use into useful light and emit the rest as heat. This also heats interior space and can damage art and plants. At about 1,000 hours of use, they have one-tenth of the longevity of CFs.

Halogen. For those who aren't ready to put the look of conventional Edison lightbulbs (or lamps) behind them, but want a little more efficiency, halogen lamps may be a good start. Halogen lights are a type of incandescent, with the addition of halogen gas and a quartz envelope surrounding the filament. Sometimes this quartz enclosure is surrounded by another glass enclosure to conceal or diffuse the quartz envelope. This also allows you to touch the "lamp" while protecting the quartz envelope. Halogens are 10% to 40% more energy efficient than standard incandescents, and last two to three times longer.

Conserving Your Own Energy

Research has shown that during the evening hours, it is important to avoid exposure to wavelengths of blue light to allow for the healthy regulation of our sleep/wake cycles (circadian rhythms). Blue wavelengths of light are emitted from televisions, computer screens, cell phones, blue LEDs on your stereo equipment, and from fluorescent light sources. Exposure to these sources of light, even in very small amounts, can suppress the natural production of the neurotransmitter melatonin, which encourages deep sleep through the night. In a bedroom setting, then, some dimmable incandescent or halogen sources are recommended. Remove or conceal items that emit blue wavelengths of light in the evening hours. If you like a nightlight, use a red LED. Red wavelengths have the least effect on altering melatonin production.

—Julia Rezek

Courtesy Mark Mularz (2)

In this bedroom, artwork and furnishings are lit with recessed, adjustable 37 W MR16 accent down-lights. The indirect cove up-lighting uses xenon lamps on a low-voltage track. The decorative pendant uses a 60 W halogen A-lamp. All of these sources are continuous spectrum lamps, offering full-range, smooth dimming.

Energy management comes from the use of a Lutron Grafik Eye (above), which allows the homeowner to program four "moods," dimming groups of lights at different levels to create drama and visual interest, and also to address different functions such as TV watching, packing for a trip, or reading in bed.

The popular MR16 halogen lamp offers precise beam control and superior color rendition; when dimmed, it shifts to a warmer tone. It is available in an infrared "IR" model, which uses only a modest amount of energy when dimmed. For example, a 12-volt, 37-watt "IR" MR16 dimmed to 50% uses approximately 18 W (similar to a compact fluorescent, but with superior color rendering and a focused directional beam of light). In the energy-efficient home, however, it should be used sparingly—for artwork accent lighting and in bedroom settings where it's important to dim to the very lowest levels for mood and atmosphere. Incandescent and halogen lamps are continuous-spectrum sources, meaning that they emit light in all ranges of the visible spectrum. When dimmed, these sources shift to the red (warm) end of the spectrum, which can help to encourage relaxation at bedtime (see the "Conserving Your Own Energy" sidebar).

Halogen bulbs are also small, fitting nicely into track light fixtures and under cabinets. The main drawback is that they produce more heat than standard incandescents, and certainly more than fluorescent and LED sources. New "hybrid" bulbs use halogen technology more efficiently but resemble standard incandescents in size, shape, and applications, making them easy replacements in standard fixtures.

Fluorescents come in several flavors: linear fluorescents, screw-in, and pin-base (aka dedicated socket). They are roughly 75% more energy efficient than standard incandescents, and typically last about 10 times longer (10,000 hours). Bulbs have dropped dramatically in price, from around $20 each a decade ago to $7 to $10 for quality bulbs.

To ensure quality, always look for Energy Star-certified CFs, which have a minimum rated lifespan of 6,000 hours and carry a two-year warranty. ES-certified bulbs cannot emit an audible noise. They must produce high-quality light, turn on in less than a second, and reach at least 80% of their output within three minutes. They also cannot contain more than 5 milligrams of mercury (see "Mercury & Fluorescent Bulbs" sidebar).

Fluorescents have come a long way in light quality, with "warm" and "soft white" models from major manufacturers now nearly indistinguishable in appearance from incandescents. It's important to some to use CFs with the warmest color temperature (more yellow/red—less blue), closer to the warmth of incandescent lamps. A color temperature of 2,700 to 3,000 Kelvin (K) is preferable. The higher range —3,500 to 5,000 K—is best used when a cooler, crisper light is desired. Choose CFs with a high color rendering index (CRI)—how accurately a light source renders perceived color—in the 80s or above only! (The ideal measurement is 100.) CFs do not offer precise beam control. They emit light in all directions much like a standard lightbulb, so they are most appropriately used when a "glow" is desired. Unfortunately, low-quality products have given CFs a bad reputation—cheap lamps can produce poor color-rendering properties, as well as buzz and flicker. They tend to be short-lived and don't dim easily. Many of the screw-in replacement CFs won't dim at all; the ones that do may dim to a visible 40% level and

A 14 W screw-in integrated-ballast CF, equal in lumen output to a 60 W general-purpose A19 incandescent lamp.

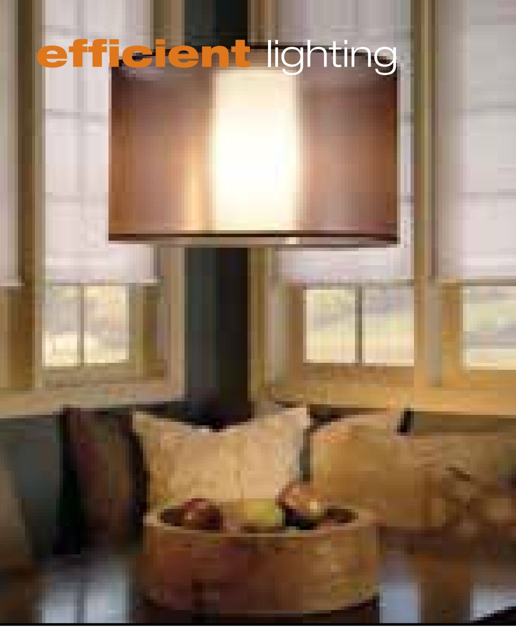
Mercury & Fluorescent Bulbs

It's the small amount of mercury that gives CF lamps their efficient glow, but it's smart to take precautions to avoid exposure. Most new CFs have 4 to 5 milligrams of mercury, and several brands have as low as 1 milligram. In contrast, a typical watch battery has 25 milligrams of mercury, an old hospital thermometer has 500 milligrams, and an old home thermostat has 3,000 milligrams. Especially in coal-burning regions, using incandescents actually results in more mercury released into the environment, since they use more energy, and burning coal is the biggest source of this neurotoxin.

Avoid putting unprotected CF lamps in rooms where children sleep or play, since young ones are most susceptible to harm from mercury, and are more likely to break something. If you want to be safe, cover the bulbs with full fixtures; consider halogens or LEDs; or check out "safety" CFs, which have a silicone covering that's designed to contain the mercury.

For perspective, the Lawrence Berkeley National Laboratory concluded that you are likely to take in more mercury from one meal of fish than from being near a broken CF. Still, if a CF or other fluorescent does break, clear everyone out and vent the room for at least 15 minutes. Carefully sweep up the pieces, place them in a sealable container, and take it to a hazardous waste disposal center.

—Brian Howard



This decorative pendant, with a 32 W CF, features a translucent organza drum with inner glass cylinder to provide a soft wash of light.

A small decorative pendant with a 26 W CF features a slender-case glass shade topped with metal detail.

This decorative wall sconce with its 18 W CF features an elegant multi-toned shade comprised of natural shells.

Courtesy Tech Lighting (3)

then flicker before they shut off. (Never put a standard CF in a fixture that's controlled by a dimmer even if you never "dim" it—this will shorten the bulb's life.)

High-quality CFs may cost more, but perform well and can be used in many household applications, particularly when the source is concealed from view—such as under a lamp shade, or behind a wall sconce or pendant diffuser. Stay with name-brand manufacturers such as Sylvania, Philips, and GE to get quality CFs, and look for the Energy Star label.

Frequent switching shortens the lifespan of CFs (by as much as 85%), so consider where you put them. CFs also shouldn't be exposed to extreme cold, since that makes them turn on slower and decreases their lifespan.

Cold-cathode CFs that lack the coating that typical CFs have work better at lower ambient temperatures, and they switch on instantly, although they aren't as bright. If your home is wired for DC, like some RVs and off-grid homes, you may be able to use DC CFs, which tend to last especially long (18,000 to 25,000 hours). On the downside, they produce fewer lumens per watt and are rarely brighter than a 25 W incandescent; plus, they cost more ($13 to $35).

It's not a good idea to put CFs in fixtures subjected to shock, since they break relatively easily. Vibrations also shorten their life spans, although there are some tougher models now marketed for ceiling fan fixtures.

As more states adopt residential energy codes similar to California's, screw-in CFs will not be in compliance for certain areas of the home. This code requires *dedicated or pin-base sockets* (preferably 4-pin or GU-24) that are designed specifically for fluorescent lamps.

Dedicated-socket CFs typically perform better than their integrated ballast counterparts—the larger ballast is isolated inside the luminaire, and designed to last longer. It also does not need to be replaced when the lamp burns out. The 4-pin lamps allow for dimming down to 10% and, in specific cases with the proper lamp/ballast/dimmer combination, you may dim to 1%, which is optimal. This last 10% of dimming is critical to the human eye because a fluorescent source dimmed to a measured 1% appears visually to be at 10%. Be aware that a dimmed fluorescent source does not color-shift to a warm (more yellow) tone like an incandescent.

For recessed down-light applications, dedicated-socket CFs are plentiful. For residential use, you will want an airtight, insulation-contact (IC)-rated housing to minimize air transfer between your conditioned space and the ceiling plenum. For the ultimate efficiency, keep recessed down-lights out of the roofline ceiling so that the insulation barrier is not penetrated.

The manufacturers of decorative residential-style pendants, wall sconces, and ceiling fixtures are beginning to include dedicated-socket CF options into their product lines. CF fixtures that employ hand-blown glass or fabric shades with beautiful patterns, textures, and colors can often completely disguise the CF source. When dimmed, most people cannot detect that it's a fluorescent source.

Linear fluorescent lamps are available in smaller-diameter sizes (T8, T5, and T2), and can be dimmable to 1% with the appropriate lamp/ballast/dimmer combination. The diameter of a fluorescent lamp is measured in eighths of an inch—a T8 is 1 inch in diameter (eight eighths); a T5 is $^5/_8$ inches in diameter; etc.). The old fluorescent lamps which will be discontinued are the T12 lamps.

Linear fluorescents are suitable for applications such as coves, vanity lighting (vertically flanking mirrors), closet lighting, suspended direct/indirect fixtures (kitchens), decorative pendants, under-cabinet task lighting, and indirect up-lighting above cabinetry. Using a concealed, linear fluorescent source to bounce light off ceilings and walls can give a general shadow-free layer of light, and helps

Courtesy Tech Lighting (3)

Fluorescent lamps can make attractive bathroom lighting. This 24 W linear fluorescent lamp features a light bar with multi-layered white glass or white acrylic.

Well-placed, efficient fixtures can provide quality lighting that's also functional and attractive.

Two 24 W linear fluorescent lamps flank a compact mirror, giving even, warm light.

balance the directional lighting used to accent artwork and furnishings. The color of the reflecting ceiling and walls affects the quality of the light in the space. Ceilings and walls finished in a warm matte wood material or painted a matte warm color can make the fluorescent source feel more like incandescent lighting. A 3,000 K, high color-rendering linear fluorescent lamp produces a very appealing warm light, which enhances skin tones and can be flattering. Gone are the days of fluorescents that make you look gray and lifeless—*if* you choose wisely.

LED in the USA

Light-emitting diode (LED) lamps are rapidly advancing beyond nightlights, flashlights, and desk lights—categories they already dominate. A 12 W LED replacement A-lamp may be a suitable replacement for a 60 W incandescent, so significant energy savings are possible by switching to LEDs. However, the high cost per bulb is a hurdle for some folks. At $20 to $60 each, they don't come cheap. Their salvation is that they will last for tens of thousands of hours.

However, industry standards for performance testing have only been in place for a couple of years and it can be difficult to sort out the good from the bad. But the payback can be worth it in convenience and increased efficiency. Lamp life expectancy ranges from 20,000 to 50,000 hours and LEDs produce less heat, saving on home cooling costs. LED sources do not emit UV radiation and this makes them good candidates for artwork accent lighting without the need for added UV filters. Incandescent, halogen, and fluorescent sources emit some levels of UV radiation. This is normally not of great concern unless you have valuable artwork, fabrics, and finishes which will be exposed to these artificial light sources continuously over long periods of time. In museums, for example, great care is taken to filter out UV radiation from artificial light sources to prevent fading and deterioration of paper, fabrics, and paintings. In a home setting, your biggest concern regarding UV fading should be about controlling daylight and direct sunlight to reduce the effects of UV damage.

Lighting Facts Per Bulb

Brightness	**800 lumens**
Estimated Yearly Energy Cost	**$1.51**
Based on 3 hrs/day, 11¢/kWh Cost depends on rates and use	ENERGY STAR
Life Based on 3 hrs/day	**22.8 years**
Light Appearance	Warm — Cool; 2700 K
Energy Used	**12.5 watts**

Philips' new Endura 12.5 W LED A-lamp serves as a replacement for a 60 W general purpose incandescent A-lamp.

Courtesy Philips

Philips' Endura LED dimmable 7 W and 10 W MR16 12 V replacement lamps have a 25,000-hour lamp life and three beam spreads. Light intensity mimics that of a 50 W halogen MR16.

Philips' Endura LED 12 W, PAR30 flood replacement lamps have a 45,000-hour lamp life and three beam spreads. Light intensity mimics that of a 60 W halogen PAR30.

Courtesy Philips (2)

LEDs are directional sources, so they lend themselves to applications such as recessed down-lights, accent lighting, task lighting, and cove lighting. Some manufacturers are designing decorative pendants, wall sconces, and ceiling fixtures specifically for LEDs. It is best to see an installed example of a fixture that you are considering, to evaluate how it really performs.

Replacement LED lamps are available to screw into your existing incandescent sockets and to replace your bi-pin MR16 halogen lamps and PAR lamps. However, be sure to examine and compare the lumen output of these lamps to their replacements. Look for either the Energy Star Label or the Lighting Facts label to ensure that the manufacturer has tested the product to meet some minimum efficiency requirements. The Lighting Facts label, implemented by the U.S. Department of Energy, is a volunteer program where manufacturers publish their test data to help consumers select quality LED lighting products. You will notice that these LED replacement lamps have significant heat sinks to pull heat away from the sensitive LEDs inside their protective enclosures. If these devices are put into a completely enclosed fixture, such as an enclosed track head, or a recessed and lensed down-light or a sealed landscape floodlight, they may suffer early failure due to excessive heat buildup.

Cree Lighting's four-LED down-light offers a deeply recessed lens for superior glare control. Its "True White" technology delivers high-efficacy light with warm color characteristics.

Courtesy Cree Lighting

Besides their somewhat steep up-front price, LED bulbs (lamps) aren't without a few other drawbacks. Some new models are dimmable, although they don't dim to low light levels compared to halogens and incandescents. In general, avoid discount LED brands and shop for long warranties and Energy Star ratings.

Most down-light manufacturers now offer a dedicated LED down-light, which is really a system that includes a housing, an LED "light engine," and a "driver," which regulates current. Many of the residential airtight insulation-contact IC rated LED down-lights are lensed to reduce glare. It is good to examine the options in person to see which products offer the best glare control and light quality. LED lensed down-lights are typically available in 4-, 5-, and 6-inch apertures, and would be used for general illumination such as in a kitchen, bath, laundry room, or hallway.

For more controlled and dramatic effects, there are adjustable LED down-lights, which perform in a similar way to a halogen MR16 accent light, including lenses to control beam pattern. A 20 W dedicated LED module produces the same lumens (equivalent of a 50 W MR16 halogen lamp) with 50,000 hours of life—and it's dimmable. The color-rendering and beam control are quite good with the higher-end products.

Energy Star Minimum Requirements for LED Down-Lights

Performance	Requirement
Efficacy (lumens per watt)	35
Color rendering index	75
Rated lifetime (hrs.)	25,000
Lumens, ≤ 4.5 in. diam.	375
Lumens, > 4.5 in. diam.	575

This angled slot reflector is one of many trim options available from Juno Lighting.

Tech Lighting's Element is an adjustable, 3-inch LED downlight, which is a good candidate for accent lighting. This shows an exploded view of the inner workings of the luminaire.

There are also some great LED track-lighting heads on the market. They can be expensive, but the beam control, punch, and color rendering are all good. Reputable manufacturers will have photometric data and performance specifications verified by independent testing labs. Avoid manufacturers that cannot provide this material for evaluation.

On the Horizon

Another lighting technology entering the market is called electron-simulated luminescence (ESL), and is based on cathode rays, like old TV sets and computer monitors. The bulbs (about $20) currently have limited distribution, but they produce warm, yellow light like standard incandescents. They are roughly as efficient as CFs and are said to last as long, yet they contain no mercury.

Halo Lighting also makes an attractive LED track head in large and small sizes.

Juno Lighting makes an LED track head with the driver incorporated into the head itself.

Tech Lighting's low-voltage monorail with LED track heads.

Let the Free Light In: A Case Study

When Scott Singer and Mary Jo Romano decided to renovate their home in Norwalk, Connecticut, they wanted to lower their electric bills. So they tapped into the power of the sun, adding several sets of French doors and large windows to the south side of the house to capture solar gain and bring in more natural light.

"We used glass that was well-insulated, with high R-values," Singer says. "To control light and heat, we use room-darkening shades on the huge bedroom windows."

In common rooms, they used translucent shades, which will let light in but help slow heat transfer. "Our house faces southeast, so on winter mornings, we lift up all the shades. This allows the low sun to come in and light and heat the home. In summer, we put the shades down in the morning to block the heat from streaming in those big windows, but we raise them up later in the day when the sun is high," Singer says.

Shortly after the renovations were complete, the family heard that their electric company was offering free compact fluorescent lightbulbs (CFs) to its customers. "So we got our first batch," says Singer. "Over time, we swapped out most of our lights that weren't on dimmers." In the kitchen alone, they replaced ten 65 W incandescents with 13 W CFs. "That's going from 650 watts to 130 watts, and that's just one room," he says.

The Singer-Romano household is now almost exclusively using CFs, and between that technology and reduced need for artificial lighting during the day, they are seeing the savings.

Singer's one regret? Not installing solar tubes, which can provide natural light in rooms that have few or no windows. Installed through the roof and into interior spaces, solar tubes can be an easy addition during new construction and a fairly straightforward retrofit project (see "Designing with Daylight" in *HP109* and "REview: SunPipe Light Tube" in *HP118*). Plus, solar tubes can bring daylight into homes without compromising the home's thermal envelope.

Enlightened Energy Savings

When Scott Singer first began changing to CFs, he also changed some dimmer switches to standard switches, since quality dimmable CFs weren't widely available. But dimming capability is helpful for mood lighting, flexibility, and saving energy. The more you dim, the more you save, and the longer your bulbs last. Halogens and many LEDs work great on dimmers, and if you do have incandescents, by all means, dim them.

Installing occupancy sensors and timers makes a good, cheap DIY project that can slash your electric bills. Put motion sensors in your garage, porch, hallway, and bathroom, and you'll never have to worry about leaving the lights on again.

If you have DC power available, low-voltage lighting requires less energy; plus, the bulbs will last longer.

—Brian Howard

Energy Efficiency in Every Room

Lighting is one of the easier things to change about an existing building. If you are planning new construction, it's convenient to pre-plan wiring for whole-house control systems, add solar tubes, or specify Energy Star-rated light fixtures. CFs and LEDs do work a bit better with dedicated fixtures. But the good news is that all you have to do is screw them into the old, legacy fixtures.

You may have three or more lighting strategies to achieve the desired look, feel, and function for the space. For example, you could use linear fluorescent or LED strip lighting in a cove for ambient illumination, bouncing light off of the ceiling for a soft fill light. You might select recessed, adjustable LED down-lights for artwork accent lighting or to provide focal glow and drama in your home. A decorative pendant or wall sconce with CF or LED lamps for added color and sparkle could add ornamentation to the space. You also might need some under-cabinet linear fluorescent lighting to illuminate a counter where specific tasks are performed.

With the lighting controls, you can adjust these various light sources to create mood, save energy, and change the function of the space as needed. A multisource approach to lighting is a great strategy for homes. The use of high color-rendering (CRI) products with consistent color temperature and the selection of high-quality lighting equipment and controls will make your home feel comfortable, functional, and flexible. With the new lighting products and some knowledge, we can now have both energy efficiency and beautiful design.

Courtesy Tech Lighting (2)

Decorative LED pendant fixtures offer a beautiful way to express your energy-efficient style.

Courtesy Juno Lighting (2)

Under-cabinet LED task lighting is ideal for kitchens, the home office, and household work surfaces.

Access

Brian Clark Howard is an environmental journalist who has written for TheAtlantic.com, PopularMechanics.com, *The Daily Green*, and *E Magazine*. He co-wrote the book *Green Lighting* (McGraw-Hill) with Seth Leitman and William J. Brinsky.

Julia Rezek, IALD, is an architectural lighting designer in Ashland, Oregon. She has been practicing lighting design since 1983 and has worked on projects that range from corporate headquarters to hotel resorts to theme parks. Julia Rezek Lighting Design (www.rezeklighting.com) was established in 1996 with a primary focus on high-end residential, retail, religious, and light commercial projects.

CF recycling • www.lamprecycle.org

Prepping for PV

Installing & Flashing PV Roof Mounts

All photos courtesy Quick Mount PV

Story & photos by Johan Alfsen

There are online instructional videos to teach just about everything—from playing your favorite guitar riff to installing dual-pane windows. But when you search for "how to mount PV modules on the roof," you will most likely get an outdated video showing improper roof penetrations that actually void roof warranties and violate roofing codes and standards.

Only in the past few years have manufacturers designed mounting and waterproof flashing systems that are easy to install and meet the codes (see "Modern PV Roof Mounting" in *HP137*). Here is a step-by-step explanation for installing a code-compliant rack system on a composition/asphalt shingle roof.

Before You Start

Safety & roofing. Working on a roof can be dangerous and OSHA safety standards should always be followed (see www.osha.gov/dep/greenjobs/solar_falls.html). Roof warranties should also be considered. The roof's condition will need to be evaluated to determine if a new roof will be needed. If not, contact the original roofing company to determine if there are any workmanship and product warranties that might be affected. If a new roof is going to be installed prior to installing the PV system, stand-off posts can be attached, which can then be flashed and waterproofed by the roofers as they install the new roof.

Layout & Attachment. Plan ahead so that you know how many roof penetrations need to be made—prior to stepping onto the roof. Online rack calculators or manufacturer specifications can help determine the proper number of roof attachments needed for your system and location (see Access).

Proper attachment to the roof structure is key to a strong rack system. If possible, it is best to attach additional wood blocking between rafters. When blocking is not an option, then you must pre-drill into the rafter and attach with a lag bolt or hanger bolt. Staggering the mounts on the roof to avoid attaching every rail to the same rafter helps distribute the load.

A common method of finding rafters is to transfer measurement points from inside the attic to the roof. If attic access is not an option, there are other methods and tricks that you can use. Looking at the gutters and bays from the ground, use a mallet to gently knock and determine rafter placement, or use a deep scan rafter finder. As a last resort, you can also use a small (typically 5/32-inch) bit to drill through the roof to find the rafters. If the bit misses the rafter, you can then use a wire coat hanger to fish through the hole and locate the rafter. Be sure to seal any holes you've made.

Once the rafter layout is determined, make chalk lines down the roof to mark the rafters and across the roof for your rail placement.

Choosing Your Product

There are a variety of code-compliant mounting and flashing products on the market. Before you buy, consider the following things.

(continued on page 96)

Pro Tips:

1. Over the years, my crew has used all lengths and diameters of lag screws—but that changed after we discovered the Simpson 1/4 by 3 inch hot-dip, galvanized, strong drive lags, which require no pilot hole and drive easily with an impact driver. Plus, the inspectors and plan checkers seem to like seeing the brand on the plans. The 1/4-inch-diameter is less likely to split a 2-by truss.

2. Finding the center of a truss is critical and test holes are a necessary evil. We use landscape flags to probe pilot holes. The thin wire will prove if you have hit a truss. If you miss the truss, bend a slight angle into the wire and rotate it until the end strikes the side of the truss. Extract the wire and hold it in the same orientation as when you touched the side of the truss and it will tell you accurately where the truss edge is. If someone needs to crawl into the attic to put in blocking, wind the flag tightly around the wire and insert it into the pilot hole—it will unfurl and be easy to spot, even in the dustiest attic.

—William Miller • www.millersolar.com

On an Existing Roof...

Step 1

Lay out chalk lines, then gently break the seal between shingles. This can be done with a "shingle ripper" or "slate bar" tool, which can also be used to remove any nails that prevent the flashing from going into position. The flashing's bottom edge should never extend beyond the drip edge of the shingle. Before drilling, place the flashing in its correct position and mark the exact pre-drill point.

Step 2

Once rafters are located and marked, and the post position is determined, drill a 7/32-inch pilot hole into the center of the rafter and fill with the roof manufacturer's approved sealant. Be sure to drill the pilot hole 90° to the pitch of the roof. Pilot holes are used to prevent splitting the wood with your lag screw (or hanger bolt). The size of the pilot drill bit should be about 60% to 70% of the screw that is being installed. For example, if your lag size is 5/16, then your pilot drill bit should be about 7/32 or 1/4 inch.

- **Roofing code-compliance**— The International Building Code (IBC) calls for flashing to be installed on all roof penetrations. A minimum of 4 inches of flashing should be on each side of the roof penetration to divert wind-driven rain.
- **Product certification (Example: ICC-ES)**—There are product evaluation services such as ICC-ES that perform technical evaluations to determine that products comply with codes and standards.
- **Approval from roofing material manufacturers**— Many roof manufacturers, such as GAF & Owens Corning, will test and evaluate products for warranty approval. It is important that your flashing/mount does not void the roof manufacturer's warranty.
- **Mount engineering strength**—The rail will govern how many mounts need to be installed based on the span charts. Mounts are tested for pull-out and shear strength. A well-engineered mount will allow further spans and fewer penetrations in the roof.
- **Ease of installation**—After the rafters are located, a well-designed mount/flashing should only take a few minutes to install. Spending less time on the roof brings down labor costs and promotes a safer work environment.
- **Product longevity and life span of materials**—The waterproof flashing and mount should have a life span that meets or exceeds the life of the roof and/or the system. Galvanized flashings only have about a 15-year life span, while aluminum has a 50-year life span. The

Existing Roof, cont.

Step 3

Slide the flashing under the shingle to align with your chalk lines and pre-drilled pilot hole.

Step 4

Drive the hanger bolt with its sealing washer into the rafter to the correct torque specifications listed by the manufacturer.

Sheet Metal & Air Conditioning Contractors' National Association (SMACNA) states that galvanized flashings should not be installed on roofs that will exceed 15 years.

Many manufacturers have this information on their websites. Obtaining a product sample for personal inspection can help verify the quality of the product being used, noting the workmanship, and weight, thickness, and size of the material.

No matter what product you choose, always follow the manufacturer's installation instructions. Many manufacturers provide installation videos. While they may not teach you how to play your favorite guitar lick, they will certainly help you install code-compliant mounting and flashing solutions for your roof.

Access

Johan Alfsen got his start in the solar industry as an installer. Currently, he is the training manager for Quick Mount PV.

Resources:

Direct Power & Water • www.dpwsolar.com

EcoFasten • www.ecofastensolar.com

Haticon • www.haticonsolar.com

IronRidge • www.ironridge.com • Rooftop mount configurator

Oatey • www.oatey.com • Flashing

Pro Solar • www.prosolar.com

Quick Mount PV • www.quickmountpv.com

SnapNrack • www.snapnrack.com

TerraSmart • www.terrasmart.com

Thompson Technology Industries • www.thompsontec.com

Unirac • www.unirac.com

Zilla • www.zillarac.com

Step 5

Cap off the block with an EPDM sealing washer to prevent standing water in the mounting block's hole. EPDM is a high-heat-resistance rubber that works well with PV system mount components.

Step 6

Attach the rack system to the mount and proceed with your PV installation! This picture shows a standard L-bracket that is fastened with a fender washer, a lock washer, and a nut. Most all-in-one flashing and mount products are designed to be compatible with standard PV racking systems. This example shows Quick Mount PV mounts with Iron Ridge rails.

On a New Roof...

For existing roof installations, many PV installers use integrated flashing and mounting solutions as shown above. Many of the same mounting/flashing products can be used on new roofs after the roof is installed, but standard post and flashing systems are more common on new roofs. Before the roofing is installed, you can attach your stand-off posts and then the roofers can install separate waterproof flashing as they shingle the roof. This allows the roofers to ensure the waterproofing is done well, maintaining the roofing warranty.

Step 1

Determine the design layout and check the roof's integrity, then locate the rafters and set chalk lines. Align the base-plate vertical holes with rafter chalk lines and mark holes for drilling. Drill your pilot holes into the center of the rafter. Then fill the pilot holes with the appropriate sealant. Note: Not all sealants are compatible with shingles. Most roofing manufacturers will list an approved or recommended sealant so as not to cause chemical breakdown and deterioration of the roofing material. Common sealants include GeoCell 2300 or ChemLink M1.

Step 2

Attach your mount. For this particular product, you will insert a grade-8 bolt through the backside of the base plate. Then, line up the base's vertical holes with your pre-drilled pilot holes and drive two 3-inch lag bolts into the rafter with an impact drill.

Step 3

Attach the post to the base. Secure the post to the base by turning the post onto the captive grade-8 bolt inside the base plate.

Step 4 & 5

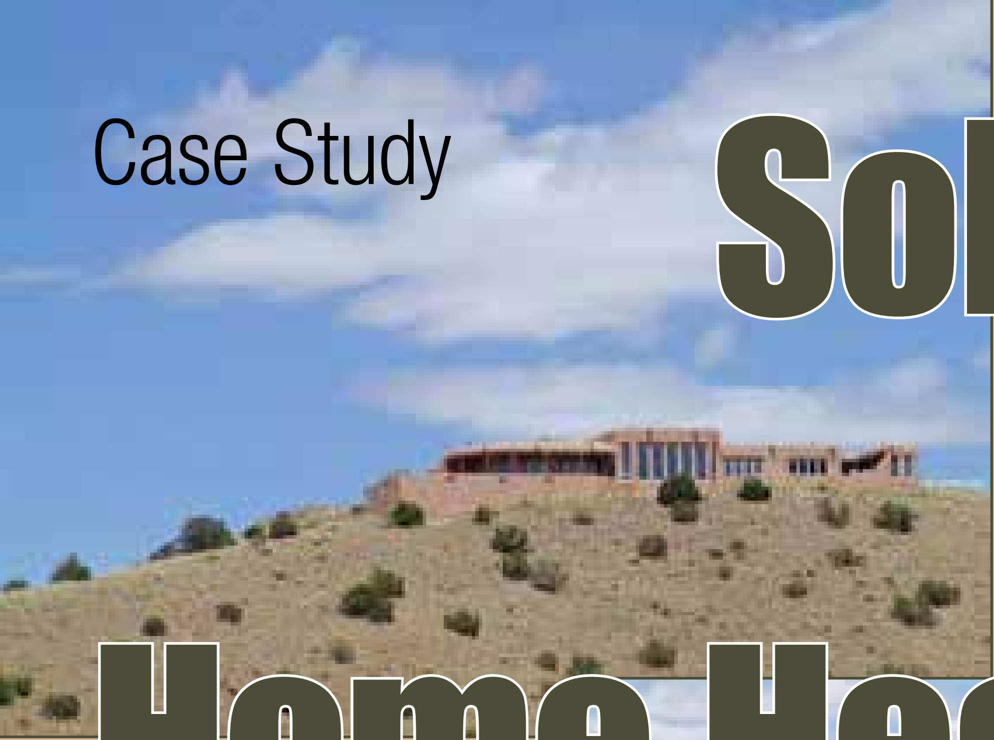
As the roofers work their way up the roof slope, they will install roofing material around the posts and install the appropriate flashing. This is a common practice, and similar waterproof flashing will be installed around vent pipes and skylights.

Step 6

An EPDM pipe collar is installed to waterproof the post-to-flashing connection. Once the roofers are done, you can continue with your PV installation, knowing that you're working on a warranted roof with code-compliant waterproof flashing and mounts.

Case Study

Solar Home Heating Retrofit



Bristol Stickney

Courtesy Jeff Stampfer/Eldorado Solar (2)

by Bristol L. Stickney

In June 2009, my former company, Cedar Mountain Solar, began designing a solar heating retrofit for a residence in the foothills in Placitas, New Mexico, near Albuquerque. This house has approximately 5,000 square feet of living space, which was heated by a propane boiler and a hydronic system embedded in the concrete floors. The building is well-constructed, with good heat retention. It is in a high altitude mountain climate where freezing temperatures and snowstorms are common in winter.

This solar heating retrofit is typical of what I call "Combi 101," which includes several specific heating system functions (connected with a primary loop): solar heat in combination with a boiler, a domestic water heater (DHW), and radiant-heated floors throughout the house.

By October 2009, 12 SHW collectors had been installed on the roof and the heating system was converted into a solar "combisystem," with all of the heat sources connected to all of the heat loads. Even though much of the roof is covered with solar collectors, they are mounted in low-profile to reduce their visual impact. The system has been showing good fuel savings for two heating seasons to date. Heating fuel consumption has been reduced by more than half, with the savings estimated at more than $3,000 per year.

Bristol Stickney

Solar thermal collectors provide the majority of domestic hot water and space heating for this Southwestern home.

What's a Combisystem?

The idea of adding solar collectors to a home often proceeds along the same lines: First, homeowners consider a solar water heater with one or two collectors for domestic water heating. Then, they may consider adding heating to a chilly room—maybe more collectors would be worthwhile. Then they consider hydronic baseboards or make connections to heat other rooms. Then, they wonder about solar heating the spa or pool, an ice-melt zone, or some future addition.

Thermal Mass in Hydronic Floors

Thermal mass is any dense material used to store heat—water and masonry are the most common. In passive solar houses, for example, interior masonry walls and floors store solar heat gained through south-facing windows.

This solar heat-storage can also use active solar hydronic collectors to feed heat directly into hydronic tubing embedded in masonry floors. Under proper control, the floors warm by day and discharge heat by night—to keep the home within the comfort range, thereby delaying or preventing the backup boiler from operating. It helps when the floors are well-insulated, both around the perimeter and underneath, to slow heat loss into the ground.

Common slab-on-grade radiant floor construction practices will work quite well as solar heat-storage floors. But they should be insulated underneath, between the warm concrete and the ground. Two to 3 inches of waterproof rigid insulation ("blue board") is reasonable for improved heat storage, but more than 3 inches is probably overkill. Common slab thickness of around 4 inches works very well, and up to 8 inches is reasonable for extra heat storage. While thicker slabs will store more heat, they will operate at lower temperatures (possibly below the range for human comfort) and have a longer lag time.

Placing the tubing in the center of the slab usually works well. In Southwestern climates, that means spacing the PEX tubing typically 8 to 12 inches apart, and locating it near the center or below the center of the concrete with an approximate 4-inch thickness.

This is also used for solar heating in concrete swimming pools and spa tubs. When hydronic tubing is embedded in the floors and walls of a concrete pool, solar heat can be delivered in a controlled way, independent of the filter pump system.

In the Southwest, large heat-storage water tanks are only necessary when hot water baseboards or fan coils require it—but not when the house has hydronically heated masonry floors. Typical slab floors contain a tremendous amount of heat storage capacity—up to five times as much as a properly sized water storage tank. When the solar heat is delivered directly to the floor, the heat loss associated with the water storage tank and its pipes and heat exchangers is eliminated. This results in about 25% more solar heating available on a typical winter day. This makes the most efficient use of the heat provided by the solar collectors, which can be sized slightly smaller.

The home's thermal mass floors are ideal for heat storage and temperature regulation.

Courtesy Jeff Stampfer

When multiple sources of heat are connected to multiple heating jobs, we call them combisystems, since it is a single heating system made up of a combination of different kinds of equipment. When one of the heat sources is solar heat, we call it a "solar combisystem."

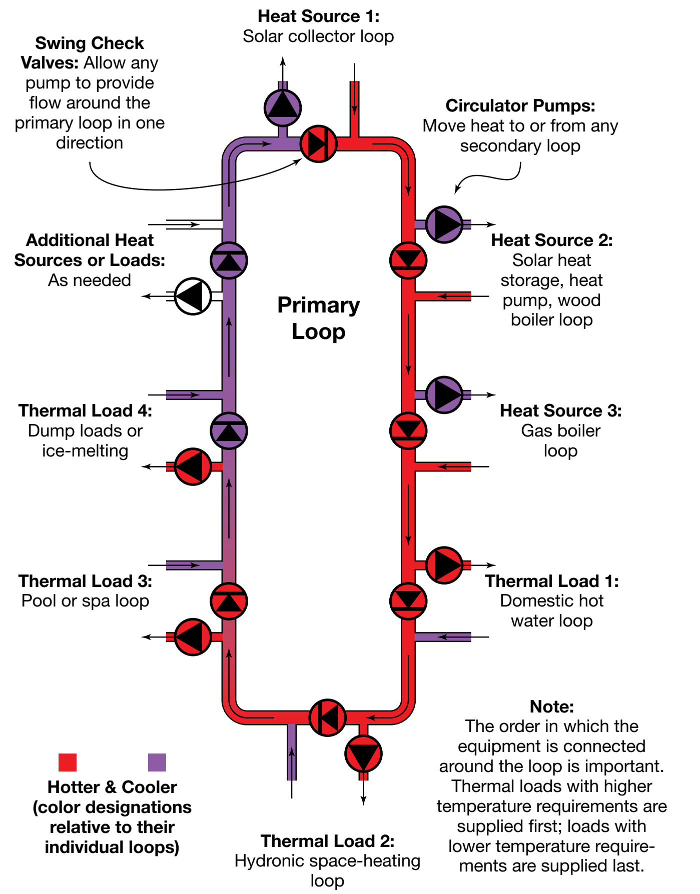
System Details

Multiple heat sources and heating loads can be connected in many ways. In the Southwest, the most typical solar-hydronic combisystem includes solar collectors, a gas boiler backup, a domestic water heater, and a hydronic floor. This most basic variant includes only four items: two heat sources and two heat loads. Yet, if you present these requirements to three different solar heating suppliers, you will get three very different designs with heat exchangers, water tanks, tees, motorized valves, and pumps in different locations—and some often cryptic control strategies (or none at all) to complete the confusion. Adding features or changing the heating system requires a redesign with different piping connections, different components, different temperatures, and different controls.

After going through this same design process with many different projects, I decided to standardize the design, making it easier to add, remove, and change components. The key is to make the system modular so that things can be added or removed as the project develops, without requiring re-engineering. I began building all my designs around a "flow center" where all the circulation pumps plug into a "primary loop" with two pipe connections, which can just as easily be unplugged. Making such major alterations with such simplicity is actually a minor revolution for water-heating systems.

The primary loop using closely spaced tees has been popular in commercial buildings for decades, and has proven its worth in residential systems. The schematic shows the basic configuration for both simple and larger systems. This system allows extending the primary loop through attic or crawl spaces to remote areas of a building to pick up or deliver heat from other mechanical rooms—especially useful in many retrofit situations when combining existing and remote heating equipment under one control system. It also allows expansion for additional heating sources and jobs by adding additional double-tee connection points.

Basic Solar Combisystem Primary Loop Flow Center



The combisystem may look complex, but to a professional, it's a simple combination of independent source and load loops.

Bristol Stickney

Solar Heating without Large Tanks

Solar hydronic heating systems are commonly designed as if they are very large solar water heaters. Several solar collectors are connected to large heat-storage tanks, and all of the solar heat is put into the water tanks, and then drawn out to meet heating needs.

Courtesy Jeff Stampfer

The domestic hot water tank does not have a heat source, but heats through internal exchangers from the primary loop and directly from the backup boiler.

A Triangle Tube propane boiler makes up for what the solar collectors don't supply.

Top: The Caleffi 2+2 flow control acts receives and distributes heat from multiple sources.

Bottom: Expansion tanks allow fluids to expand as they heat.

But most (or all) large heat-storage tanks can be eliminated when the heat distribution is from radiant-heated masonry floors (see "Thermal Mass in Hydronic Floors" sidebar). High thermal storage in the existing concrete floors allowed a relatively large solar heating system without any additional heat-storage tanks, except for a single 115-gallon domestic hot water (DHW) tank.

The Details

Temperature regulation. Because the thermal mass of a concrete slab is so large, its temperature can be easily regulated within the range for human comfort. The room temperature can be allowed to drift as much as 8°F from day to night while staying reasonably comfortable. However, comfort range is a personal preference and therefore needs to be controllable room-by-room.

The easiest way to do this, especially in retrofits, is to replace each room's single-stage thermostat with a two-stage thermostat. As the temperature drops, the first stage calls for heat, but it only delivers solar heat when solar is available. If the room temperature continues to drop, the second stage will then call for heat, which causes the backup boiler to fire (along with solar preheating from storage tanks, if available). The advantage of individual room heat controls is that, for some rooms, a wider daily temperature swing can be tolerated, and this will result in higher heating savings in those rooms.

Two-stage thermostats are adjustable in many ways, and the owner or installer can choose an allowable temperature swing and a low limit to suit the comfort needs of the occupants, zone by zone, to achieve the necessary balance between comfort and energy savings. The room temperatures can be adjusted to drift up and down as little as 1°F or as much as 8°F, depending on how the room is used. The more the room temperature is allowed to drift, the more solar heat is stored and released in the mass floor, resulting in more fuel savings.

If the first stage of a room thermostat has not kicked on, the system sends the solar heat to any other room where stage one *is* activated. If none of the rooms require stage one heating, then the heat is sent to the water heater, water storage, or pool. If the water from the solar collectors is hot but there's no use for it, then the heat dissipation cycle is activated (see below).

The key to success with this approach is the substitution of more intelligent controls in place of large water tanks. If done effectively, this can lower the cost of a solar heating installation, while improving the solar thermal system's efficiency. In our Placitas retrofit, there are eight room thermostats, and all of them include two-stage switching (solar first; boiler second) and programmable temperature swing capability.

For the Placitas system, a hydraulic separator—a "flow center" device that eliminates the need for a primary loop—was used instead of a Combi 101-style primary loop. These devices can be purchased from various plumbing equipment manufacturers. They provide a large, open container that is filled with "boiler fluid" and receives the heat and then provides heat to the other equipment. The Caleffi Hydrolink eliminated the need to assemble a primary loop piece by piece. As seen in the piping diagram, a primary loop consists of tees, valves, elbows and connective piping. A prefabricated hydraulic separator comes from the manufacturer with many of these parts built in.

The Hydrolink 2+2 model was configured to provide the same heating functions and advantages of a primary loop system. The result is a piping system that resembles a Combi 101 system with very compact central piping, incorporating a substantial number of collectors (12) and heating zones (8).

Courtesy SolarLogic

Two-stage thermostats allow custom tuning of the zones to optimize the solar versus boiler heat balance.

System Control & Monitoring

This retrofit's controls were originally designed with common equipment such as conventional room thermostats, mechanical relays for switching pumps and zone valves using several differential thermostats, and set-point temperature controls. This is the conventional way solar/boiler heating systems have been controlled. For the Placitas retrofit, the technically proficient owner was willing to test a control system that included a solar logic integrated control (SLIC)—a computer- and Web-based control of our own design.

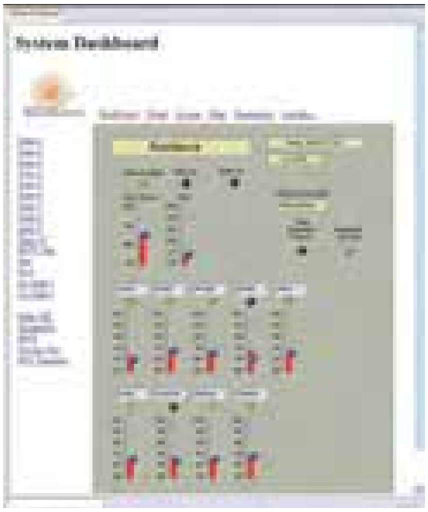
The SLIC control system replaces all of the relays and temperature controls with a single box. It is easy to operate using familiar room thermostats and allows both the installers and the owners to monitor and record the heating system's performance and data, and adjust settings locally or remotely over the Internet. This is great for fine-tuning the balance between comfort and efficiency.

The fuel efficiency and comfort provided by a solar combisystem is only as good as the control system. There are many ways to save energy through the control system. Features that are not needed are simply turned off at the time of installation. The internal software controls have many functions, such as solar-only and backup-only settings, heat dissipation, and room target-temperature control, plus many other settings subtle and not so subtle that affect system performance and monitoring.

Fuel-Saving Strategies for Heating

Each 4- by 10-foot collector can produce enough heat to offset up to 0.5 gallons of propane per day. But the savings are not entirely from solar heat gain—other factors include a high-efficiency condensing boiler and heat-saving control strategies. Solar priority over the boiler is guaranteed both by the piping configuration and the control logic. Solar heat for the floors has an adjustable priority over heat storage in the water tank, and is controlled by the SLIC using virtual two-stage room thermostats. (The room thermostats transmit the room temperature and the user's setpoints to the central control, which implements the two-stage functions.)

Heat storage is also optimized in the DHW tank and DHW recirculator by software control. The SLIC controller is programmed to save heating fuel in every way possible, such as stranded heat recovery—routing hot fluid left in the pipes after a heating cycle is completed to a water-heater tank



Courtesy SolarLogic

The solar home-heating system's "dashboard" shows vital system information and allows changing the settings to tweak system performance.

Overview

System type: Closed-loop antifreeze SHW with single heat exchanger feeding hot water flow center. Solar combisystem provides both space heating and domestic hot water

Location: Placitas, New Mexico

Solar resource: 6.7 average daily peak sun-hours

Production: 9,333 kBtu per month, average

Domestic hot water produced annually: 91%

Hot water (boiler fluid) produced annually: 60% fuel savings

Solar Equipment

Collectors: 12 Solar Skies SS-40 , 480 sq. ft. nominal area

Collector installation: Low-profile, roof-mounted at a 75° tilt

Heat-transfer fluid: 50/50 propylene glycol/water

Circulation pumps: 2 Laing D5

Pump power supply: 2 BP350J 50 W PV modules (one for each D5 pump)

Storage

Domestic hot water storage tanks: Oventrop 115-gal., dual-coil, in-tank heat exchangers

Heat exchanger: Triangle Tube TTP3-40 flat-plate

Backup DHW: No other tanks installed. Boiler backup for Oventrop tank

Performance Monitoring

Dial thermometer: 3 probe-type, in brass wells

Pressure & temperature dial gauge: 2 generic P&T gauges in brass wells

Data logging, diagnostic & control package: Solar Logic Integrated Control (SLIC) Gen1 (The SLIC controller monitors and operates all sensors, pumps, and valves)

Room sensors: 10 standard 10 kOhm thermistors in thermostats

System sensors: 6 standard 10 kOhm thermistors on heat system piping and tank

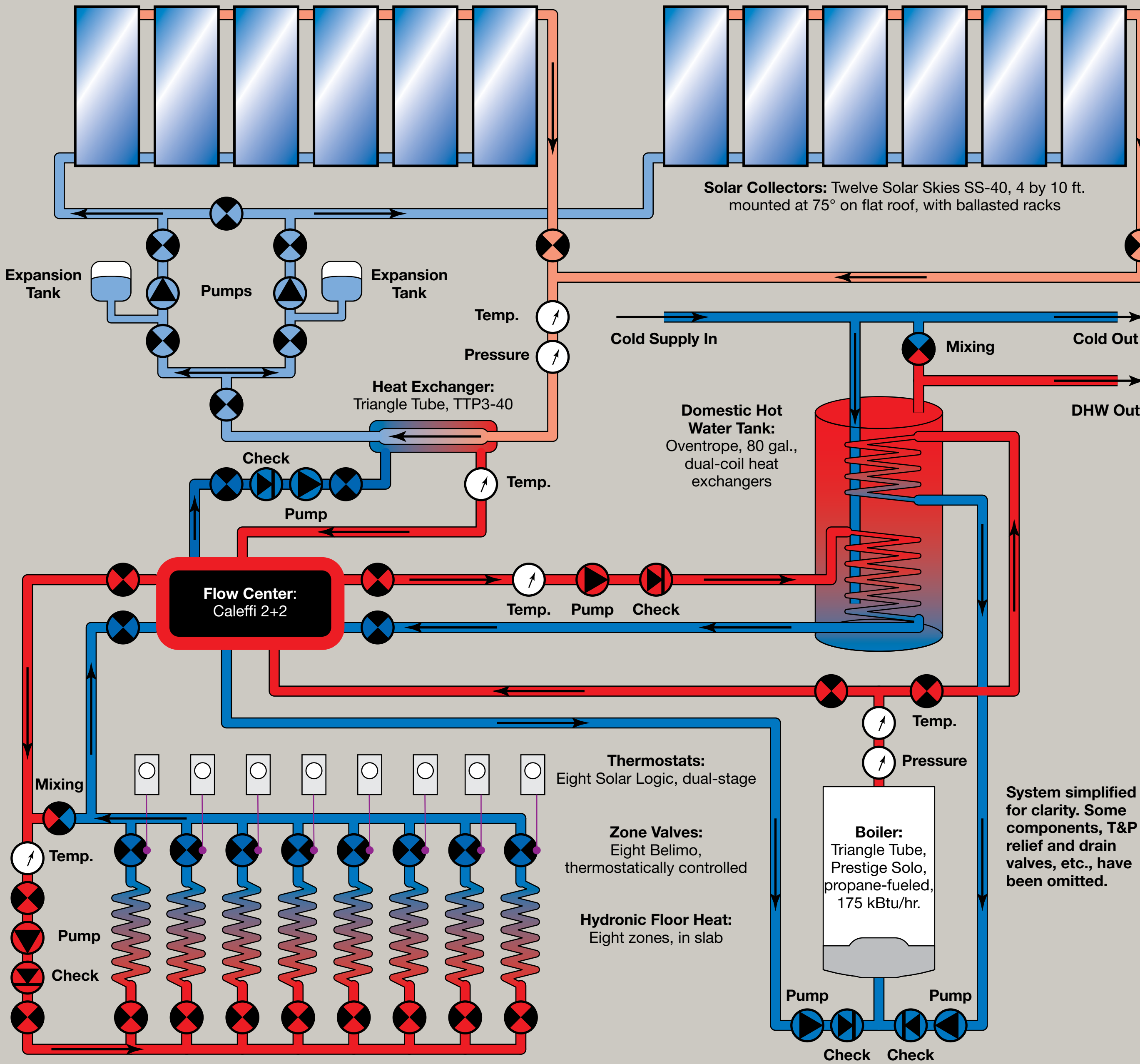
Radiant Floor System

Floor tubing: Wirsbo (Uponor) 1/2-inch HePEX

Boiler: Triangle Tube Prestige Solo (LP); 175 kBtu/hr.

Length of tubing: 5,000 ft.

Placitas Solar Combisystem Retrofit



Number of zones: 8

Circulation pump: 5 Grundfos UPS15-58 (three-speed)

Pump Controller: SLIC Gen1 operates all circulator pumps

Zone valves: 8 Belimo 3/4 in., latching valves, 24 VDC, LRB24-3-S

Tempering valve: Honeywell 1 in., AM102R-US-1; set to between 70°F and 180°F

Auxiliary Heat Source(s) to Solar Storage

Source: Same boiler used for zone heat (listed above) is used for DHW backup

Circulation pump: Listed previously; one of five circulators, all identical

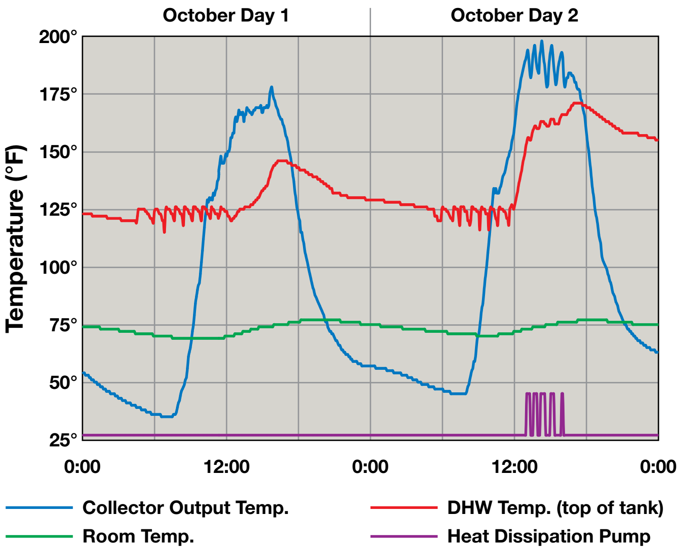
Pump controller: SLIC Gen1 operates all pumps

Other Equipment

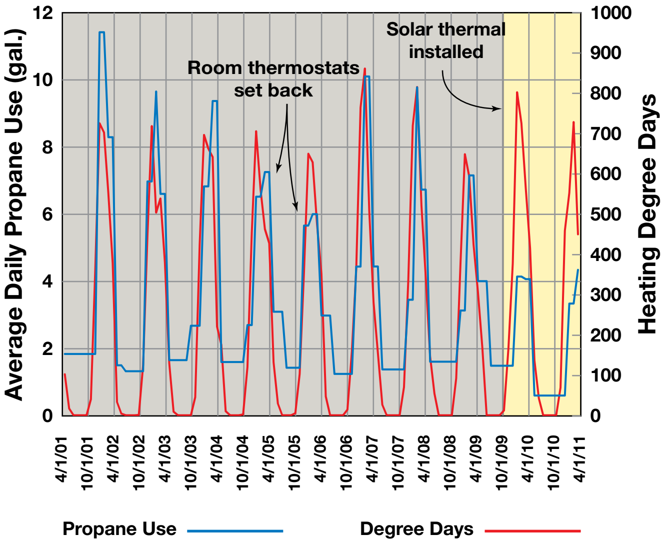
Overtemperature dump valve: All zone valves and all circulators listed previously can be used by the SLIC control system to dissipate extra heat into the concrete floors by day and through the solar collectors by night

Overtemperature dump-valve controller: Heat dissipation is controlled by the SLIC Gen1

Example Combisystem Performance



Propane Use vs. Heating Degree Days



or some other useful load—and intelligent priority control based on temperatures and critical loads.

Past and current performance can be reviewed and analyzed at any time. The graph shows an example from two days in October 2009. On Day 1, the room temperature is kept within a comfortable range, and the solar heat is diverted to the water tank after the room warms up in the morning. On Day 2, the weather is even warmer and sunnier, so the room warms up, the water heat gets very hot, and the intelligent heat dissipation kicks in to cool the collectors all afternoon, typically routing heat to the concrete floor in the garage. This verifies that the control system is set correctly; data like this can be viewed at the house or remotely at any time.

Electricity-Saving Strategies

The opportunities for saving electricity in a heating system are sometimes small but worth considering. In this system, circulator pumps are disabled when they are not needed. Multispeed circulators are used and set to the lowest speed that is effective for each job. The number of transformers are limited to eliminate their "phantom load." "Latching" zone valves are used, which only require power when they change their state. There is no "primary pump"—all circulation through the flow center is provided by the secondary pumps that are smaller and thus require less energy. Solar circulation for collectors using closed glycol loops is achieved with very small pumps that were energized by PV power.

Overheating Control

The SLIC controller is programmed to prevent solar overheating and to maintain safe high limits and comfortable temperatures. Keeping the collectors below 230°F prevents the propylene glycol from breaking down and becoming acidic, corroding the pipes over time.

When the solar heat is not needed and the collector temperature approaches 200°F, several mass floor zones are opened automatically to cool the collectors by 5°F or so. The cooling cycle only takes a few minutes and does not typically contribute any noticeable heat to the floor. (See the graph on day 2 when the cooling cycle occurs five times.) It is most common to use a garage floor, outdoor ice-melt zone, or swimming pool as heat sinks.

When heat in the house is not wanted, the flat-plate solar collectors are used to radiate heat to the night sky. The DHW tank is used as a heat accumulator by day, and can be cooled through the solar collectors by night. This can be very useful when the house is unoccupied and hot water is accumulating in the storage tank. The floors in the warmest rooms in summer can be cooled by night circulation through the collectors as well.

Final Analysis

The homeowner carefully recorded heating fuel consumption, both before and after the solar heating retrofit. Between 2004 and 2006, some fuel savings came from using thermostat setbacks with the old boiler. But, because some of the rooms became uncomfortably cold, the thermostats were raised to around 65°F between 2006 and 2009.

The owner's analysis of this data includes some interesting highlights. Propane use has been reduced from about 2 to 3 heating degree-days (HDD) per gallon before the retrofit to about 5 to 7 HDD per gallon after the retrofit. For HDD determinations, an outdoor baseline temperature is established (65°F) where it is assumed that no space heating is used. Whenever the outdoor temperature drops below this baseline, it is assumed that the house will need some heat. If the average outdoor temperature drops 1°F (to 64°F) for 24 hours, that condition is defined as "1 HDD." If you know how cold it is in HDDs over a given period of time, and you know how much fuel you used (e.g., in gallons), then you can calculate gallons per HDD, or the inverse: HDD/

gallon. This is a good way to compare the fuel efficiency of your house over any period of time, much the same way automobiles are compared using mpg.

For domestic hot water, propane use is down to an average of 0.6 gallons a day versus 1.5 gallons per day previously. This past winter, the house netted 273 to 375 kBtu per day of solar heat (80 to 110 kWh per day). Annual propane consumption has dropped by about two-thirds, saving about 1,300 gallons a year. At current local prices, this translates into saving $3,000 per year. The total cost of the retrofit was $57,315. After state and federal tax credits totalling $21,459, the net system cost was $35,856, resulting in a simple return on investment of 10 years.

Access

Bristol Stickney has been designing, manufacturing, repairing, and installing solar hydronic heating systems for more than 30 years. He holds a B.S. in mechanical engineering and is a licensed mechanical contractor in New Mexico. He holds several patents related to solar/hydronic heating and control and is the Chief Technical Officer for SolarLogic, where he develops solar heating control systems and design tools.



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PV Ground-Mounting

STRATEGIES & INSTALLATION TIPS

by Greg McPheeters & Tim Vaughn

Ground-mounted PV arrays are not hindered by roof size, and allow installation, maintenance, and troubleshooting with your feet on the ground.

Although ground mounts are typically more expensive than roof mounts, they are an ideal solution when a roof is unavailable or impractical. Plus, you get to avoid climbing ladders and the dangers of clambering around on the roof. Ground mounts also eliminate the need for roof penetrations and keep electrical components off the roof. Ground-mounted systems can operate more efficiently, since there's usually more airflow underneath the array and thus less energy loss from heat.

On the downside, ground-mounted systems involve concrete foundations and digging trenches for conduit. Installation is more susceptible to rocky ground and the weather, as rocks, mud, or frozen soil can turn an otherwise easy installation into a serious challenge.

Types

Most ground-mounted arrays are fixed-tilt. And they are often based on a steel pipe substructure, made from schedule 40 pipe, which is available from your local hardware store or pipe supplier. There are tracking arrays available as well, but they are less common and sufficiently different, so we have omitted their discussion here.

Multipost ground mounts provide the most efficient use of structural materials and are the cheapest and most common. The fundamental structure is a set of four posts that can be

Monopole installations offer easy tilt-angle adjustability and can be appropriate for smaller arrays.

SnapNrack (3)

expanded toward either side. Longer rows of modules can be easily made by adding pairs of posts in the east-west direction to extend the array. On flat ground, the array is extended in the north-south direction by adding rows of modules. If the array site is on a large south-facing slope, you may be able to simply extend the array up the slope by adding posts to create a single, large array all in the same plane. Multipost ground mounts are typically the most adaptable to these types of installations.

Some manufacturers offer **single-row multipole** mounts. The main difference between this and a more conventional ground mount is that the basic structure for these arrays is cantilevered off of a single row of poles or posts, rather than two rows. As a result, the structure and foundation need to be more robust; larger steel members are usually required for the poles, and larger foundations are needed. The end result is that this style of structure tends to add cost compared to a four-post design, although this may be mitigated by the savings of using fewer poles overall. However, these mounts are much easier to design for seasonal adjustability, since they tend to pivot about a single horizontal pipe rather than being supported by multiple rows of posts. Being able to change the tilt helps maximize the array's production throughout the year, or more readily shed snow loads in the winter.

Arrays on single-row multipole ground mounts can be adjusted seasonally to optimize production. Arrays must be spaced carefully to avoid shading each other.

Monopole mounts ("top-of-pole" mounts), sometimes referred to as "solar on a stick," are perhaps the most interesting-looking, but least practical of the ground-mount types. The post and concrete requirements per module area are greater than for single-row multipole mounts. They are usually the easiest to tilt, and can be easily adapted to varied terrain since they are not configured in long rows. The majority of monopole mounts used today are for single- or dual-axis tracking arrays or for small-area arrays like those used in remote solar water pumping or small DC power applications.

Array Design

A layout starts with siting and orientation. This usually means that the array is facing south and has good solar access throughout the year. Since they sit lower than roof-mounted arrays, ground-mounted arrays can be more susceptible to shading, but not being restricted to the roof opens up the possibilities to other places on a property that may have better solar access.

Make a maintenance plan to keep ground cover and vegetation from shading the modules—most ground-mounted arrays are installed 2 to 3 feet off the ground on the south (or short) side but may be higher depending on the average snowfall for the area. Common vegetation control methods include a regular mowing schedule and weed control mats or gravel. If you opt for a goat, make sure you don't have exposed wires. Be certain to check with your local building department for any special code requirements, such as fencing or a fire break area around the array.

Foundation work requires basic knowledge of your local soil conditions. Most generic rack engineering specifications assume relatively poor soil conditions, which means that specified piers and footings are deeper/larger than may actually be needed. If your project is large, spending some money for a soil survey first may lead to saving money on the installation.

If the array area is sloped, look for signs of creep or movement in the ground. Foundations on sloped arrays typically need to go deeper than they would if they were installed in a flat area. Look for signs of water drainage, and erosion or ponding, and take these into account as well. If you have rocky soil, be ready for some extra work digging your foundations. Sometimes it's hard to know what you have until you start digging.

Since a ground-mounted array typically stands alone, you will need a strategy for locating your electrical equipment and running conduit. For modern grid-tied systems, mounting the inverters at the array is common, as this provides a convenient shaded location and minimizes DC runs. Another acceptable

EXPERT TIP!

Before you pour the concrete, put rock or coarse gravel under the bottom of the post to ensure that the post can't creep down over time (through the bottom of the concrete). Other ways to prevent this include deforming the bottom of the pipe or drilling a hole in it, and putting a bolt or small piece of rebar through it.

SnapNrack (4)

Power augers can make large installations go a lot faster. But in good soil, a hand post-hole digger can get the job done.

option is to mount the inverters on a nearby structure or next to your electrical meter.

Consider your needs for accessing the array. In addition to controlling vegetation, you may want to access the array to clean it, or to view the inverters if they are mounted on the array structure.

As you get into the details of your array design, you will need to know your local wind speed and snow accumulation. The easiest way to get this information is from your local building department.

If your site slopes to the east or west instead of south, you can either install the array at an angle parallel to the ground or level, with occasional "steps" as it goes down the slope. Running your array parallel to the slope lends to an easier installation. Stepped arrays require additional substructure and bracing, and also require gaps in the array to prevent self-shading. In either case, multiple rows of arrays have to be laid out so that one row's high back edge does not shade the next row's lower edge.

Mendocino Solar Service

Producing a level array on side slopes takes careful calculations of post length and placement. But following the slope with the array is a completely acceptable solution.

Array Layout

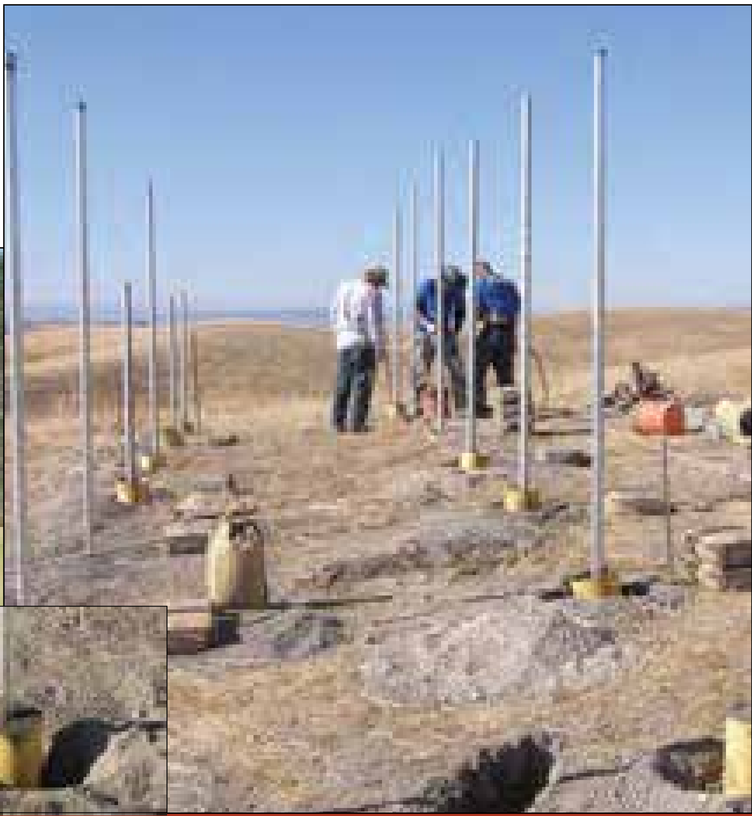
Once your array is designed and the building permits are approved, it's time to start playing in the dirt. First, clear the vegetation from the site. You may also want to grade the site to get it level and down to bare soil.

Always call 811 before you dig (www.call811.com). The site could have a gas line or electric cable buried in the location, which could make working in that area dangerous or costly. Also, some utilities have a right of way on private property, which could prevent you from building on that site. Make certain that your local utility has flagged all underground pipes, lines, and cables before doing any digging—especially if you are using power equipment for this task! Look for common signs of underground utilities and consult past plans for the site. When in doubt, dig by hand and always proceed with caution.

There are many options for array foundations. Concrete piers are the most common due to their basic design and adaptable nature. Digging holes and setting posts in concrete is straightforward, and piers can almost always be installed without rebar reinforcements.

Grade beams are a fantastic variation on concrete piers for flat soil where you can't dig deep due to rock, shallow water tables, or filled land. A grade beam is a narrow, shallow foundation that usually runs from the north to the south edge of the array. They are typically installed very shallow (18 to 24 inches) or even right on the surface of the grade, avoiding the necessity of digging deep piers. Their only drawbacks are

Cardboard-tube forms work well for the concrete, and the holes can be dug with a hand post-hole tool.




SnapNrack (3)

Above: All cuts in galvanized steel should be treated to prevent corrosion. Right: Diagonal bracing helps provide rigidity and strength to the structure. Below: Use a string line to help line up rails or modules.

that they tend to require rebar and more concrete, and may also require some additional form work. Other options—like screw-in piers and driven piles—are available, but may be less accessible or practical for the DIYer. The equipment for these more specialized supports tends to be expensive and they may be less robust over the long term than posts in concrete.

Local jurisdictions may require that your concrete go below the frost line, which can mean deeper piers. However, PV array foundations aren't as sensitive to frost heave as building foundations, so this may not be necessary—check with your local building jurisdiction to be sure.

Once you have your system design and foundation strategy, you can lay out and mark post locations. Marking out an array can be difficult if you haven't done it before, particularly if you are working on a sloped surface. Common methods for marking out foundation locations include wood stakes, string, and marking paint.

Using a power auger will save lots of work compared with digging post holes by hand. If you are using screw-in or driven piles, you will need the appropriate equipment as specified by the post manufacturer for installation. Most screw-in post companies provide installation service.

Once the holes are dug, it's time to set the posts. Some installers will use braces made of 2 by 4s or other materials to hold the vertical posts or poles in place while the concrete sets. Others skip this entirely by using quick-setting concrete. Check the structural engineering documents for the system you are using to be sure you are meeting the requirements for the concrete you use. A typical compression strength requirement is 2,500 to 3,000 psi, with higher values being stronger. If installing without the use of forms, the first step is to fill the hole to the top with concrete.

From there, the post is lowered into the hole and positioned in line with the other posts, and checked for vertical alignment with a level. The viscosity of the concrete will hold the post in place as you move on to the next one. Be sure to keep checking your posts as the concrete sets to ensure that they stay lined up and plumb!

Once the posts have set, you can trim them to the right height. Be sure to double check the geometry before trimming posts—measure twice, cut once. Use a laser level or string line to mark the

SnapNrack (2)

With sufficient room underneath the array, wiring and other maintenance is much easier.

Inset: For the greatest ease of alignment, install modules from the bottom, working your way up.

post heights. If you are following the slope of the soil with your array, you may have to get creative to make a laser level work. In these cases, it's probably easier to stick with the string line.

Most array mounts require cross bracing, which may need to be installed before the top cross members of the array structure go in. PV arrays are large and catch a lot of wind. Follow the guidelines for system bracing specified in the engineering documents. Cross bracing is about creating triangles within the structure, typically between the top of one post and the bottom of the next. Note that most array designs require bracing in both directions.

In most systems, the next steps are to install the horizontal cross members, followed by sets of module rails. Set the rails at the ends of the array and line up the rails in the middle with a string line or laser. Review your trigonometry, as it will come in handy when squaring the rails on most types of arrays. Take the extra time to line up the rails correctly to ensure a good-looking array.

Module Installation

Module installation tends to go pretty quick on ground mounts, but keep these tips in mind:

- Don't assume your PV modules are square. This can make installation very frustrating!
- Watch for module creep. A common technique is to use a string line for installing the bottom row of modules. Once that first row is in, the rest of the array will "stack up" from there. Take the time to get the first row in straight, and the rest of the installation will go very quickly.
- Strings are good for lining things up but they also tend to blow in the wind. Make sure your string line is tight. Line of sight is a very useful tool for lining things up, and lasers may be an option as well.
- Work as a team. Having a second pair of hands is particularly useful during module installation and alignment.


SnapNrack

Some locations require theft-prevention hardware.


Namaste Solar

Fencing may be required, and may prevent animals—including the human kind—from tampering with array wiring.

- As modules get installed, you can wire as you go. However, since ground-mounted arrays often have very good underside access, you can always postpone this task.
- An increasing number of rack systems have wire-management channels for holding module leads and home-run wiring. These are particularly nice for ground arrays given the underside visibility and access. Note that these channels may not be UL-listed as a raceway, so check with your local authority having jurisdiction to make sure this approach complies with their interpretation of *NEC* 690.31(A), which addresses PV wiring accessibility.

Once the modules are placed, you can think about some of the finishing touches:

- Trim the rails close to the array. Particularly on ground mounts, having rails sticking out of the edge of the array is a hazard. If possible, use a system that has end clamps that allow the rails to be cut flush to the end of the array. Many of these systems also have rubber end caps to make for a safer, more attractive installation.
- If you haven't already done so, take appropriate steps to mitigate vegetation under the array. A weed control mat, covered with mulch or gravel, is an effective barrier.
- Protection from vandalism is often critical for ground-mounted arrays. Theft-deterrent hardware is available to thwart would-be module thieves.
- Electrical safety is more critical for ground mounts. Access to wiring by children, pets, or varmints should be considered. Some jurisdictions require screening the back of the array to restrict access to wiring and junction boxes, or you might fence around the entire array. (Just make sure the fence doesn't shade the array.)

Access

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Introduction to the 2011 *NEC*

by Ryan Mayfield

The *National Electrical Code* (*NEC* or *Code*) is a document that PV installers should be dealing with on a daily basis. For those installing PV systems, having a working knowledge of the *Code* and being able to navigate it is a critical skill. This takes many hours of your nose in the book, jumping back and forth between references and following the logic that is the *Code*.

Years ago, one of the comments I heard from an electrical inspector was that he was annoyed with PV installers because all they knew of the *Code* was Article 690. While familiarity with 690 is important to a PV installer, the rest of the *Code* also applies and needs to be followed.

In the Beginning

Article 90, Introduction, gives you the opportunity to look at the whole *Code* picture. It lays out the *Code's* structure and format, and sets the stage for the language and expectations for those using the *Code.* The first section, 90.1, covers the purpose of the *Code*, listing "practical safeguarding of persons and property from hazards arising from the use of electricity." The *Code* is not meant to serve as a design specification, instruction manual, or best practices manual, but rather specifies the *minimum* requirements for a safe electrical system.

Section 90.2 covers the scope of the *Code*. In nearly all cases, PV installations will be covered by the *NEC*. It is a rare situation where a PV system will not be held to those requirements.

Section 90.3 outlines the *Code*'s arrangement. These chapters are broken into articles, and then subsequently down to parts and sections. The first four chapters generally apply to all electrical installations and set the base requirements. Chapters 5, 6, and 7 cover special considerations. The articles in these middle chapters may modify the general requirements in the first chapters. This means that requirements for PV equipment may take precedence over the general rules. For example, the method for sizing equipment-grounding conductors as outlined in 690 differs slightly than in 250. So for PV installations, the requirements in 690 shall be followed.

Chapter 8 of the *Code* covers communications systems and Chapter 9 contains tables referenced throughout the *Code.* The Informational annexes are not considered mandatory portions of the *Code*, but include handy tables, such as conduit fill tables. While these annexes aren't considered enforceable parts of *Code*, they are still useful.

Section 90.5, Mandatory Rules, Permissive Rules, and Explanatory Material is another section to take note of. When the *Code* uses language such as "shall" or "shall not," these are mandatory rules that must be followed. The terms "shall be permitted" or "shall not be required" are considered permissive and are typically included in the exceptions and modifications of the general rules. Finally, there are the explanatory materials. The *Code* is full of informational notes to help you better understand certain sections. These notes, like the informational annexes, are not enforceable parts of the *Code*. For even more explanations, buy the *Code Handbook*, which includes many more specific examples and illustrations.

Defining Code

Article 100, Definitions, is one of the most important articles. Reading this entire article with the intention to gain as much familiarity with the definitions will make your life easier down the road. There isn't enough room within this article to review all, or even the most common definitions, so I will cover a few that cause miscommunications. In future articles, I will point out definitions for specific applications as they are discussed—for example, all of the different grounding and bonding definitions.

- Accessible, Readily (Readily Accessible): Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth.

For equipment and conductors, this means that you can walk right up to the equipment and access it for repair or installation. There will be scenarios where you don't want equipment readily accessible. One common method to prevent access is to install a fence with a lockable gate around

Code Communication

Section 90.4, which outlines *Code* enforcement, says that "the authority having jurisdiction for enforcement of the *Code* has the responsibility for making interpretations of the rules, for deciding on the approval of equipment and materials, and for granting the special permission contemplated in a number of the rules." Anyone who has worked enough with the *Code* knows that its interpretative nature can be overwhelming at times.

The *Code* tries to be as clear as possible, but there are always interpretations. So, when having a friendly discussion with your local inspector about some of the finer points, you may be inclined to tell them, "That's, like, your opinion," but that may not be your best move. Having your *Code* book in hand and being able to navigate to specific sections to back up your case will be your best defense.

a PV array, for example. This may not completely eliminate access but that access is no longer "easy." If someone really wants to climb the fence to gain access they probably can, but that is a deliberate and unnatural approach to the equipment. And remember, the *Code* is all about "practical safeguarding."

- Approved: Acceptable to the authority having jurisdiction.
- Authority Having Jurisdiction (AHJ): An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

I lump these two together because to understand the definition of "approved," you need to know what an AHJ is. Ultimately, the approval of the electrical installation comes from the AHJ. Products that you install will carry various listings and identifications (two more definitions to look at) but that alone does not guarantee approval. I know of cases where listed equipment was installed, but the AHJ didn't approve it because the listing agency wasn't known. In this situation, the AHJ needed education on the listing agency to feel comfortable with the product.

- Continuous Load: A load where the maximum current is expected to continue for three hours or more.

PV systems are considered continuous since the current from the systems can be sustained for more than three hours. This requires specific consideration when it is time to size current-carrying conductors within a PV system, on both the AC and DC sides of the system.

Moving Forward

In the next article, we will discuss more definitions and move into specific requirements for all electrical installations, not just PV. Having this base knowledge makes having discussions with inspectors and electricians who are used to "normal" electrical installations easier. You will be better prepared to answer questions about why PV installations are allowed to do some things differently if you understand the base requirements.

Access

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Off Grid, Not Offline

by Kathleen Jarschke-Schultze

The first time I spoke to my husband Bob-O was over an amateur HAM radio link to his remote wilderness cabin. This was the only method of voice communication available. The conversation was short and each sentence ended with "over." I decided then to come to the mountains and meet the man with whom I had been writing and radioing.

I met Bob-O and a year later we married. That was 25 wonderful years ago. In that time, our personal experience with off-grid connectivity has evolved, slowly at first, then with the speed of a satellite link.

Airwaves

On the Salmon River, everyone used citizen band radios for communication. Every vehicle and every home sported a CB. As a matter of safety, people traveling on the skinny one-lane road would call mile markers to warn oncoming drivers of their approach. Neighbors would chat with each other—it was like a huge party line that was always on speaker mode. I remember one Sunday morning when a CB call asked if anyone knew how to spell "piranha."

I tested for and received an amateur radio license and became KB6MPI. This opened up more radio frequencies for my use and enabled Bob-O to set up a two-meter radio/phone relay system from a friend's house 7 miles downriver. Being within a couple of miles from the town of Forks of Salmon, California, the friend had a land line (telephone service). Bob-O set up the relay so we could access our phone from any two-meter radio by being on the right frequency and hitting "*2" on the numerical keypads on the backs of the microphones.

We also installed two-meter radios in our vehicles and in our house. We carried handheld radios in the woods. We became the "relayed communications central" for our neighbors in the mountains around us. Bob-O built and installed a self-contained, PV-powered two-meter repeater on a nearby mountaintop and we were able to use our radio/phones within a 20-mile radius.

My computer came with me to the river. It was a Commodore VIC-20. Her name was Carrie. We used Carrie mainly for word processing and for playing cheesy little games on the tiny monitor. Our printer was of the dot-matrix persuasion. I also brought a tiny color TV and VCR to the cabin. We used to joke with our friends that the only TV channel we got was KVCR.

Before we left the river cabin, we had both started writing for *Home Power*. Publishers Richard and Karen Perez loaned us an old "Fat" Mac so we could submit our articles in a format compatible with their Macintosh computers.

This Fat Mac would overheat after a short period of use, so Richard had cut the top off, lined the hole with a ring of split garden hose and installed a muffin fan on top. I am sure this extended the life of the little Mac.

Hard Lines

When we moved—21 years ago!—to the canyon where we live now, we were gratified to already have land-line phones. The neighbors up the creek had paid the phone company to lay the underground cables all the way to the end of our road so that they could enjoy phone service, too. We started out with two business lines, then added another. Later, we changed one of the business lines to a personal phone number. These phones lines are not foolproof and not capable of handling DSL (high-speed Internet). They have a tendency to get hinky, especially during stormy weather. We get phantom rings and crackly calls, and sometimes no service at all. The phone company is familiar with the problem and usually fixes it within a day or two.

We still use the three land lines. Cell phones don't work where we live, so that option is off the table. We have to drive about 5 miles to get cell service.

With several other HAMs in our neighborhood, we kept our two-meter radios in our vehicles and one in the house. The HAMs all agreed on a radio frequency and we stay tuned there for the most part.

One dark and snowy night as I drove over the pass, Karen and Bob-O kept me company via the two-meter as I slowly rolled through the drifts on a deserted road to get home. I was very glad to have the security of someone knowing where I was and what I was doing.

Other Upgrades

Our TV got bigger and Bob-O raised a directional Yagi antenna, with a motorized rotor on it. While watching one of the four local channels, we could turn the antenna from inside the house until the TV reception had the least amount of interference.

Our Macs were upgraded slowly over time. Technology growth was kept in check by keeping our computers for several years until forced by software upgrades to get the next generation of hardware.

We first had an AppleShare local area network in our home office, with tentacles of cabling reaching from Bob-O's office in our dining room to my office in our basement. When it became available, we graduated to using a wireless network and my desk moved upstairs to make room for our winery.

Cell phones had been around for a long time when we finally succumbed to their siren song. Of course, they don't work here at the house, too many mountains to get around and too few customers to entice the phone companies to put up an additional tower. But they are a genius invention for when I am in town, standing in an aisle of hardware and I want definitive descriptions of the parts Bob-O needs. (One universal rule of rural living is that you cannot fault a field decision. If you are out in town, on your own, and a choice must be made, that choice must be respected. Just sayin'….)

As soon as small-dish satellite TV was available, we subscribed. We have enjoyed the choice of viewing options and the clarity of the signal. For a self-avowed "vidiot" like me, it's a playland.

With a Net

Our first Internet connection was by dial-up modem over the less-than-adequate phone lines. So as soon as satellite Internet was available for Macs, we eagerly jumped on board. The difference in speed was amazing…at first. The elation of a faster Internet is fleeting. You get used to the new speed very quickly, leaving you wanting even more speed.

A local company started offering wireless broadband service in our county. We called and a tech came out and wandered around with an antenna to see if we could get their signal sent from atop Bogus Mountain, about 10 miles south, near Montague, California.

We could get a signal from a building across the canyon and down the creek a-ways. The answer was a small PV system to power a repeater with an antenna pointed at the Bogus site and another aimed at the antenna on our house. Bob-O had to trim some branches from a few trees for us to get an unobstructed signal from the repeater across the creek. It was at this point that we finally let our dial-up account go. We had rarely used it in the last 10 years, but had kept it as a backup to our satellite service.

More Off-Grid Gadgets

My iTouch was a revelation. I had used the first Palm PA and loved it, so the iTouch was the next giant step forward. With it, I could connect to wireless networks and surf the 'Net. I was introduced to apps.

I'm fond of saying, "It's a George Jetson world." This had never been so evident to me as when I sat in my office and video-chatted with Bob-O, who was in town with another iTouch. Heck, once he was in the office and I video-chatted with him from the couch four feet away. Isn't technology grand?

Now I have an iPad 2. This appears to be what I've been waiting for. I'm guilty of downloading apps with the abandon of a drunken sailor. There are plenty of free ones, so I pick and choose the few I want to buy.

I can keep track of my garden, my homestead bounty stores, beekeeping, cooking, email, weather, writing, and reading. I never thought I would like reading a book from a handheld device, but I do. It's really wonderful. I can have larger text, white print on a black background at night, and zoom in on pictures—and notation explanations are a link away. It is not a full-featured computer, but it works for a lot of the tasks I performed on my desktop Mac, with very little power use and incredible mobility.

Living off-grid for the last 26 years has not meant we are isolated—we are connected to everything except the utility grid. I climb down from the high stool in my greenhouse, press "Send" on my writing app, email this column to *Home Power*, set down my iPad, and turn to re-pot the rest of the vegetable starts.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is sharpening her skills and honing her wit at her off-grid home in northernmost California.


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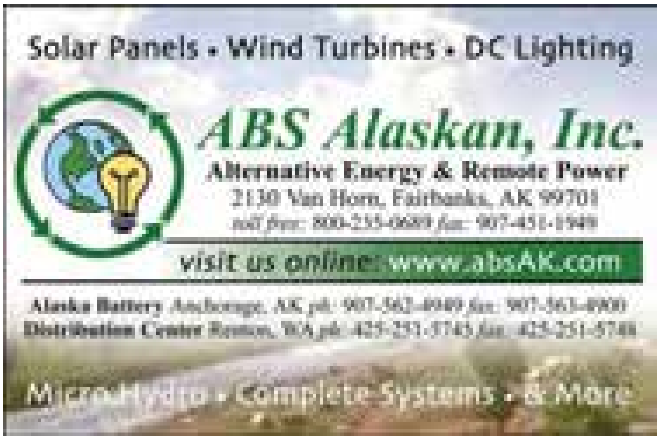

Net Zero-Energy Buildings

Homes are going beyond green by going to zero.

According to the National Renewable Energy Laboratory, the foundation of the net zero-energy building (ZEB) concept is the idea that buildings can meet all of their energy requirements from low-cost, locally available, nonpolluting, renewable sources. At the strictest level, a ZEB generates enough renewable energy on-site to equal or exceed its annual energy use.

There are a variety of ways that homeowners and builders alike can reach the goal of a ZEB, but typically they start with a grid-tied home. The grid can provide backup energy as needed and surplus energy, generated on-site, can be banked and accounted for in the home's energy balance.

Under the ZEB metric, four subcategories break the definition down further:

- **Net Zero Site Energy:** A site ZEB produces at least as much energy as it uses in a year, when accounted for *at the site.*
- **Net Zero Source Energy:** A source ZEB produces at least as much energy as it uses in a year, when accounted for at the *source*, which refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversions.
- **Net Zero Energy Costs:** In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
- **Net Zero Energy Emissions:** A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources. An on-site emissions ZEB offsets its emissions by using supply-side options, whereas purchasing emissions offsets from other sources would be considered an off-site zero emissions building.

Courtesy Katrin Klingenberg

Despite the type of ZEB, the emphasis remains the same: a ZEB should *first* adopt energy-efficiency and passive renewable energy measures, such as passive solar heating and daylighting, and *then* use active renewable energy sources and systems (preferably on-site). It is almost always easier to save energy than to produce energy.

ZEB Renewable Energy Supply Option Hierarchy

1. **Reduce site energy use through low-energy building technologies:** Daylighting, passive solar design, high-performance windows, abundant insulation, etc.

On-Site Supply Options

2. **Use renewable energy sources available within the building's footprint:** Solar-electric and solar hot water systems located on the building.
3. **Use renewable energy sources available at the site:** PV, solar hot water, low-impact hydro, and wind-electric systems located on-site, but not on the building.

Off-Site Supply Options

4. **Use renewable energy sources available off-site to generate energy on-site:** Biomass, wood pellets, ethanol, or biodiesel that can be imported from off-site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.
5. **Purchase off-site renewable energy sources:** Utility-based wind- and solar-electric systems, emissions credits, or other "green" purchasing options. Hydroelectricity is sometimes considered.

—Adapted from "Zero Energy Buildings: A Critical Look at the Definition" by P. Torcellini, S. Pless, and M. Deru, National Renewable Energy Laboratory; and D. Crawley, U.S. Department of Energy