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The Power of Now!

Home Power has been excited about renewable energy (RE) since "back in the day," when no one could make an easy argument about financial payback for renewable energy. I first installed solar-electric modules on my roof in 1984, and *Home Power* founders and RE pioneers Richard and Karen Perez got into the solar game at about the same time.

We think solar energy is smart whether it's a "good financial return" or not. But in recent years, in many situations, excellent financial return has been easily documented.

However, there's still a gap between public perception and reality. The public perception has too often been that solar energy doesn't work well yet, and that solar energy doesn't pay. The reality is that solar energy (and solar electricity in particular) is an amazing and durable technology—witness the 31-year-old modules still working on my roof. And the reality of financial return is that, depending on location, it can be somewhere between sensible and amazing. Due to federal and state incentives and the dramatic lowering of the cost of equipment, solar-electric systems in my home state of Washington have been giving better financial return than most traditional investments.

Recently installed systems in my neighborhood are on target to go cash-positive in five to six years. In many places, the cost of a PV system can be met by paying for it with the money saved on the utility bill. This extraordinary financial situation may change in the near future:

- The federal tax credit that allows you to deduct 30% of your system cost from the amount of taxes you would have to pay is scheduled to end after 2016.
- As for Washington, the state incentive is decreasing—both because it is a per kWh payment, and it's getting closer to the end of the program (June 2020), and because the state incentive program's PV capacity cap will soon be met by some utilities. Check your local and state incentives at dsireusa.org.

Both of these things could change—politics is politics—and industry groups are working hard to continue the current incentive programs. But many industry sources are pessimistic about significant changes to the existing laws and their sunset provisions.

So right now is a good time to invest in a solar-electric system! You'll get the benefits regardless of the political picture—clean, reliable energy, stabilized energy costs, and the good feeling of doing something to better your community and world. And you'll also still get a solid financial return, depending on your tax situation, your local and state incentives, and the specific type and size of system you invest in.

—Ian Woofenden, for the *Home Power* crew

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—J.M. Power, author

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– **Glen Koedding**
President, Green Sun Energy Services, LLC

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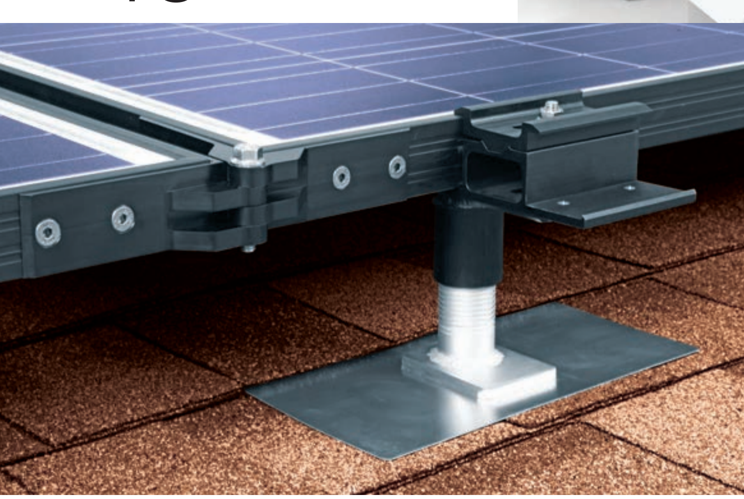
Despite the cold Bend, Oregon, winters, multiple uses of solar energy keep Barbara Scott and Tom Elliott comfortable in their high-desert, energy-efficient home.

Photo by Ross Chandler



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Photos: Courtesy Ross Chandler; courtesy True South Solar

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contributors
this issue's experts

Home Power Managing Editor **Claire Anderson** lives in a passive solar, (almost) net-zero-energy home she and her husband designed. She and her family are developing their 4.6-acre homestead to incorporate more resilience in their energy, food, and water systems. Chickens and ducks were new additions last spring.

Chris Henderson works as an engineering consultant on utility-scale wind turbines; co-owns and operates a small vegetable farm in Washington State; and previously worked as a test engineer at DNV-GL. In addition to owning two grid-tied PV systems, he's installed and maintained several off-grid systems in rural Latin America.

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

Paula Baker-Laporte, FAIA, is an architect, Building Biologist, author, healthy building consultant, and educator. She is the primary author of *Prescriptions for a Healthy House*, and co-author of *EcoNest* and T*he EcoNest Home* with Robert Laporte. Their light straw-clay and timber frame EcoNest homes have been built throughout North America • www.econest.com

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

Vaughan Woodruff owns Insource Renewables, a solar contracting firm in Pittsfield, Maine. His firm, along with Assured Solar Energy, was selected to run the Solarize Freeport campaign. He is a NABCEP Certified PV Technical Sales professional, NABCEP Certified Solar Heating Installer, and an instructor for Solar Energy International.

Chris Calwell is an energy-efficiency consultant in Durango, Colorado, and the cofounder of Ecos Consulting. He first worked on residential lighting efficiency for the Natural Resources Defense Council in 1989, helping utilities implement compact fluorescent bulb programs. He recently designed and built a net-zero-energy (NZE) home, and now consults independently on plug loads, lighting, NZE home design, EVs, and clean-tech investing.

Chris Magwood is obsessed with making the best, most energy-efficient, beautiful, and inspiring buildings without wrecking the whole darn planet in the attempt. He is a founding director of The Endeavour Centre, where he brings this passion to life.

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

Environmental writer **Juliet Grable** lives in southern Oregon, where she writes about sustainable building, renewable energy, and issues related to water conservation and watershed restoration. This year, she completed training to serve as an Ambassador Presenter for the Living Building Challenge.

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

Zeke Yewdall is the chief PV engineer for Mile Hi Solar in Loveland, Colorado, and has had the opportunity to inspect and upgrade many of the first systems installed during Colorado's rebate program, which began in 2005. He also has upgraded many older off-grid systems. He teaches PV design classes for Solar Energy International.

Eric Hansen is the general manager at True South Solar, southern Oregon's largest licensed solar-electric contractor. True South Solar designs and installs turnkey grid-tied, battery backup, and off-grid solar-electric systems for residential and commercial clients.

Contact Our Contributors

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

Courtesy Morningstar

Morningstar ProStar MPPT Charge Controllers

Morningstar (morningstarcorp.com) has two new ProStar MPPT charge controllers that support lithium, nickel cadmium, and lead-acid (12 and 24 V) battery banks, with PV arrays up to 1,100 watts. The controller is available in 25 and 40 A models (PS-MPPT-25 or -40), and has a maximum open-circuit voltage (Voc) input of 120 VDC. They also include automatic PV-based lighting control—up to 25 and 30 A, respectively. They can store up to 200 days of data and have a five-year warranty. Options include a digital meter, remote temperature sensor, ground fault protection, and a wiring box for connecting conduit.

Fronius Primo Inverters Revenue-Grade Metering

Fronius (fronius-usa.com) offers revenue-grade metering for its 3.8 to 15 kW Primo grid-tied inverters. This option offers metering accuracy within 2% and simplifies installations for systems taking advantage of performance-based incentives. These programs pay based on the system's accurately recorded and reported production data. Including revenue-grade metering integrated in the inverter package removes the need for additional hardware, such as a designated socket meter and base. PV production data can be exported from the Fronius Solar.web monitoring server or sent directly to third-party servers.

Courtesy Fronius USA

Courtesy Crown Battery

Crown AGM Batteries

Crown Battery (crownbattery.com) released the Crown1, a deep-cycle absorbed glass mat (AGM) battery series. These sealed, maintenance-free batteries are available in 6, 8, and 12 V models, with capacities ranging from 55 to 300 Ah (20-hour rate). The batteries feature heavy plates for low internal resistance and offer more power under load. Also, a high-strength glass-mat separator with an advanced composite improves recovery from deep-discharge cycling and aids in high-efficiency charging.

—Justine Sanchez

Pole-Mount Strategies

For Slopes, Setbacks & Shade

Comment & Discuss this article @ homepower.com/171.14

Nestled in the foothills of the Cascade and Siskiyou mountains, Buckhorn Springs resort has a welcome retreat from the hubbub of everyday life, offering a guest lodge, house, and cabins on 120 acres just outside of Ashland, Oregon. A former mineral spa, the grounds and historic buildings have been lovingly restored by the Sargent family, to host guests from March through early November. Produce from the organic gardens provides nourishment for the family and guests, and hiking trails give everyone the opportunity to experience the area's natural beauty. Meeting their electricity needs on-site fit within their overall goals of sustainability and the Sargents wanted as much solar electricity as possible to offset their utility usage.

PV Design

The resort sits on plenty of acreage, but most of the land is forest and the solar window is fairly small. With a specified system size of 23.5 kW, the challenge was to find suitable sunlit space for 72 modules. Property and creek setbacks, tree shade, and the potential for inter-array shading complicated the system's design. The property and creek setbacks had to be outlined to ensure the arrays would fall within the required area.

The best site was on a northeast to southwest slope, which further complicated the array layout. The solution was to divide the system into six arrays on pole mounts, and stagger them down the slope in sets of two. The final layout aligned each set of poles on an east-west axis to create a nice visual line between them.

Each pole-mount holds 12 SunPower SPR E20/327 modules. Their high Voc (STC) constrained the design to a maximum of eight modules per string. To avoid jumpers between poles, two strings of six modules are wired to meet the inverter's MPPT specs. Each inverter has two inputs, allowing four strings of six modules. The physical layout worked nicely with each of the six subarrays having its own MPPT in the three inverters.

Each pole mount has a DC disconnect, used for the transition from PV wire to THHN, array servicing, and to de-energize the underground conductors in the event of another digging project. Since these inverters are transformerless, both the positive and negative PV conductors are ungrounded. Because the *NEC* requires that all ungrounded conductors be de-energized when the circuit is opened, the two strings at the PV power source were paralleled at each array, using MC4 Y connectors. From the

Six MT Solar pole mounts (each with 12 SunPower 327-watt modules), staggered up the slope, feed 23.5 kW to three inverters.

Courtesy True South Solar (3)

Overview

Project name: Buckhorn Springs

System type: Batteryless grid-tied

Installer: True South Solar

Date commissioned: August 2015

Location: Ashland, OR

Latitude: 42°N

Average daily peak sun-hours: 4.9

System capacity: 23.5 kW STC

Average annual production: 32,020 AC kWh

Equipment Specifications

PV modules: 72 SunPower SPR-E-20-327, 327 W STC

Inverters: 3 SMA SB7000TL, 7,000 W rated output (each)

Array installation: MT Solar top-of-pole mounts, south-facing, array tilt adjustable from 0° to 90°

MC4 Y connectors, one set of paralleled PV output conductors runs to a two-pole DC disconnect mounted on the pole. This reduced the number of connection points that each of the DC disconnects needed from four to two. Paralleling also reduced the number of wires that needed to be managed from the arrays, through the DC disconnect, and 220 feet to the inverters. This reduced labor and material costs.

MT Solar's Solar Pole Mounts were used for their ease of PV module installation—the arrays were assembled at waist-level and hoisted to their final height, minimizing ladder use. Also, the MT system can accommodate most rack manufacturers' rails and top clamps.

After a small learning curve on the first assembly, the other five went quickly. Two crew members assembled five pole-mount systems in one day, including mounting the modules. A third crew member mounted the SnapNRack rails on all six poles in one day without the use of a ladder. A pulley hoist was used to jack each array to its desired height and the final bolts, washers, and nuts were placed and tightened in the pole cap, securing the assembly in place. Then the center module was set in each of the arrays and the desired tilt was set by the hand crank.

Assembling the lifting, locking, and tilting mechanism before mounting junction boxes and disconnects.

The installers experienced a few unforeseen challenges. The tilt crank occupies the same area where the DC disconnect would typically be placed. To avoid working-clearance issues—with the crank being in front of the DC disconnects—they offset the vertical conduit slightly to locate the disconnects to one side. MT Solar's system needs to be assembled and the modules mounted to it before it is raised up and set. This delays the installation of boxes, disconnects, and conduit that need to be fastened to the pole. On other top-of-pole mounts, this work can be done while the rack system is being installed. While this wasn't a huge issue, from a job-flow perspective, it would have helped to plan this from the beginning.

—Eric Hansen

The BOS equipment is mounted on the north wall of a building that's within 40 feet of the main electrical panel.

Courtesy Al Latham

Old Array Back in Service

If you were floundering around, cobbling together an off-grid power system way back in the 1980s, you probably remember the day that a friend handed you a stapled copy of *Home Power #1*, which came out in November 1987. What a revelation! Great how-to articles and connections to suppliers of all the alternative energy gear you needed—an ARCO M-75 PV module for only $6.48 per watt! But if you were like us, you didn't have the bucks to buy new modules and were struggling along with an old lawn mower engine hooked to a car alternator, or some such gizmo, for battery charging.

Then, in 1990, ads started appearing in *Home Power* for recycled ARCO 16-2000s, ARCO 120-watt "tri-lams" and "quad-lams." They came from solar power plants that were constructed in the early 1980s, but were being dismantled because the energy credits or something like that ended, and they were determined to not be cost-effective anymore. For us, it was an opportunity to get some affordable PV modules.

So, we got tri-lams and quad-lams, and were on our way to getting rid of our Briggs & Stratton addiction. As time went on, prices for new PV modules came down some, and our economic situation improved to where we could replace the used panels with new ones. The tri- and quad-lams got used for various applications, but many of them ended up in storage.

Fast forward to 2015. A young friend outfitted a school bus for off-grid living, and had everything except money for a solar-electric array. Out of storage came my tri- and quad-lams and his neighbors had some too. They may be old but they're still putting out amps and volts, happily charging a battery bank again. If you look closely in the photo, you can almost see them smiling! Déjà vu all over again!

Al Latham • Chimacum, Washington

Happy with EV

We bought a 2015 Chevy Spark EV (all-electric). It has a range of about 75 miles per charge, which covers my daily commute and then some. The total cost was about $16,000 after government credits and rebates. It's a surprisingly wonderful little car, with amazing power and room for four people. It costs about 3 cents per mile in electricity—less than half of what it costs to drive our Toyota Echo, which gets about 39 mpg.

There is almost no maintenance—tires are the main thing. Regenerative braking should triple normal brake life. The battery and drive train is warranted for eight years/100,000 miles. We installed the charger on a post next to the driveway—much more convenient than going to a gas station every week. The state of Maryland pays up to $900 to offset the charger installation. And I was able to get a "high-occupancy vehicle" permit, which saves me about 10 minutes per day on my commute.

New Chevy Spark EVs are only available in California, Oregon, and Maryland. Green Car Reports speculates that General Motors offered it in these limited markets to meet upcoming state EV quota mandates, and to seed the public for the upcoming 2017 Chevy Bolt, which will feature a 200-mile range.

We liked our Spark EV so much that we leased another one for my daughter's daily commute to school. Her gas-engine car was starting to break down a lot, so the deal for reliable transportation is saving me money in the long run. We also enrolled in our electric company's EV time-of-use rate schedule where they charge more during weekday "peak" hours, and less at other times.

In addition to recharging the two EVs at night, we've made adjustments to our energy usage to use less during peak hours. Although we're using more electricity overall, our bill has stayed nearly the same, practically negating the cost of driving the cars.

Jim Mattson • via homepower.com

Courtesy Jim Mattson

Jim Mattson and his daughter with their matching Chevrolet Spark EVs.

12-Volt Space Heating

I'd like to comment on a couple of the points made in Allan Sindelar's response to a reader's question in *HP169* about using spare electricity in his cabin for heating. My experience with low-power space heaters is that they work exceptionally well in small cabins. It's not about heating the room so it's warm and snug, it's about increasing the "background" temperature a bit. Even warming by a few degrees above the outside temperature is significant when you arrive at your cabin.

Whether a small PV system can supply energy for helpful heating depends on the cabin's size and insulation. The cabin I use is 10 by 20 feet, well-insulated, and has a 12 V, 300 W storage heater powered by two 300-watt modules once the batteries are charged. It's enough to keep the inside

Courtesy Julian Thrussell

Courtesy solarconduit.com

temperature above freezing in a Scottish winter, and has been reliable for the last five years. This has huge advantages in preventing frost damage to food, and also keeps the cabin dry inside.

In my own home, I have a radiator with a 240 V, 100 W heater to dry towels in the shower room. This got me thinking about how much heat would take the chill off a small cabin. I'd be pushing my luck if I claimed any complex math was involved, but 300 W sounds about right. As solar energy is sparse in the winter, an old cast-iron radiator, with its relatively large thermal mass, seemed the best to soak up the heat when it was available and radiate it into the room over time. The radiator has a single 300 W, 12 V heating element fitted in the bottom inlet, filled with oil, and sealed. It has to be filled with oil just in case it ever freezes.

The cabin PV system has a 600 W diversion charge controller (with a dump-load feature) and three 120 Ah deep-cycle batteries. The battery bank is a bit large, but as the cabin is used primarily on weekends, it typically has several days to fully recharge between use. There is a 1 kW diesel generator just in case. One problem we do have is snow, which can cover the array and stop production.

When the batteries become fully charged, energy is automatically "dumped' into the heater element. This tends to happen when the cabin has been empty for a while, so it's ideal. The cabin is certainly not warm by comfort standards, but it is frost-free and dry, which is good for the electronics and batteries.

It would be a shame for readers to disregard a simple and effective use of energy when my practical experience has been entirely positive.

Julian Thrussell • via homepower.com

Perspective

Remember when your home solar-electric system seemed huge? Or when a 10,000 W PV system was groundbreaking news? I just read a story about an 80-megawatt (MW) solar-electric system planned for Virginia! It is slated to be operational by fall of 2016.

All I can say is, wow—solar has sure grown up! Think of it—80 MW is more solar-electric modules than could have been produced in 1985 or 1986—maybe combined! Still, for mainstream energy, I am hoping for many more solar roofs on homes and businesses, and large wind farms for producing MWs of electrical power.

Fred Golden • via homepower.com

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Grid-Tied Inverter Problem

I just installed a grid-tied inverter with 3,000 W of PV. Unfortunately, the machine brings a "grid abnormal" error and tries to constantly reconnect without success. The line voltage and frequency seem to be well within an acceptable range. Tech support mentioned that this could be due to high total harmonic distortion (THD) in the grid and suggested giving the machine some time to reconnect once grid quality improved. But I monitored the system through a whole day and it never reconnected.

Although I have commissioned hundreds of off-grid systems over the years, our local electricity authority only recently approved the installation of grid-connected systems. Because it's my first grid-connected installation, I'm absolutely clueless about how the problem can be rectified. If, as the inverter company's tech experts mention, it's a line harmonic issue, how do I overcome this?

Sajay Kumar • via homepower.com

I have experienced a similar problem with our 3.8 kW grid-connected PV system located in a relatively rural area of Washington State. Immediately upon system commissioning, our inverter would trip offline, and stay offline between 9 a.m. and 4 p.m., Monday through Friday. If I reset the inverter during these hours, it would attempt to reconnect, but fail. It worked perfectly after 4 p.m. to sunset and during the weekends. Here are the troubleshooting steps we took to resolve the problem:

- To make sure that loads at our own property were not causing power-quality issues, we turned off all circuit breakers except for the PV system's. The inverter still tripped offline, suggesting that the power-quality problems originated off our property.

Chris Henderson's inverter display shows nonoperational periods that coincide with a neighboring factory's operation schedule.

The Solectria inverter that replaced the original unit is more tolerant of harmonic distortion on the grid.

Courtesy Chris Henderson (3)

What's the point of a 3.8 kW array if it won't operate during the best solar times of the day?

- Our installer set wider voltage and frequency operating ranges in the inverter to make it less sensitive to grid fluctuations; however, this did not make a difference.

- Our installer swapped out the inverter with the same model, twice. No success. The inverter supplier checked the error logs of the two removed inverters and ran tests on them to confirm that they were in working order. The error logs suggested faults due to harmonics on the grid, which make it difficult for the digital signal processor to synchronize the inverter output waveform to the grid waveform. Once the harmonics are clear, the inverter will resume normal functionality.

  We contacted our utility, who installed measurement equipment and determined that THD, frequency, voltage, and power factor were all within allowable ranges and not a problem at our site. This was confirmed by configuring our eGauge measurement system to record the THD, which was between 1% to 3%—an acceptable range. The utility continues to take measurements, but has been unable to identify the power-quality problem. They're stumped.

- Our installer finally achieved success by replacing our inverter with a different brand, a Solectria, which was more tolerant of whatever the mysterious power quality issues are at our site. Our PV system is now operational, but the fundamental grid issue has not been identified or resolved.

I'm not sure if we will ever figure out the root cause, but at least we are producing kilowatt-hours with the new inverter. I suspect the issue is related to variable speed drives at a nearby grain mixing facility that operates on a typical Monday to Friday work schedule, but this has not yet been confirmed by the utility. If we had gone with the replacement inverter to begin with, we might never have known that we have a noisy grid and wouldn't have had a reason to complain to the utility.

Chris Henderson • Hendo Consulting

Efficient Electric Cooking

I'm getting ready to choose appliances for my energy-efficient home, and have to face the issue of cooking. We use a solar cooker at times, but that's not always convenient and there's not always sun. We've ruled out using propane and natural gas because they are not renewable energy sources. Our house uses solar electricity, and our utility generates some renewable energy, so the most sensible choice seems to be an electric stove. But which one? Are there more-efficient options?

Dave Berger • Lyle, Washington

Consider an induction range. They offer a smooth, sealed glass surface under which electric coils inductively couple with stainless steel or cast iron cookware to rapidly transfer heat.

Induction cooktops cook faster, more efficiently, and more safely, by putting the heat directly into the pot instead of into the cooking surface and the surrounding air. U.S. Department of Energy research found a 10% greater heat transfer compared to conventional electric cooktops, and more efficient internal conversion of electricity to heat, ranging from a modest improvement to a 35% improvement, depending on the test.

Induction cooktops are easier to clean than exposed electric elements and can accommodate a variety of pot shapes and sizes. They look great and offer excellent control over cooking temperatures, competing well against high-end gas ranges that need to be able to boil water fast, sear foods quickly, and still simmer evenly at very low temperatures.

The ovens on most induction ranges are pretty conventional, but you can choose a convection option, which stirs up the air inside the oven during the cooking process, and can speed up baking a bit, but is by no means necessary and only minimally impacts energy use.

Their only real disadvantages are their higher cost compared to conventional electric ranges and requiring steel or iron cookware instead of aluminum. Prices on induction ranges start at about $1,000 and depend on what features you want, and there are many brands to choose from. For cabins and such, you can find induction hot plates at modest prices.

Chris Calwell • Ecos Research

Induction cooktops heat the pan, not the cooktop or the air.

Courtesy Electrolux

Matching Inverter to Array

I have a grid-tied inverter with a maximum DC input of 750 V and 5,250 watts, with a two-array connection. I also have 20 identical PV modules, each rated at 270 W and 38.5 Voc (open-circuit voltage). I wanted to have two 10-module arrays, but connected in series, the total voltage for the 20 modules exceeds the inverter's maximum input voltage. I'm wondering if there's any benefit to wiring one array in parallel and the other array in series. Or should I connect both arrays in parallel so that the total power is 5,400 W, which slightly exceeds the inverter's max input power?

Mohamed Didi • via homepower.com

There are four main parameters to look at when matching the design of a PV array to the ratings of a grid-tied inverter.

- Maximum open-circuit input voltage. This number—most often 600 V DC—must not be exceeded on a cold winter's morning, when the array's output could be at its maximum. Take the rated open-circuit voltage of your particular number of modules in series, multiply it by the correction factor for cold modules at your site's low temperature, and make sure that it's less than the rated maximum voltage. Exceeding this voltage will void the inverter's warranty (most of them internally record maximum voltage, so the manufacturer will know) and could destroy the inverter.

- Minimum peak-power tracking voltage. If the maximum power point (MPP) of the PV array falls below this voltage on a hot summer day (PV array voltage drops as the temperature increases), the inverter cannot track the array's MPP, and the power may fall drastically until the array cools off. There is no safety or warranty concern here, but energy collection will be reduced.

  As modules age, or weather hits new record-high temperatures, the module voltage will drop further. Allowing some headroom (10% or more) for this value when the modules are new is a good idea. Another consideration is partial array shading. If there is a shadow, such as a chimney or fence that might shade one or two modules in a string during part of the day, you want to ensure the inverter can still operate on a lower voltage string without those modules and allow the modules' bypass diodes to function when they are shaded. If the inverter has two independent DC inputs that you can connect different length strings to, you need to examine each input separately.

- Maximum array wattage. Most inverter manufacturers list a maximum array DC wattage, but this value may not be correct for your location. For example, it is common for a 5,000-watt inverter to have a recommended maximum DC array wattage of 6,000 W STC. However, if you use this recommendation for an array installed in the Colorado mountains (a high elevation, cooler climate, with lots of winter sun), it may be subject to power clipping. During a cold, sunny winter day, the array could produce near 6,000 W DC—more power than is necessary to produce 5,000 W of AC output. Besides wasting potential energy, this condition will run the inverter at its maximum power for more hours, shortening its life. Conversely, if your array is in a hazy climate at sea level, where partly cloudy conditions and not much clear full sun predominate, or a really hot climate where the modules will always be running hot, then a 6,000 W STC array may rarely produce more than 5,000 W, and the manufacturer's recommendations are probably fine.

  An array that's producing more watts than the inverter's rating will likely result in the inverter reducing power by intentionally moving off the array's maximum power point. However, in some inverters, overheating and damage may occur.

- **Maximum rated array current. Unless you design a high-current, low-voltage array that operates near the minimum PV operating voltage, the array current is usually well below the maximum allowed. Designing with a good amount of clearance from the minimum PV array operating voltage should eliminate concerns. However, if you are using only one input of an inverter with two inputs, you may need to check maximum DC array current for the single input you are using to make sure it is safe.**

Most inverters will have a number of other specs, such as maximum peak power tracking voltage and minimum start voltage. If the first four conditions are met, these are almost always automatically met when using crystalline silicon modules.

Inverter manufacturers generally offer an online series-string sizing tool that walks you through the process of calculating how many modules can be in series for each string at your site, and they do a good job of calculating voltages. However, you may need to adjust the total wattage depending on your site.

Zeke Yewdall • Mile Hi Solar, Loveland, Colorado

Mechanical Ventilation, Building "Breathability" & Natural Ventilation

I'm interested in building a high-performance green home and understand that a main strategy in conventional green building (and passive houses) is to use ample insulation, reduce or eliminate thermal bridging, and seal all joints and cracks to reduce air infiltration as much as possible. However, reducing air infiltration also results in a "tight" house, in which some sort of mechanical ventilation—usually a heat- or energy-recovery ventilator—is required or strongly recommended. Does this requirement also apply to straw-bale or light clay-straw homes, which are said to "breathe," due to the nature of the building materials that are used? Would normal spot-ventilation (bathroom fans, range hoods) provide enough ventilation to maintain good indoor air quality, so I can avoid the cost of buying and installing a whole-house ventilation system?

Susan White • via email

The term "breathability" is often associated with various natural building methods, but it is often misunderstood. It does not refer to air exchange, but vapor permeability. A more accurate term to describe the physics in a traditional (natural) mass wall construction is "vapor open" or "flow through." There is no need for a vapor barrier because the material in the wall has a very high capacity to take on vapor when conditions are humid, to store it without any damage to the wall system, and then to re-release it when the indoor or outdoor climate has changed. It is this ability that has enabled the historic buildings made of clay and fiber to endure for hundreds of years all over the world.

Whether the home is made with conventional or natural materials, uncontrolled infiltration (i.e., leakage) is not a desirable source of fresh air. A leaky home may contribute to air exchange, but it will also contribute to drafts, and result in less comfort and more energy consumption. In the case of conventional light-frame building (stud walls with insulation in cavities), infiltration of moisture-laden air will also cause condensation and moisture problems within the wall cavity.

Traditionally, air exchange has taken place through operable windows which also displaces indoor tempered air for outdoor frigid air. Bathroom and kitchen fans extract polluted air, and replacement air will find its way into your home either randomly, or where you choose to supply it. It is safer to choose where we want our replacement air to come from. In this case, a more energy-efficient method would be a heat recovery ventilator (HRV), which is designed to automatically bring in fresh outdoor air and temper it with outgoing exhaust air without mixing the air streams.

So how much fresh air do we need? It depends on many factors, such as the number of occupants and their activities (i.e., cooking, showering, smoking, etc.), and what materials the house is made of. A much higher air exchange rate might be needed in a home with off-gassing building materials, or if someone smokes indoors, for example.

How much automation and mechanization do you wish to invest in? In a natural building, built with nontoxic materials, mass walls and windows designed for cross ventilation, is mechanical air exchange necessary? Yes and no. If you live in a very cold climate, such as Canada or Alaska, opening the windows in your natural home in the wintertime will let in a blast of very cold air. However, in a more moderate climate, such as temperate parts of the Northwest, we have found that, once your mass walls are up to temperature, you can open windows, exchange air, and close them again without significantly changing the interior air temperature or your comfort. This is how our ancestors did it and it has also worked well for us in the straw-clay homes we've built for ourselves and our clients. Unless you live in a state where mechanical ventilation is mandated for all new homes, it's largely a lifestyle choice.

Paula Baker-Laporte • Econest Architecture

Reducing leaks into the house is a good thing. We can't achieve a high degree of energy efficiency if our conditioned air is leaking out of the building. Even thick insulation will be subverted if air leakage provides a bypass. Equally important, we can't have healthy indoor air quality if there are leaks. If our homes are getting their "fresh" air supply through unintentional cracks and holes, air will enter the home carrying whatever dust, moisture, spores, and odors it picks up as it travels through building materials.

An energy recovery ventilator provides tempered fresh air, transferring most of the heat from the outgoing exhaust air to the incoming fresh air.

Courtesy Chris Magwood

The notion that straw-bale or straw-clay wall systems “breathe” is misleading. It is both possible and desirable to make these homes airtight. If the walls breathe—in other words, leak—they aren’t good walls! The term “breathable” should be replaced by “permeable” or “vapor open,” meaning that moisture in vapor form is able to transpire from one side of the wall assembly to the other. This is a highly desirable trait, as it helps prevent excessive moisture buildup in the home and in the walls, and allows for dynamic drying of the wall to take place year-round. This doesn’t happen when nonpermeable materials like polyethylene barriers and oriented strand board are part of a wall system; these materials greatly increase the likelihood of moisture issues within the walls.

If our goal is to have homes with top-notch energy efficiency and the best indoor air quality, then active ventilation is the way to achieve that goal. The “exhaust only” ventilation strategy, using only bathroom fans and a hood range, depressurizes the house and causes replacement air to be sucked into the home through whatever tiny holes are left after it has been carefully sealed. This depressurization increases the chances of dangerous backdrafting of combustion gasses into the living space if combustion appliances are used. Exhaust-only strategies cannot provide the good indoor air quality you are seeking,unless there is a provision for fresh air supply.

The most common strategy for proper ventilation is a whole-house ventilation system, which involves ductwork on the exhaust and the supply side, and makes use of a heat exchanger to balance the temperature of the incoming air with the outgoing air. If the home is heated by a forced-air system, the supply side can be twinned with the existing ductwork, reducing the amount of unique ducting required. Other systems, like the Lunos e2 or FreshR HRV, are through-wall exchangers that require no ductwork. These systems are relative newcomers, but already have many devoted fans.

Whatever your choice of system, the controls are very important. Simple on/off systems are wasteful if left on constantly and useless if turned off. Controls that monitor humidity, carbon monoxide levels, and other variables will result in a system that runs only when needed.

The cost of ventilation systems becomes very reasonable once a building reaches Passive House standards of airtightness and thermal efficiency. Then, the amount of heating required (even in very cold climates) is so small it can be delivered via the ventilation system. This eliminates the typical furnace or boiler and its entire delivery system, making the full cost of such an approach very reasonable and worth considering.

While some might object “on principle” to mechanical ventilation, we already rely on mechanical devices to heat and cool our homes, provide our hot water, and refrigerate our food. We accept the need for these devices because they do something desirable for us. Fresh air, balanced humidity, and energy efficiency are also desirable, and the machines that provide these benefits are well worth the investment.

Chris Magwood • Endeavour Centre

write to:

asktheexperts@homepower.com

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

SOLARIZE! Your Community

by Vaughan Woodruff

A growing movement seeks to expand the use of solar electricity, one community at a time.

In 2014, researchers from Yale University and the University of Connecticut published a study on the factors that influenced Connecticut households to install solar-electric systems. The single biggest factor in deciding to go solar is whether a neighbor had done it.

The Solarize Movement

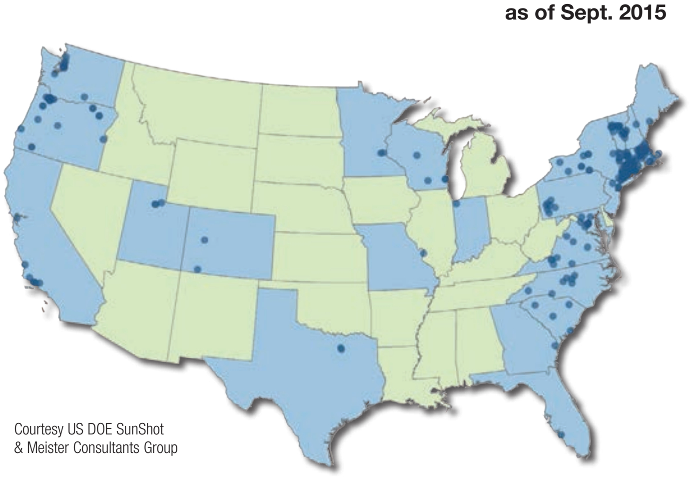
Solar energy has become infectious, partially a result of "keeping up with the Joneses," but also because of the increased confidence from seeing neighbors choosing these systems. To capitalize on this phenomenon and make systems more affordable, communities are organizing Solarize campaigns. Organizations and municipalities in at least 19 states and the District of Columbia have launched community Solarize projects.

One of the first projects was launched in Oregon in 2009, when a group of Portland residents seeking to reduce their costs banded together for a volume discount. By organizing their collective buying power through the Southeast Uplift Neighborhood Coalition nonprofit and in coordination with the Energy Trust of Oregon, community members were able to reduce their PV system costs by about 30%.

That campaign initially attracted 300 residents to sign up for more information. By the end of the program, 130 homes had PV systems installed. Based upon the success in southeast Portland, other communities in the city followed suit. As a result of the various campaigns, 400 PV systems were installed in Portland in 2010.

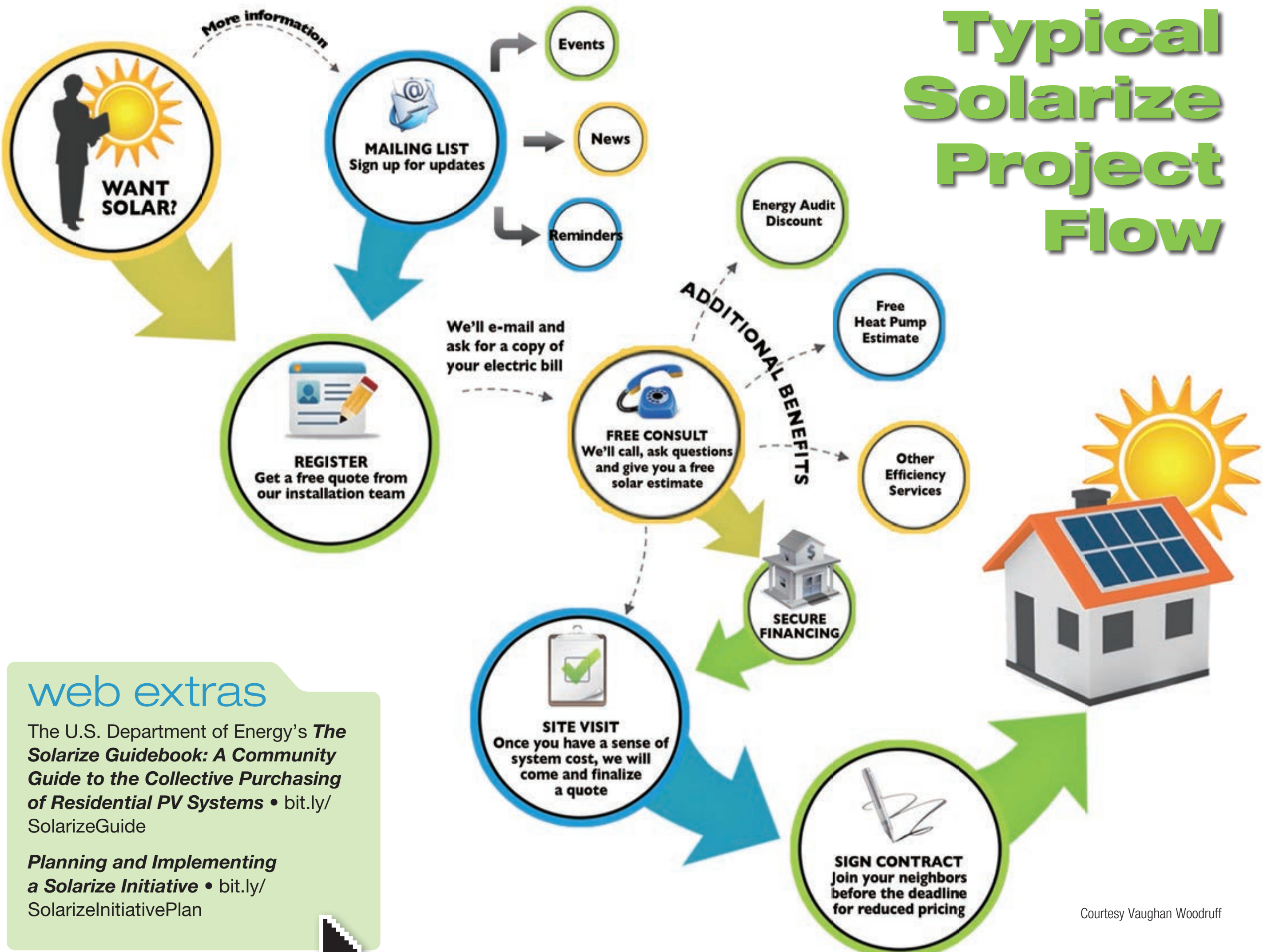
Locations of Known Solarize Campaigns

as of Sept. 2015



Courtesy US DOE SunShot & Meister Consultants Group

Typical Solarize Project Flow



Courtesy Vaughan Woodruff

web extras

The U.S. Department of Energy's ***The Solarize Guidebook: A Community Guide to the Collective Purchasing of Residential PV Systems*** • bit.ly/SolarizeGuide

Planning and Implementing a Solarize Initiative • bit.ly/SolarizeInitiativePlan

Courtesy Solarize Freeport

One of the earliest Solarize projects was launched in Portland, Oregon, in 2009 and resulted in more than 500 installations.

Courtesy Solarize Portland

Spreading the (Renewable) Energy

Solarize efforts can coalesce in several ways. They may be initiated by a solar installation company targeting a particular market by offering bulk discounts in that community. Local nonprofit organizations or community groups, such as a recycling committee or clean energy coalition, may also serve as a catalyst. Municipalities themselves may initiate a program for local residents and businesses.

The Solarize Guidebook examines these varied approaches and offers recommendations for establishing an effective campaign. If you want to initiate a project in your community, reviewing these recommendations will establish a solid foundation.

Courtesy Solarize North Fork

A solar home tour can help educate community members.

web extras

Benchmarking The Solarize Model: A Survey Of Campaign Organizers by DOE Sunshot & Meister Consultants Group • bit.ly/SolarizeSurvey

Courtesy Solarize Freeport

Yard signs identify what the "Joneses" are up to.

Find a project head. The success of a project depends heavily upon having a champion with strong community connections and the time to supervise the project. You could work with an existing organization, develop an ad hoc committee of like-minded individuals, or approach a municipality. Consider the group's standing in the community, its existing networks, and the bureaucratic processes that might accompany their involvement. For example, working with a municipality may mean wading through maze of approvals, slowing the project significantly. In light of the pending federal solar investment tax credit expiration in December 2016, a program's timeliness might be paramount.

Solarize Campaign Example Roles

Task	Project Manager	Volunteers	Contractor	Utility/Municipality
Planning	Manage program; provide resources	Provide ideas	–	Provide tech support; provide resources
Volunteer recruitment	Recruit & organize committees	–	–	Advise committees
Request for proposal (RFP)	Issue RFP; advise on RFP & contractor selection	Draft RFP; select contractor	Respond to RFP	Advise on RFP
Outreach	Manage outreach campaign; create & print fliers; lead workshops	Build website; distribute fliers, outreach materials; schedule workshops; identify venues	Teach nuts & bolts and Q&A session	Provide workshop curriculum; teach workshops
Enrollment	Compile database of enrollees; engage customers	Recruit neighbors	Conduct preliminary assessment & schedule site assessments	–
Site assessments	Track contractor turnaround time & signed contracts	–	Conduct site assessments with homeowners; prepare bids	–
Installations	Track contractor turnaround time & customer experience	–	Execute contracts; install systems; complete paperwork	Streamline solar permitting process; inspect installations; interconnect systems
Celebration!	Issue press release; promote, evaluate & replicate	Plan &/or host party	Plan &/or host party	Assist/attend

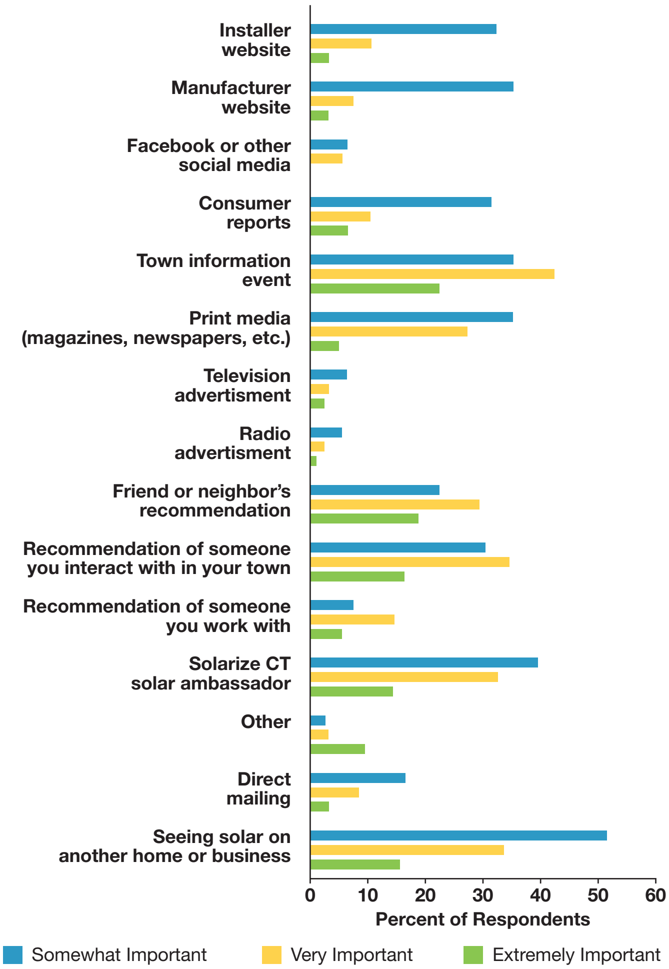
Source: *The Solarize Guidebook*

Be visible. Use press releases and community events to spread the word about your campaign. Host solar open houses. Use signage visible on the street to increase program visibility. Use viral marketing and social networking to make the community as aware of the technology and the program as possible.

Engage the community. Solarize campaigns should use community education to increase understanding of solar technologies. Encouraging community involvement in the program development, installer selection process, and community outreach spreads the word and supports other marketing efforts. Involving the community increases trust and can provide feedback to the project installers. A competitive bidding process for the solar contractor(s), including a rigorous technical review, can build trust.

Importance of Social Network Effects

Homeowner Responses Related to the Relative Importance of Different Factors in the Decision to Adopt Solar



Source: Ken Gillingham, Yale University School of Forestry and Environmental Studies, SEEDS

Courtesy Solarize Freeport

A group of community leaders, Solarize participants, and installers celebrate the Town of Freeport's recognition as a Citizen Climate Champion for its Solarize Freeport program.

Bringing RE to Freeport: A Municipal Approach

In early 2014, I received an email from Donna Larson, the town planner of Freeport, Maine. She was seeking bids from area installers for a Solarize Freeport project she had initiated after learning about similar projects in New Hampshire.

"Because Maine no longer has a rebate program [for PV systems], I started Solarize Freeport to further bring down the cost of PV systems," says Donna. She had compiled a list of roughly 150 interested Freeport residents before releasing the town's "request for proposal." She recruited participants by canvassing near election polls, having a sign-up sheet at the town office, and promoting the effort through Freeport communication channels.

Donna first learned of the Solarize model from Vital Communities, a nonprofit organization that has coordinated 11 projects in New Hampshire. "What I hadn't anticipated was the great community-building effect that would result when neighbors shared their questions, concerns, and hopes for going solar," Donna says. "As the citizens got to know each other's motivations better; the town's sense of community got stronger."

Solarize Freeport was based on a tiered pricing model—the more participation, the lower the installed cost for everyone. Participants were required to place their system under contract by May 2, 2015, to receive the full Solarize Freeport discount, which was roughly 10% less than market cost.

Solarize Freeport offered incentives to early adopters—those who committed by March 28 received gift certificates from local businesses, and the installation firms offered discounts on related services, such as tree-stump removal and mini-split heat pump installations. As a result, the program reached its lowest pricing tier five weeks before the buying deadline. This simplified the selling process significantly, since the final pricing was already determined for later buyers. The discount offered through the Solarize Freeport effort was the only local incentive.

Based upon participation in other similar efforts, I originally estimated that 20% of those who requested a quote would actually purchase a system. By the end of the program, out of 100 people from Donna's original list who had requested a quote and another 100 who had learned of the program following its launch, 41 PV projects were installed, totaling more than 240 kW of capacity. The program also led to 20 energy-efficiency projects that either supplemented a PV installation or better met the client's needs than a PV installation.

Successful Solarize projects seem to breed others nearby. One has launched in neighboring Brunswick and another is currently in development in the Waterville area.

—Vaughan Woodruff

A Nonprofit-Led Solarize Program

Solar Energy International (SEI) in Paonia, Colorado, is a nonprofit organization providing solar training. In addition to SEI's training on their Paonia campus, it is also involved in education and renewable energy development across the world. Through its Solarize North Fork Valley program, SEI was able to foster solar development in its own backyard. Partnering with AmeriCorps VISTA volunteers enabled the adoption of more solar-electric systems in Paonia, Hotchkiss, and Crawford.

"SEI occupies a unique platform to stimulate economic development through local renewable energy," says Kathy Swartz, executive director of SEI. SEI is in a community that once mined more than 1.5% of the nation's coal. Swartz says, "As our coal mines close, we have a unique opportunity to create local jobs through solar energy. We are committed to building a resilient local solar market and this program is one way that we are achieving this."

SEI took the lead in educating interested buyers about solar technology, connected participants with energy-efficiency resources, and coordinated a solar homes tour for interested individuals to see a previously installed PV installation. Out of a population of approximately 5,000, 75 households expressed interest in Solarize North Fork Valley. By the purchase deadline of July 31, 2015, 22 systems were sold through the program. SEI had initially targeted a total installed capacity of 100 kW. They ended up with 120 kW, which reduced the system cost from a base price of $3.25 per watt to $3.10 per watt.

As a result of the program, $400,000 of projects were secured and three full-time positions were created with the installation firm selected for Solarize North Fork Valley. The program also catalyzed interest from homeowners in neighboring communities due to the campaign's visibility. Typically, Solarize projects create more visibility for the installation firm, which tend to increase future sales. An expanded clientele also generates more business.

Solarize North Fork Valley participants Sarah and Bill Bishop are now the proud owners of a 6.24 kW PV system.

Courtesy Solarize Freeport

Insource Renewables and Assured Solar Energy were selected to collaborate for Solarize Freeport. Here, installers from the two companies meet up at the site of the program's first installed system.

Put the sales burden on the installers. Some programs provide the initial site evaluation and consultation themselves, instead of relying on solar installers. While the intent is to guarantee impartiality, this approach can slow the process significantly. In the early days of the Portland program, the large volume of interested parties compared to small number of site assessors led to delays—and didn't increase the likelihood that the participant would buy a system. Objectivity in assessment and oversight can increase trust by participants, so there needs to be balance between that organizational involvement and merely turning it over to the installation contractors.

Empowered Energy Systems owner Brad Burritt was selected as a Solarize North Fork Valley installer. This effort enabled him to add three installer positions to his company.

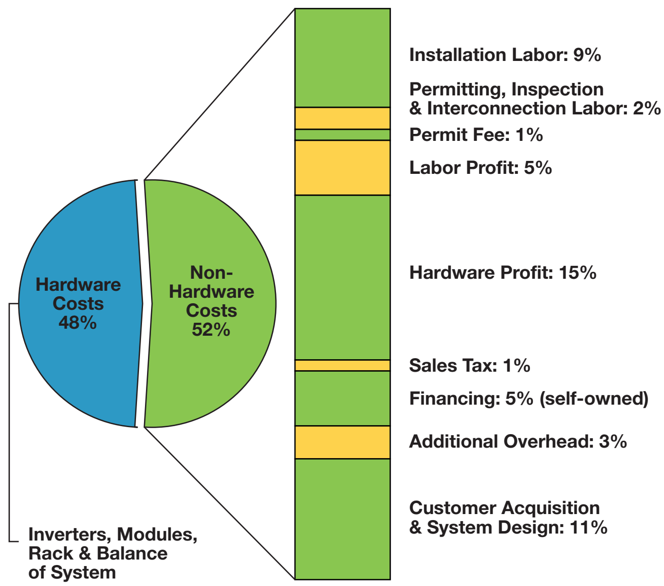
Courtesy Solarize North Fork (2)

Consider value in addition to pricing. When you select solar contractors, consider the value the companies bring, in addition to the upfront system prices. A successful campaign builds a strong foundation for solar development into the future, so it is important to select reputable, skilled contractors. Having qualified individuals review the proposals—including the equipment specified, product and labor warranties, and crew qualifications—helps ensure that the contractors reflect the values of your organization or municipality. When considering pricing, the Department of Energy found that the perception of getting good value is more critical than getting the lowest pricing.

Consider how the pricing structure will promote participation. Many campaigns use a tiered pricing structure to promote increased participation. The pricing tiers are typically based upon the cumulative capacity of the systems—individual system prices decrease as more people buy solar. This provides motivation for participants to promote the program to friends and neighbors.

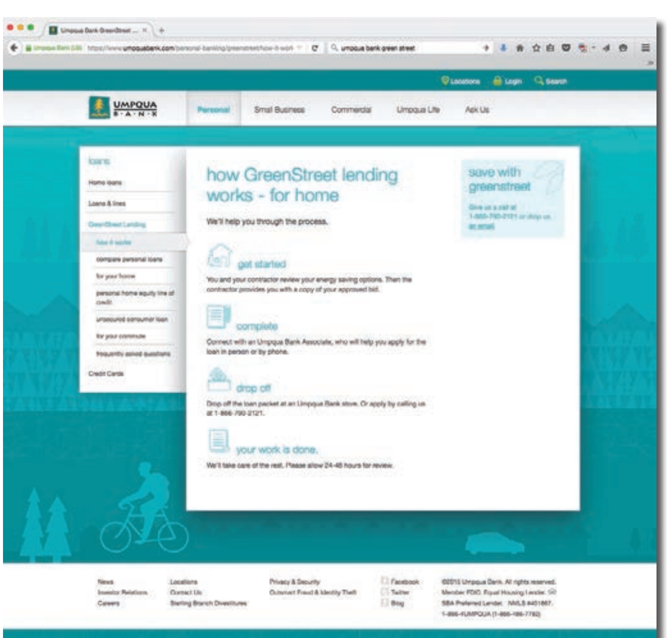
However, this pricing structure has its challenges, since program pricing is not determined until the buying deadline or until enough contracts have been signed to reach the lowest pricing tier. This tiered structure requires some buyers to join before they know their final pricing. Some programs opt for flat-rate pricing, offering the lowest pricing tier from the beginning, with the assurance that the community will assist installers in recruiting participants. Another approach is to provide incentives for homeowners who purchase a system early in the program, such as was done in the Freeport, Maine, campaign (see "Bringing RE to Freeport" sidebar).

Typical PV System Cost Breakdown



Courtesy Solar Energy International

Some lending institutions offer energy- and/or efficiency-specific loans with special interest rates and streamlined application processes.



Provide financing options for participants. One of the largest impediments for potential participants is upfront cost. While solar electricity is often less expensive than utility-generated electricity in the long term, the up-front cost of "prepaying" for this electricity can often put a system out of reach. Loans can reduce this barrier by allowing monthly payments that are similar to a monthly utility bill. Participants can be educated about home equity loans, as well as unsecured loans that have higher interest rates and/or closing costs. Engaging local lenders in the effort can help support the Solarize program and open up long-term opportunities for renewable energy lending programs.

Support other residential energy-efficiency efforts. Although energy efficiency usually should be the cornerstone of any renewable energy project, the market reality is that a solar-electric system is often more appealing to consumers. Solarize programs capitalize on the curb appeal of solar technologies, but they can also be effectively leveraged to promote other energy-efficiency measures, especially since many of the goals—including saving money or reducing pollution—are the same. Including energy auditors, heating and cooling professionals, and information on reducing energy demands as part of the program's educational efforts will increase a project's impact. These complementary services can be offered as a supplement to the program. If you want to provide more emphasis on one of these services (e.g., weatherization, solar water heating, heat pumps), it is worth considering offering it as an entirely separate program.

Future Programs

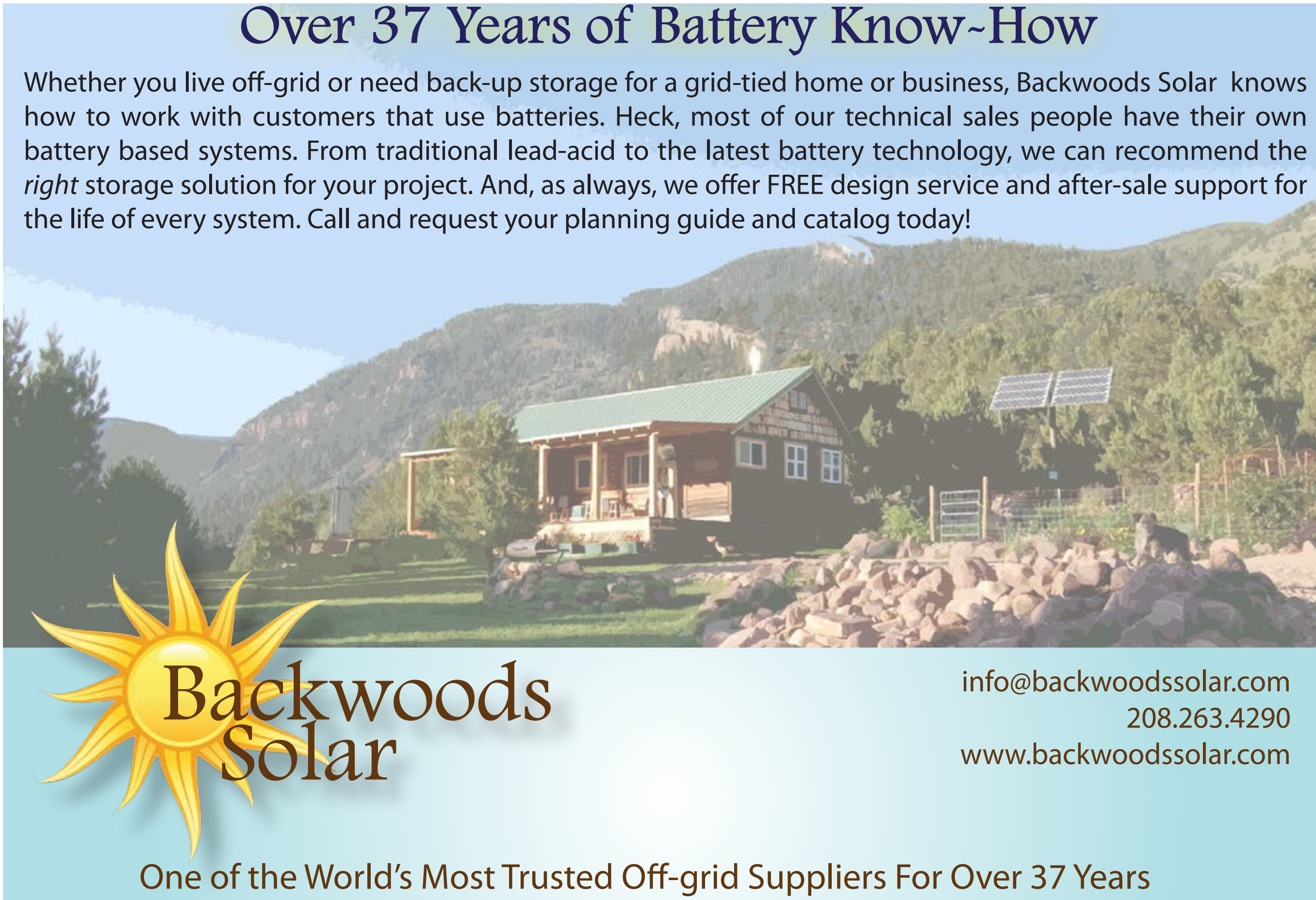
Coordinating a Solarize program can be an inspiring way to promote immediate change and support the long-term development of solar energy infrastructure in your community. The beauty of these programs is their ability to be customized to meet a community's particular needs. Whether your town has a little PV or a lot, Solarize programs create a buzz that moves us all a little further toward creating a more sustainable future.

Post-Campaign Attitudes of Solarize Organizers

	Massachusetts						Other States					
Attitude	1	2	3	4	5	Avg.	1	2	3	4	5	Avg.
The community was supportive of Solarize	0	1	1	3	16	4.6	0	0	0	1	13	4.9
Local government was supportive of Solarize	0	1	0	4	16	4.7	0	1	2	2	9	4.4
State government was supportive of Solarize	0	0	0	3	18	4.9	0	1	5	3	5	3.9
The local utility was supportive of Solarize	0	1	14	5	1	3.3	0	1	5	4	4	3.8
The Solarize campaign was a success	0	1	0	4	16	4.7	0	0	0	1	13	4.9
Solarize strengthened the local solar market	0	0	1	6	14	4.6	0	0	0	3	11	4.8
I am interested in a repeat campaign	0	3	6	5	6	3.7	0	2	2	4	6	4.0

Continuum Key: 1 = Strongly Disagree; 5 = Strongly Agree

Courtesy US DOE SunShot & Meister Consultants Group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Pushing the Envelope with a Green Home

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by Claire Anderson

Pushing the building envelope by maximizing its "green" features can be rewarding personally, economically, and environmentally—but how do you build houses that perform well, providing thermal and visual comfort, using as many passive inputs as possible, while minimizing the amount of active inputs they need?

While there's not one path for all homes, there are steps along the way that we can take to make sure that form does not trump function.

How Low Can You Go?

At the heart of green building is doing more with less—or perhaps we should say, doing more *in* less. In the 1950s, according to the National Association of Home Builders, the average U.S. home was 983 square feet. By 2008, it had mushroomed to more than 2.5 times that size—nearly 2,500 square feet. Meanwhile, the average family size has shrunk—there are fewer of us occupying that space. In 1950, the U.S. averaged 3.8 people per family but today it's 2.6 people.

In a 2010 article published in *Yes!* magazine, architect Jason McLennan advocates for a national standard of 200 to 600 square feet per person. To be considered "green," he says, an average American family house or condominium, which today is built for three people, should be no larger than 1,600 square feet.

Smaller homes require fewer building materials, resulting in lower embodied energy. On our finite planet with limited resources, this matters a lot. Well-built small homes require less energy to operate—there is less volume to heat and cool, less surface area for heat loss, and fewer lights to power. When you're planning your home, consider the tenets of "stacking functions"—i.e., instead of having a dedicated room as an office, you might instead designate a corner of a kitchen, complete with desk and built-in shelving, to serve that same function.

Beyond small design, shrinking your energy use with conservation measures—changing your energy use behaviors—is another crucial step to achieving an "energy-smart" house. After that, efficiency comes into play, with low-energy (and low-water) appliances and electronics.

Solar-electric systems can be tailored to fit a variety of rooftop designs, but simpler roofs, with no obstructions to create shade, are better for system performance.

©istockphoto/hansenn

web extras

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

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

The Problem with "Comps"

While small may be beautiful to green builders, lending agencies may not share that sentiment. Lenders providing mortgages rely on "comps"—comparables, homes of similar size, with similar attributes—that appraisers use to arrive at a monetary value. Square footage still plays prominently in valuation, with no (or little) nod to a home's design quality or sustainability (see Web Extras).

My husband and I faced this dilemma after completing our 1,472-square-foot high-performance home. Our first appraiser compared our new, energy-efficient home—which earned the highest rating from a regional green-home certifier—with funky mobile and poorly built manufactured homes, or old, drafty (small) bungalows. Why? Because of its size. In our rural area, it's difficult, if not downright impossible, to find custom-built homes that are *small*. There is also a lack of knowledge about what constitutes "green building" and home energy efficiency. At the time, there was only one appraiser in our region who had additional training in appraising green houses. We worked with her to arrive at a more accurate valuation of our home and secure a conventional mortgage.

Our perseverance paid off, but not everyone has this experience, nor access to educated green appraisers. Before you build small (unless you're building out of pocket), be sure you understand the market you're building in—and have a backup financing plan in case securing conventional financing is difficult.

Financing for small homes and those built with unconventional materials can sometimes be difficult to obtain.

Courtesy Kim Kurian

Assess Your Renewable Resources

A green home maximizes passive strategies for heating and cooling through good design, conservation, and energy efficiency, and then considers active renewable strategies. Take inventory of the renewable resources at your site, and think beyond electricity. Consider how you can use each resource to your home's advantage.

Sunshine. In many locations, orienting your home's long axis to face true south (rather than magnetic south) and including the proper amount of south-facing glazing will ensure the greatest solar heat harvest. Measure the solar window (solar access) at your proposed building location. How wide is it—that is, does the site receive sun from 9 a.m. to 3 p.m. during all seasons, or is there a narrower window due to obstructions? Are there local climate conditions that impact your solar resource, such as regular morning fog? These conditions can influence how you should orient your home. For example, if winter fog is an every-morning occurrence, perhaps a building with more southwesterly orientation would be better for solar gain. Of course, not every site has suitable solar access, and that's where good design and active strategies come in (see "Creating a Green Envelope").

Wind. What are the prevailing winds at your site, and how do they change over the seasons? Finding a wind rose for your location can give you a good idea of how the winds might behave—and how you might best channel them. In heating-dominated climates, understanding the prevailing winds should show where to locate a windbreak. In cooling-dominated climates, this information could help you decide where best to place windows in the envelope to encourage passive ventilation.

web extras

"Getting the Green for Your High-Performance Home" by Andy Kerr • **homepower.com/153.54**

Design your house for your climate. In this Southwest home, large overhangs provide shade and thermal mass decreases daily temperature swings inside.

In mixed climates, a mixed but balanced design is key to good performance.

Creating a Green Envelope

The less complex the shape of your house, the fewer materials it will use. The more you deviate from nominal measurements (increments of 4, 8, 10, or 12), the more scrap (and waste) you'll have, and the higher the home's embodied energy will be. Homes with simple rooflines and envelopes are also less complex to build.

Make the building shape suit your climate and site. Sometimes, vernacular architecture can inform your design. Saltbox homes, with deeply sloping roofs to the north and few to no windows on that side, were common in the Northeast, as this shape helped thwart cold winter winds. The wide, shaded, wrap-around porches on old Southern homes provided some relief from the sweltering summer sun, while large operable windows aided in ventilation.

Whatever shape and orientation you choose, the basic strategy for a deep-green home is to use lots of insulation, eliminate thermal bridging, and minimize air infiltration. Creating a tight, well-insulated envelope can go far in achieving a high level of thermal comfort and significantly reduce the need for supplemental heating and cooling. How much insulation will depend on your climate. The values in the table are for *whole-wall* R-values, which take into account the framing members—they are *not* the nominal values listed on insulation packaging. For example, a 2-by-6 framed wall insulated with R-21 fiberglass batts will not result in an R-21 wall, but will have a lower value due to thermal bridging and thermal properties of the wood studs.

Thermal bridging is eliminated by creating thermal breaks between the exterior and interior. Staggered or double-stud walls have a gap between the exterior and interior framing members, infilled with cellulose or fiberglass, and (usually) have a layer of exterior rigid insulation. Structural insulated panels also offer reduced thermal bridging, since panels are usually studless (although there can be some thermal bridging where the panels join one another). Straw bales notched around framing members is yet another strategy. A continuous layer of insulation, which creates a thermal break, is key. Similarly, underslab insulation and foundation insulation should provide the same thermal break, slowing heat loss or gain to the interior.

Establishing a "tight" home—controlling air movement into and out of the house—depends on your construction methods and attention to detail. Air barriers such as house wrap block random air movement through the envelope, but the type used depends on the climate. Taping the housewrap seams can improve performance by about 20%, according to the U.S. Department of Energy. Caulk, sealants, tapes, and gaskets can all be effective in reducing airflow through building material joints and seams in subfloors, drywall, and sheathing.

Want design feedback? A variety of software for estimating your home design's performance, such as the U.S. DOE's EnergyPlus, is available, sometimes at no cost.

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R-Value Recommendations

Climate Zone	Class	Windows	Foundation Slabs	Foundation Walls	Above-Ground Walls	Attics or Roofs
1-2	Hot	3	5	10	20	60
3-4	Moderate	4	5	10	30	60
5-7	Cold	5	10	20	40	60

Source: Building Science Corp. & Alex Wilson of the Resilient Design Institute (bit.ly/HowMuchR)

From the Ground Up

Here are some typical methods used in designing and building a green home. See the "Anatomy of a Green Home" illustration on the following pages for a visual of the key green-design features described below.

1. Foundation

Provide a thermal break between earth and slab (if applicable) or insulate under floor. Also provide a thermal break (with insulation) between the foundation wall and slab. Typically, rigid foam board (expanded polystyrene; EPS) has been used for both applications. Sub-slab mineral-wool board may be substituted for EPS in underslab applications. Made from industrial byproducts of the steel industry (slag) and stone, it doesn't contain brominated flame retardants like EPS does and is not a petrochemical product. However, it does contain a formaldehyde binder.

A vapor barrier is covered with rigid foam board before pouring the slab floor.

Foundation forms before the concrete pour show exterior insulation and an interior thermal break from the slab floor.

Courtesy Robert Riversong (2)

2. Slab

Most passive solar homes use a concrete slab as the main thermal mass to absorb solar gain for heating. For good thermal performance, experts advise a 4- to 6-inch-thick slab. Although high in embodied energy, concrete is durable, almost maintenance-free, and fire resistant. Plus, no additional floor finish is needed, although some people elect to stain and polish it for color and aesthetic appeal.

3. Walls

Design a wall with as much insulation, as little thermal bridging, and as little air infiltration as practical. For stud-framed walls, an exterior layer of insulation might be necessary to achieve the desired R-value. Structural insulated panels offer another effective wall-construction method that meets the three goals, although their materials (oriented strand board and polystyrene) and transport from the factory may drive up their embodied energy. Straw bales paired with load-bearing supports might be a lower embodied energy choice, but may not offer the highest R-value.

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web extras

"Basics to Building a Better Home" by Rachel Connor • **homepower.com/126.40**

"Back Page Basics: Thermal Bridging" by Claire Anderson • **homepower.com/164.76**

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

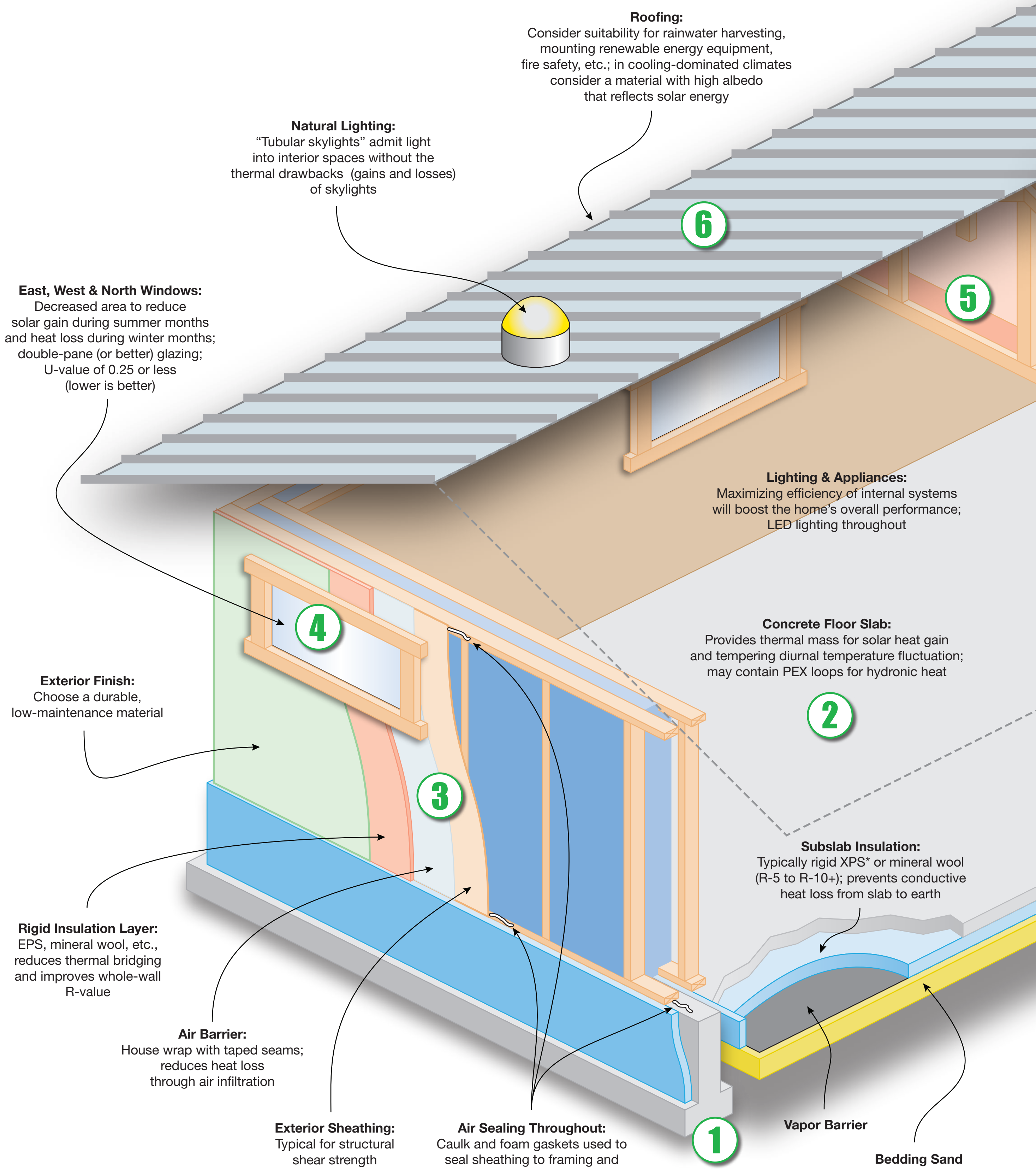
"Green Framing Options" by Scott Gibson & David Johnston • **homepower.com/130.58**

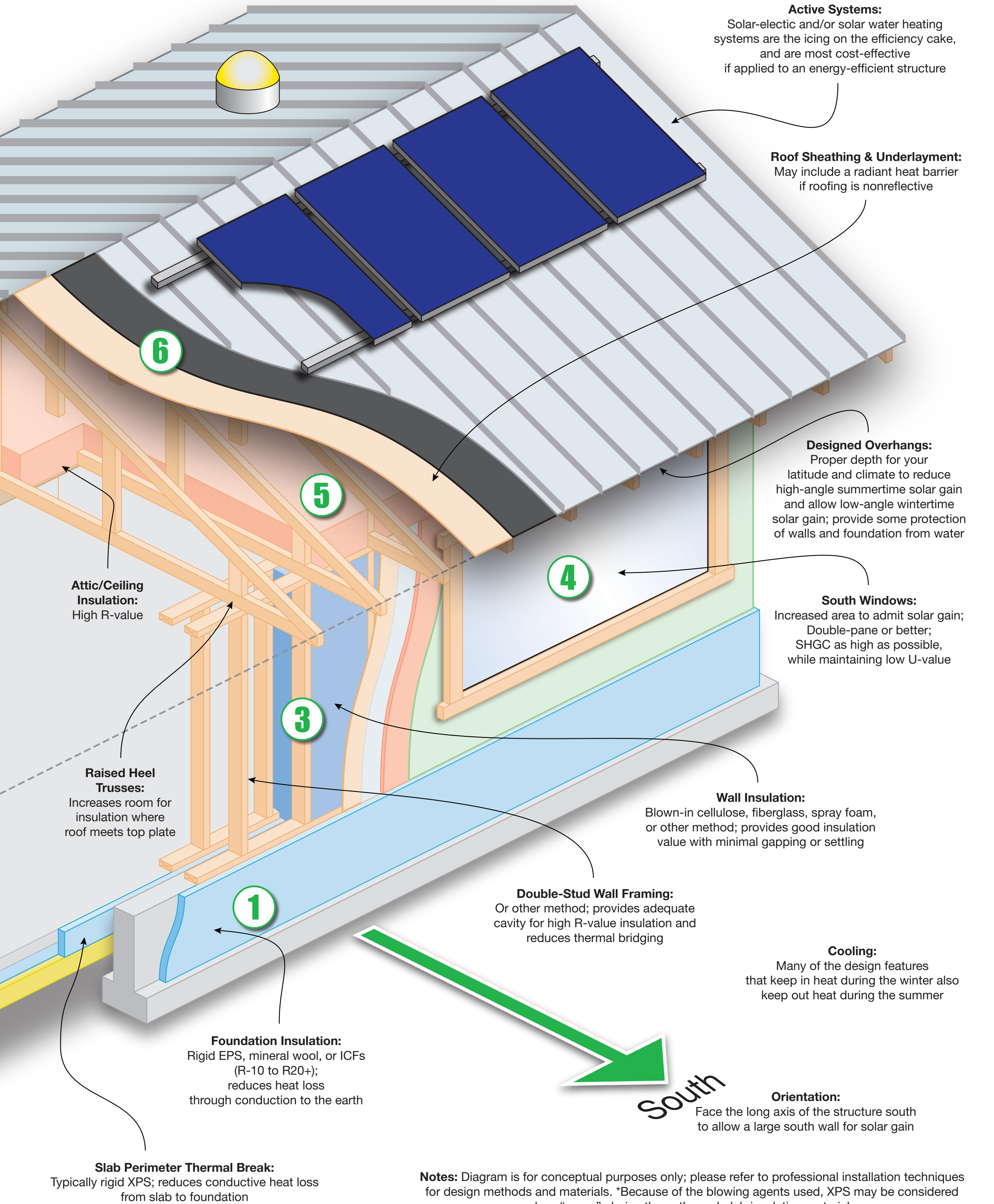
"Designing a Passive Solar Slab" by Robert Riversong • **homepower.com/136.60**

Courtesy NREL

Double-stud framing, whether aligned or staggered, reduces thermal bridging and provides a large cavity for insulation.

Anatomy of a Green Home





Notes: Diagram is for conceptual purposes only; please refer to professional installation techniques for design methods and materials. *Because of the blowing agents used, XPS may be considered a less “green” choice than other subslab insulation materials.

From the Ground Up

continued from page 33

4. Windows

Openings in the envelope, such as windows and doors, lower a wall's overall thermal performance, so plan carefully and minimize windows on the north, east, and west faces. One large window instead of multiple windows in a wall will reduce thermal bridging and potential leakage spots. Casement windows will usually offer the best seal. Double-pane windows with a gas fill and low-emissivity coating will offer fine performance. but for colder (and even some moderate climates), consider triple-pane units. For south-facing windows, consider windows with the highest solar heat gain coefficient (SHGC) but balance this against the window's overall U-factor, which should be 0.25 or less, according the Efficient Windows Collaborative. Associated Materials (Alpine, Alside, Gentek, Preservation, Revere); Fibertec; Marvin (Infinity, Integrity); and Wasco offer double-glazed, high SHGC, argon-gas-filled units that meet these parameters. (For more on window selection, see the Efficient Windows Collaborative window selection tool at efficientwindows.org.)

Ben Root

Raised heel roof trusses allow insulation to be placed between the top plate and the roof sheathing.

Double-pane windows are the minimum for all but the warmest climates. In colder climates, performance requirements increase.

Courtesy Alpen HPP

5. Ceiling

Aim for high insulation values in the ceiling/roof assembly, and minimize penetrations. Skip the skylights and use tubular skylights (aka solar skylights, like solatube.com) to admit natural light while minimizing heat loss/gain. Solar tubes can be effective and efficient for windowless rooms, such as closets, bathrooms, utility rooms, and laundry rooms. Solatube's "Smart LED" system integrates LED into the unit to provide efficient lighting, no matter the time of day.

6. Roof

Durable and made with recycled and recyclable material, standing seam metal is one of the best choices for a roofing material. In cooling-dominated climates, specify a color with a high reflectivity.

Structural insulated panels (SIPs) provide high thermal performance in a modular format for a quickly assembled, energy-efficient envelope.

Courtesy Structures NW

web extras

"High-Performance Windows: Looking through the Options" by Alex Wilson • **homepower.com/157.82**

"Improving Window Performance" by Alex Wilson • **homepower.com/160.74**

Straw bale walls utilize a nontoxic agricultural waste product and provide relatively good insulation performance.

continued from page 32

Parts & Pieces

When it comes to the materials used to build a greener home, there is a lot to consider when comparing choices. Find out about a material's embodied energy—the energy required to harvest/mine, manufacture, and transport it. Then there's the material's toxicity (such as off-gassing), plus any toxic byproducts or waste created in its manufacture. Architect William McDonough has long preached the idea of "cradle-to-cradle," instead of "cradle-to-grave," design, in which the manufacturing loop is a closed one, and "in which valuable, high-tech synthetics and mineral resources—technical nutrients—circulate in a perpetual cycle of production, recovery, and remanufacture." At the end of a product's life, will it biodegrade? If not, can it be reclaimed or recycled—or will it be destined for the landfill?

web extras

"Assessing Green Building Materials" by Chris Magwood • **homepower.com/164.46**

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

"Maximizing the Sun" by Juliet Grable • **homepower.com/171.48**

Ventilation & Tight Homes

To maintain indoor air quality in an energy-efficient, tight home, mechanical ventilation is usually necessary. Depending on the temperature and humidity, an energy- or heat-recovery ventilator (ERV; HRV) is specified. These appliances draw in fresh air but condition it using the outgoing air via a heat exchanger before distributing it throughout the house. Using a normal vent fan to get fresh air can throw away a lot of energy by exhausting conditioned air. The disadvantages to either an HRV or ERV are the initial installation cost; the space required for the equipment and ducts (although ductless HRVs are now available); and the energy usage of the unit itself. In most regions, however, providing heat or energy recovery is a good idea and worth the cost, compared to ducted balanced ventilation.

Although some builders questioned him about his approach, net-zero-energy homeowner Eric Thomas elected not to install an HRV in his Passive House home in Seattle, finding it more cost-effective to add a few more watts of PV modules to his solar-electric system, which would offset additional heating energy needed. Instead, he has a balanced ventilation system without heat recovery, which works fine given the mild Northwest climate. His house uses several exhaust fans—one each in the bathrooms, laundry room, and kitchen. A motion-activated exhaust fan in the upstairs bathroom runs steadily at a low rate and increases airflow when someone enters the room. When the 242 cfm kitchen exhaust fan is turned on, it also activates a Fantech supply fan that sends fresh air to all three bedrooms and the living room through the home's ductwork. The supply fan includes a HEPA filter.

But what about well-insulated but "breathable" buildings, such as homes built with straw bales and light clay-straw methods? Read what our experts have to say on page 20.

An energy-efficient house should be tight, necessitating some form of fresh air circulation. An HRV or ERV is a common, efficient option.

web extras

"Heat & Energy Recovery Ventilators" by Neil Smith • **homepower.com/145.76**

Courtesy Forest Stewardship Council

Forest Stewardship Council-certified lumber is tracked and verified from the forest to the point of sale, helping consumers make more responsible lumber-purchasing decisions.

The Living Building Challenge offers a set of product evaluation parameters. Its "Red List" imperative considers not only the "health of the people who may be exposed to toxins while occupying the building, but of those involved with a material at every stage of its life, from extraction, manufacture, transportation, installation, and disposal," and can be a valuable guide for green material choices. The Quartz Project (quartzproject.org) is a database that can help guide decisions about choosing safer, more environmentally responsible building materials, although it is just in its formative stages, providing information on only about 100 products.

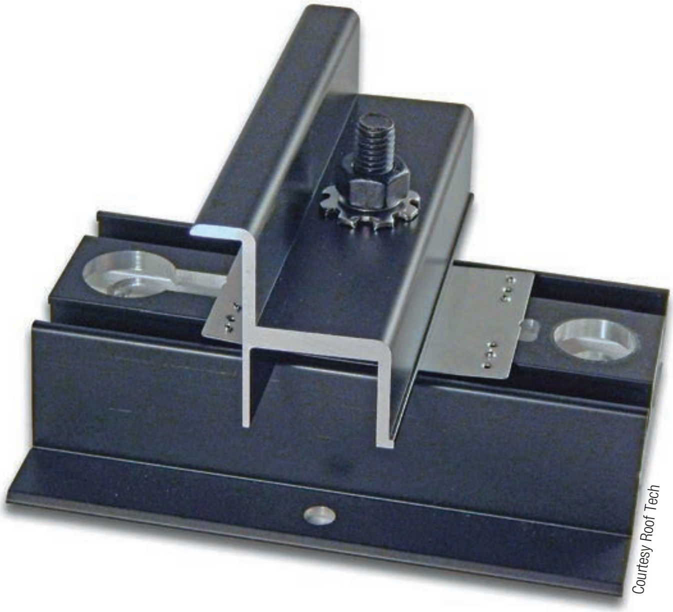
Railless PV Array Mounting

by Justine Sanchez

Comment & Discuss this article @ homepower.com/171.40

Courtesy Quick Mount PV

For residential roof-mounted PV systems, railless racks offer the benefits of fewer materials and less embodied energy, plus improved aesthetics. Here, we take an in-depth look at the various railless rack options available.



Courtesy Roof Tech

Railless rack components, like this Roof Tech RT-[E] Mount, are often extruded aluminum and designed to clamp directly onto PV module frames.

Courtesy Ecolibrium Solar

Railless racks can provide aesthetically pleasing arrays with less cost. This EcoX railless rack from Ecolibrium Solar features pre-assembled components and can be installed with standard module frames.

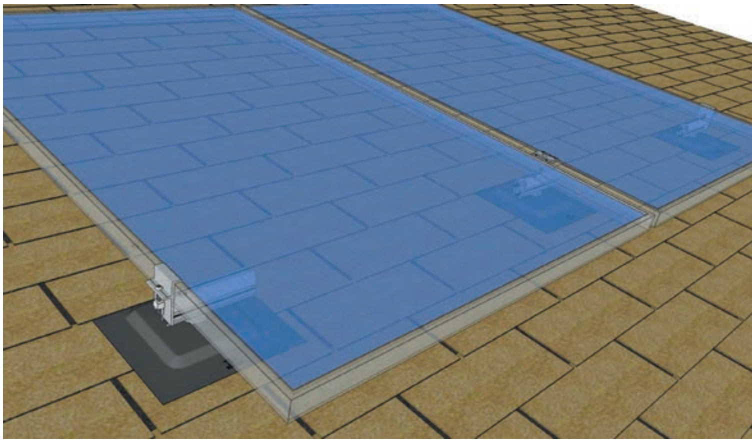
Similar to top-down racks with rails, most railless rack systems require locating rafters and precise component layout.

Courtesy SnapNrack

PV array mounting methods have steadily evolved. In the early days, the only option was to attach pre-drilled module rails to the mount holes on the back of PV module frames with nuts and bolts. While this method works when you can access the back of the array, it is not practical with an array that is flush-mounted to a roof. Thus, "top-down mount" methods, which hold modules in place with clips, became the standard. Tightened down from the front, these clips hold the module frames against the rails.

However, both of these mounting methods require long rails of anodized aluminum. To reduce system cost, an increasing number of PV mount manufacturers now offer "railless" mounting systems.

By substituting long aluminum rails with shorter extrusions, railless systems inherently reduce material use and embodied energy.



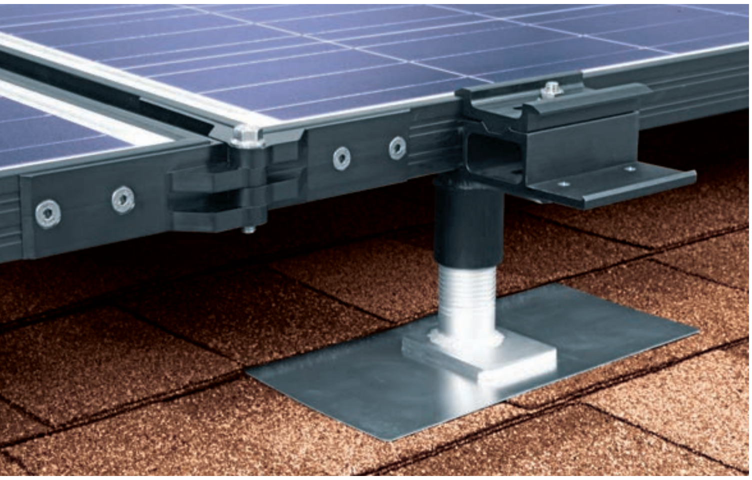
Courtesy Zilla Corp.

Railless PV Mount Systems

Manufacturer	Racking Model #	Grooved Modules Required?	Frame Thickness Range (mm)	Roof Types	Flashing Type	Flashing Included
EcoFasten Solar ecofastensolar.com	Rock-It System	No	30 – 50	Comp shingle	Metal	No
Ecolibrium Solar ecolibriumsolar.com	EcoX	No	33 – 50	Comp shingle	Metal	Yes
Pegasus Solar pegasussolar.com	LightSpeed Mount	No[1]	31 – 40	Comp shingle or tile	Metal	Yes
PMC Industries pmcind.com	ACE Clamp Solar Kit	No	31-50	Standing seam metal	N/A	N/A
Polar Racking polarracking.com	PRL	No	DNR	Comp shingle, metal, or tile	Metal	Yes
Quick Mount PV quickmountpv.com	Quick Rack	No	Manufacturer lists approved modules	Comp shingle	Metal	Yes
Roof Tech roof-tech.us	RT-[E] Mount & E Mount AIR	No	31 – 50	Comp shingle	Butyl rubber	Yes
S-5! s-5.com	S-5-PV Kit with S-5-PV Grab Kit	No	30 – 51[3]	Standing seam metal[4]	N/A	N/A
SnapNrack snapnrack.com	RL	No	Manufacturer lists approved modules	Comp shingle or tile	Metal	Yes
Spice Solar spicesolar.com	Built-In Racking	Yes	Spice-certified modules	Comp shingle, metal, or tile	Not specified	No
Spider-Rax spiderrax.com	Red Widow	No	28.5 – 50	Comp shingle	Metal	Yes
	Black Widow			Tile		No
Zep Solar (via Solar City) zepsolar.com, solarcity.com	ZS Comp	Yes	Zep-compatible modules	Comp shingle	Metal	Yes
	ZS Tile			Tile		Yes
Zilla Corp. zillarac.com	Phantom XL Low-Pro	No	31 – 52	Comp shingle	Metal	Yes

DNR - Manufacturer did not provide this info. 1. Pegasus and its module partners pre-install "LightSpeed" corners on standard modules;
2. Rating applies to both with and without array skirt; 3. 30–48 mm (with L-flange below the stud hex nut) & 34 – 51 mm (if above);

Pegasus Solar's LightSpeed Mount attaches directly to module frames. Adjacent modules are then secured together via pre-installed LightSpeed corners.



Courtesy Pegasus Solar

Railless Reasons

Railless mounts use the modules' frames as the overall array structure. Instead of attaching individual modules to rails, these systems use specialized hardware to secure module frames together. This approach can offer environmental, logistical, financial, and aesthetic benefits.

Rails take significant raw materials and energy to produce and ship. Getting rid of rails reduces a system's embodied energy and energy payback time (EPBT)—the time it takes the system to produce enough energy to offset the energy it took to manufacture, ship, and install it.

Without rails, an entire mounting system can be contained in a few small boxes, which are much easier to transport. Additionally, installation labor is reduced because there are no rails to splice or cut to fit the array and roof.

Roof Attachment	Level Height Adjustment (In.)	Wind Speed Rating	Snow Load Rating	Fire Class Rating/ Module Type	UL Listing	Grounding Notes	Wire Management, Skirting & Additional Notes
Rafters	1.5 – 2	45 psf (max. down force & uplift)	45 psf	Class A with Type 1	2703	Inter-row/column bonding provided, one ground lug per 300 modules	Integrated wire management & array skirt included
Rafters	1	Up to 150 mph	Up to 70 psf	Class A with Type 1 & 2	2703	Inter-row/column bonding provided, one ground lug per array	Array skirt optional
Rafters	1.5	Up to 150 mph	Up to 90 psf	Class A with Type 1 & 2	2703	Inter-row/column bonding provided, one ground lug per 100 modules	Array skirt optional
No penetrations	None	Not avail.	Not avail.	Not rated	2703 & 467	–	Wire management clips integrated on the clamp
Rafters	DNR	DNR	DNR	DNR	DNR	–	Wire management clips optional
Rafters	1	Up to 150 mph	Up to 60 psf	Class A with Type 1 & 2[2]	2703	Inter-row/column bonding provided, one ground lug per 300 modules	Array skirt optional
Rafters or decking	<1	Up to 180 mph	Up to 90 psf	Class A with Type 1	2703	Inter-row bonding required for portrait, inter-column bonding required for landscape	Wire management clips included & array skirt optional (for E Mount AIR only)
No penetrations	Depends on roof	Not avail.	Not avail.	DNR	2703	Intercolumn bonding required	Wire management hooks integrated
Rafters	1.5	Up to 150 mph	Up to 60 psf	Class A with Type 1 & 2[2]	2703	Inter-row/column bonding provided, one ground lug per array	Integrated wire management & array skirt optional
Rafters	1.5	Up to 170 mph	Up to 60 psf	Class A with Type 2	2703	Inter-row/column bonding provided, one ground lug per 144 modules	Wire management clips optional
Decking	1.5	Up to 115 mph	20 psf	Class A with Type 1	DNR	Interrow bonding required, one ground lug per 10 modules	Butyl pre-installed on base plate
Rafters	1.25	Up to 150 mph	Up to 60 psf	Class A with Type 1 & 2 Not rated	2703	Inter-row/column bonding provided, one Ground Zep per ~60 modules	Wire management clips & array skirt optional
Rafters or decking	Optional[5]	Up to 120 mph	Up to 40 psf	Not rated	467	Interrow bonding required for portrait; intercolumn bonding required for landscape	Wire management clips optional

4. Exposed fasten metal roofs (corrugated or trapezoidal);
5. Phantom XL has an adjustable standoff option, while the Phantom XL Lo-Pro provides two fixed-height options.

Spice Solar has a "built-in" rack system that integrates the rack into the module frames ("Spice Solar Certified"). The Spice Splice slides into the module frame's grooves, locking the frames in place and electrically bonding the frames together.

Courtesy Spice Solar

Module grounding is integrated into railless mounts. The same specialized hardware that secures modules together electrically bonds adjacent modules, eliminating purchasing and installing separate module-to-module bonding hardware. However, a bonding method between rows of modules (or columns of modules, depending on layout) may still be necessary. All arrays still require an equipment grounding conductor (EGC) attached to at least one array bonding point (such as a lay-in lug). (See "PV Racks with Integrated Equipment Grounding" in *HP166*.)

While there is a learning curve with installing railless mounting systems, once installers are used to the nuances of the product, time on the roof can be decreased. No rails to transport, install, splice, and ground means reduced labor costs.

With mounting feet otherwise exposed, a bottom-edge skirt, like on this Quick Mount PV Quick Rack, improves aesthetics. (Note: The Class A fire rating for Type 1 and Type 2 modules applies, with or without the array skirt.)

This SnapNrack RL flashed mount foot allows up to 1.5 inches of height adjustment.

Railless racks are considered by some to be more aesthetically pleasing, as you no longer have a full substructure of aluminum rails beneath the array. A few manufacturers have gone the extra mile of adding a bottom edge array "skirt" for a more cohesive appearance.

Railless Considerations

Railless mounts present some design, equipment, and installation challenges. Some of these rack systems require grooved module frames, which limits module choices. Other railless systems can use standard modules if the frame depth lies within a specified range.

Without a continuous rail to secure module interconnects and home-run wiring, wire management can also be more difficult. Some module frames have lips on the bottom of the frame to attach cable clips, but some only on the side frames (module in portrait) and not on the top and bottom, limiting the areas in which you can secure wiring.

Modules in a railless system have to be leveled individually, potentially increasing labor time. The amount of leveling adjustment available varies among manufacturers (see "Railless PV Mount Systems" table). For roof planes with less uniformity, the amount of leveling adjustment can become a key factor in selecting an appropriate racking product.

Different Flashing Techniques

Early generation PV system racks were commonly secured directly to the roof via L-feet, which were lag bolted to the roof. Waterproofing the penetrations was accomplished using roof sealant, applied in the predrilled bolt hole, and beneath and around the L-feet, with a caulking gun. Now, roof flashings help ensure that roof attachments and the penetrations below them remain watertight for the long term. There are basically two different materials used to flash penetrations—metal and butyl rubber. We reached out to two representative racking manufacturers to discuss each method.

Quick Mount PV

Founded in 2006, Quick Mount PV has become instrumental to the U.S. PV industry by creating awareness for the need to install flashings around roof penetrations. The company also brought to the attention of PV installers the importance of considering a roof's existing warranty, along with local roofing codes and standards. To address this need for flashings specifically designed for PV system racks, Quick Mount PV developed its QBlock metal flashing products.

HP: How do installers find out if the existing roof has a warranty and how to maintain that warranty?

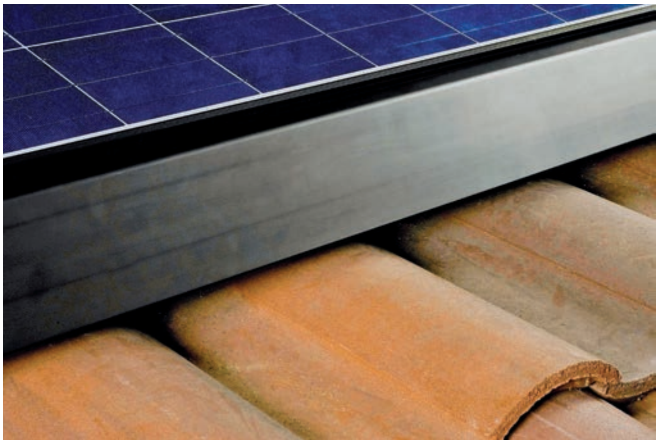
QM: They should start by asking the homeowner if they have knowledge of an existing roof warranty and/or if they know who installed their roof. Even if the homeowner can't locate the warranty or roofer information, the best advice is to follow the building code requirements and follow the flashing guidelines from the roofing product manufacturer. When flashing penetrations on tile roofs, use the Tile Roofing Institute guidelines (tileroofing.org) for penetration flashing required by all major roofing tile manufacturers.

HP: How do installers determine what roofing codes and standards are applicable in their area?

QM: The International Residential Code (IRC) requires that all penetrations be flashed per the approved manufacturer's installation instructions. Even if permitting officials or inspectors do not mandate flashing, it is advisable to follow these code requirements as they are required to preserve the roof's warranty. Any repairs due to leaks that result from failure to use manufacturer-approved flashing methods would be the legal responsibility of the installing contractor.

HP: Are there key certifications to look for when considering a particular flashing method or product?

QM: Recently, we have seen the accreditation of UL 2703 for PV racking systems, but this standard does not address roof attachments or flashings. There is an International Code Council (ICC) certification for flashed roof mounts, but its focus is more on structural ratings



Courtesy ZEP Solar

Railless racks are designed for certain roofing materials. Here, a ZEP ZS Tile system is mounted on a ceramic tile roof.

Courtesy S-5!

Left: S-5! specializes in attachments for metal roof systems. The S-5! miniclamp (shown here with an S-5!-PV-Kit) attaches to a standing seam metal roof without penetrating the roof. (Note: The mounting disc has integrated wire-management hooks.)

Below: PMC Industries' ACE Clamp Solar Kit clamps to a standing seam metal roof, while securing and electrically bonding module frames.

Courtesy PMC Industries

Railless Rack System Traits

Pro	Con
Less embodied energy	Specialty modules required for some
Less materials expense	Wire management challenges
Less shipping cost	Roof types limited
Integrated grounding	Individual module leveling
Faster installation (once learned)	Limited snow load ratings
Aesthetics	–

than long-term waterproofing. Waterproofing tests only validate initial waterproofing when the seal is new, but don't address the long-term performance of waterproofing methods. For this reason, the sensible approach is to follow the roofing manufacturers' approved flashing guidelines; this is also required by the IRC.

HP: Describe how metal flashings keep each roof attachment watertight.

QM: Metal flashings divert water away from the penetration so any cracks that form in the sealant over time will not result in leaks. Metal flashings have proven lifetimes of 30 or more years, making them a standard flashing method approved by the majority of shingle and tile roof manufacturers.

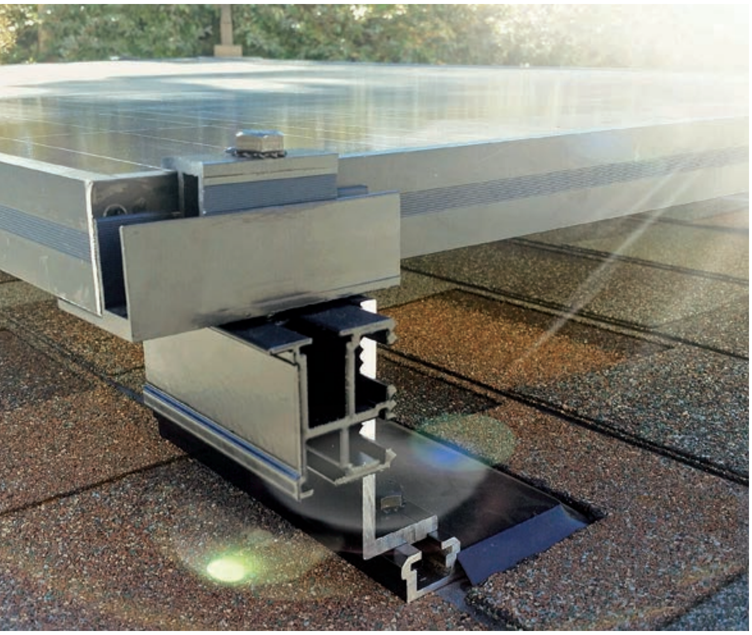
HP: Are there important features in metal flashings for installers to look for?

QM: If the seal is located at or near the roofline, there is increased potential for wear and tear, especially from freeze-thaw cycles that occur in freezing climates. In our QBlock flashing products, the seal is elevated 0.7 inches above the waterline and is completely enclosed inside the cavity of the QBlock, protecting the seal from the elements.

— Jeff Spies

Courtesy Quick Mount PV

Quick Mount PV's QBlock mounting system relies on large flashing and a penetration seal that is elevated above the roof surface.



Courtesy Spider-Rax

The Spider-Rax Red Widow system for asphalt composition shingles utilizes metal flashing with an integrated butyl sealant.

Some railless racks are designed only for specific roofing materials, such as asphalt shingles or standing seam metal. Additionally, there are tables in product literature that provide engineering information for various wind exposure categories, roof zones, array layouts, and roof attachment methods—all of these factors dictate wind and snow load limitations. As is important with any rack system, designers need to pay close attention to wind- and snow-load ratings, along with fire class ratings, and choose a product that will meet local requirements.

Flashing Techniques, continued

Roof Tech

Incorporated in 2012, Roof Tech is a subsidiary of Yanegiken, founded in 1968 in Japan. Roof Tech has recently entered the U.S. PV market with its railless mounting products. The company has become the first PV racking manufacturer in the United States to use butyl rubber pads instead of metal flashings to waterproof roof penetrations.

HP: How do installers find out if the existing roof has a warranty and how to maintain that warranty?

RT: The roof warranty should be provided by the home or building owner. If the owner cannot provide the warranty details and the roof is more than 15 years old, installers might recommend roof replacement prior to the PV installation. Another consideration is if the solar mount manufacturer has written verification from roofing manufacturers that approve the installation of its product without voiding the roof warranty.

HP: How do installers determine what roofing codes and standards are applicable in their area?

RT: The local inspector enforces applicable codes and standards, and that is where the installer must get this information. Most jurisdictions have a website that can provide guidance, but the best thing to do is call and ask the inspector to provide you with their expectations.

HP: Are there key certifications to look for when considering a particular flashing method or product?

RT: First and foremost, the product should meet International Building Code (IBC) and International Residential Code (IRC). An ICC tested product will provide that verification. Look also for other third-party testing results, such as water submersion or windblown rain tests. The long-term track record is yet another good way to measure a product and company.

Roof Tech engineering and ICC testing documents are provided to assist with permitting requirements. Additionally, Roof Tech Inc. has a letter from Owens Corning that allows installation on its shingles without voiding the warranty.

HP: Describe how butyl rubber flashings keep each roof attachment watertight.

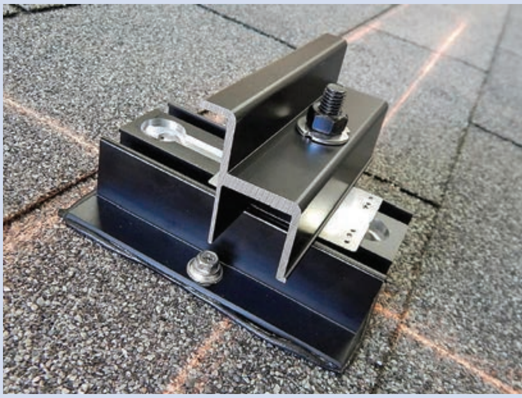
RT: When the fastener is installed, it pulls the butyl down into the decking and wood beam to seal it from any moisture. The butyl is also an ideal sealant for asphalt shingles—the shingles contain butyl and when you apply butyl rubber to butyl rubber, it creates a bond that makes it completely sealed.

HP: Butyl rubber flashing is new to the U.S. PV market and AHJs may not be familiar with this waterproofing approach. What do installers need to know to address potential code-compliance questions from building departments or inspectors?

RT: Butyl is not new to roofing; in fact, butyl was created in the United States in 1930 by a petrochemical engineer and has been used as a sealant since. It is used in the manufacturing of all asphalt shingles as well.

— Tim Vaughan

Roof Tech's pre-attached butyl seal can cut installation time and material cost. While new to the United States, Roof Tech's track record includes about 500,000 installations worldwide over an 18-year period.

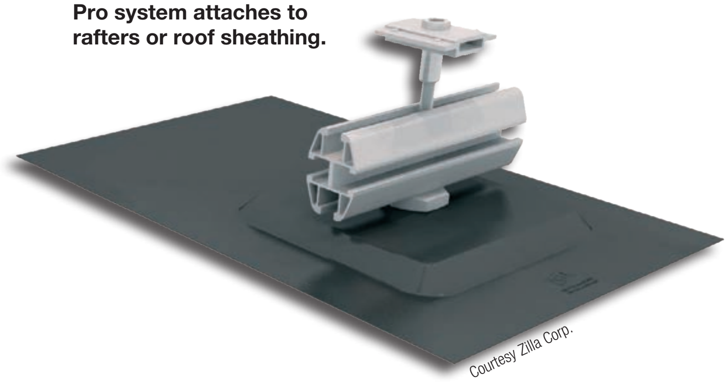


Courtesy Roof Tech

Roof attachment and flashing techniques for railless mounting products also vary. Some products attach to feet which are secured directly to roof rafters, while others attach to the roof decking. Flashing techniques include metal flashings or butyl rubber pads integrated into the roof attachments. Make sure the product you choose provides a reliable attachment to the roof and a dependable method to eliminate leaks. These attachment points need to remain watertight and satisfy any flashing requirements your authority having jurisdiction (AHJ) might have. See "Different Flashing Techniques" sidebar.

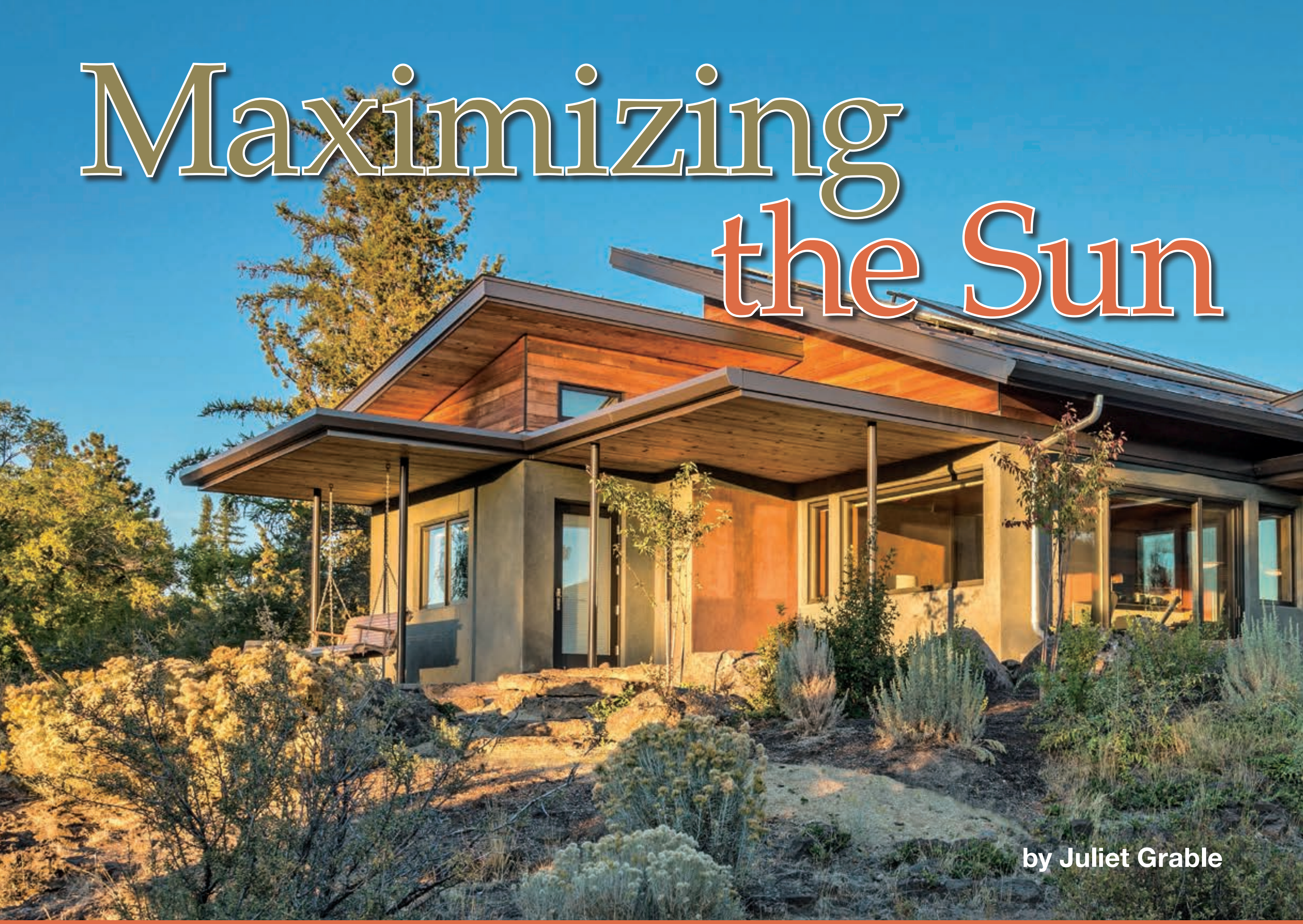
Each year, it seems the PV industry offers up another product to speed up system installation and lower the cost per installed watt. Add that to compelling environmental, logistical, and aesthetic benefits, and with more than a dozen manufacturers now offering railless rack systems, this appears to be the latest step in that evolution.

EcoFasten's Rock-It system includes an integrated array skirt and wire management tray.



Zilla's Phantom XL Low-Pro system attaches to rafters or roof sheathing.

Maximizing the Sun



by Juliet Grable

A green building certification program, the Living Building Challenge (LBC) ups the ante on resilience and sustainability. With seven performance categories (known as "Petals")—Place, Water, Energy, Health and Happiness, Materials, Equity, and Beauty—the resulting homes often push the eco-design envelope.

Barbara Scott and Tom Elliott's home in Bend, Oregon, is no exception to pushing the envelope. Their home, Desert Rain, and its accessory buildings were designed to Living Building Challenge standards from the ground up (see "The Living Building Challenge" in *HP159*). For their designer, Al Tozer, who'd been practicing sustainable design for nearly 20 years, it was the opportunity of a lifetime. "Instead of picking one or few design tools," says Tozer, "it was like dumping the toolbox upside-down on the floor and saying, 'We're going to use all of these.'"

The main house includes staggered-stud 2-by-4 double walls that were insulated with spray foam, for 8- to 12-inch-thick walls with R-36 to R-47 insulation. A concrete floor provides thermal mass to store passive solar gain. In the summer, overhangs prevent direct sunlight from heating the space and well-placed windows provide cross-ventilation for

Courtesy Chandler Photography (3)

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Above: The Scott-Elliott home in Bend, Oregon, utilizes passive solar design, high levels of insulation, and solar electricity and solar thermal (air and water) technologies.

passive cooling. The arid climate—Bend's average annual precipitation is 9 inches—drove parts of the design, including the large roof area for rainwater collection, constructed wetland, graywater cistern, and 35,000-gallon potable water cistern, which is housed under the two-car garage.

The home uses both passive and active renewable energy inputs. The intent of the Energy Petal is to signal a new age of design, wherein the building relies solely on renewable forms of energy and operates year-round in a pollution-free manner. To eliminate wasting energy, resources, and money, it aims to prioritize energy reduction and optimization—before technological solutions are applied. The single imperative under the Energy Petal was net-zero energy. [Ed. note: The latest LBC Standard, 3.0, requires the systems to meet 105% of the homeowner's energy needs and to provide energy storage for resiliency.]

Conservation First

As important as all of Desert Rain's energy-efficiency features are, one variable will determine if the home will live up to its potential—occupant behavior. "There are all kinds of examples of efficient buildings that do not perform because of human behavior," says Elliott. He and Scott are good about turning off lights, conserving water, and so on. On the other hand, they admit to leaving windows open in the dead of winter because they like a cold bedroom, or keeping the shades open on a starry night.

A Nest "learning" thermostat helps optimize the radiant floor system. Beyond that, they did not invest in systems that would control their home's functions for them. "We intentionally veered away from too much automation," says Elliott. Daily engagement with their home's operation fosters awareness—reminding Scott and Elliott of their important roles in saving energy and water.

Below: Unique architecture ensures the requirement for "beauty" is met, without compromising performance.

Left: High-performance triple-pane windows keep the home comfortable during the frigid winters and hot summers.

Below: Double-stud construction allows an adequate insulation cavity to achieve R-50 walls.

Courtesy Chandler Photography

Courtesy Elliott/Scott

Net-Zero Energy

LBC's net-zero energy imperative aligned with Scott and Elliott's commitment to sustainability in all aspects of their lives, including transportation. With that in mind, they wanted Desert Rain to function as a "power house," producing enough energy not only to supply all three dwellings and the site's infrastructure, but also to charge two electric vehicles.

The design of Desert Rain optimizes passive solar orientation, especially for the main residence. Both it and the accessory dwelling unit (ADU) are oriented east/west; both buildings are longer than they are wide, and include most glazing on the south façades. Overhangs block direct sun in summer but allow solar gain in the winter months, when the sun follows a lower path across the sky.

The home uses materials that help regulate indoor temperatures by storing and then slowly releasing heat. A double layer of drywall throughout the main residence combines with the finish plaster to create thermal mass, as does the concrete slab floor.

Insulation also plays a critical role in the home's efficiency. In the main residence, UltraTouch cotton batts, made from 80% postconsumer-recycled cotton, fill interior walls and ceilings. Because of its high R-value per inch, closed-cell spray foam was used in the exterior walls. Sealing was accomplished by caulking

Courtesy Chandler Photography (2)

The home design integrates living space with the outdoors.

The insulated concrete slab floor and double-layer drywall provide ample mass for storing passively gained solar energy.

Energy Star appliances and LED lighting help keep the all-electric home net-zero.

Seven solar thermal collectors provide space heating and domestic hot water preheating.

all joints between the sheets of exterior sheathing and between framing members. Nighttime thermal imaging, performed from both the inside and outside of the house, helped identify leaks in the envelope. Blower-door tests also helped the team evaluate the building's airtightness. A test performed after insulation was installed, but before drywall, measured leakage in the main residence as 0.70 air changes per hour (ACH)—very close the Passive House standard of 0.60 ACH.

Generous windows provide a visual connection between the indoors and the outdoors and bring in ample light so daytime artificial lighting is seldom needed. The Loewen metal-clad wood windows are triple-glazed and filled with argon gas; and thermal spacer bars provide half-inch air spaces between panes, which result in a higher insulation value.

Insulation Comparison

Location	Oregon Minimum Insulation Requirement	Desert Rain
Walls	R-21	R-50
Roof	R-38	R-72
Floors	R-30	R-50

Meeting Energy Needs

Bruce Sullivan and Matt Douglas, green building consultants for Earth Advantage, performed the energy modeling for Desert Rain House, which helped guide decisions leading to lower energy demand. "The biggest thing they did was reduce the size of the main house," says Douglas.

The tight building further reduced energy demand, and the next step was how to most efficiently heat living spaces and provide domestic hot water. Scott and Elliott chose an in-floor hydronic radiant heat system, which also combined water and space heating. The system is primarily a solar thermal drainback system. The sun heats a propylene glycol solution in thermal collectors on the roof. The glycol protects the system from freezing during Bend's cold winters, and transfers heat to a tank of water with a heat exchanger. The glycol drains back into a smaller tank when no more heating is needed, protecting the storage tank from overheating.

Courtesy Chandler Photography (4)

Left: Windows surround the dining area bump-out, providing natural light and fabulous ambience.

Right: The solar thermal system manifold maze and the heat recovery ventilator.

Left: The in-slab hydronic floor loop gets its hot water from the solar thermal panels.

Above: An air-to-water heat pump is backup for the solar thermal collectors.

Courtesy Elliott/Scott (2)

Solar Radiant Floor/ SDHW Tech Specs

Overview

System type: Drainback solar water heating

Installer: Bobcat & Sun

Location: Bend, Oregon

Solar resource: 1,800 hours (6 hrs./day, 300 days/yr.)

Climate: Zone 5b (IECC) or Zone 5 (ASHRAE)

Hot water produced annually: 100%

Solar Equipment

Collectors: 7 Heliodyne GOBI 408 (4-by-8 ft.)

Collector installation: Roof-mounted, 5/12 pitch

Heat-transfer fluid: Water

Circulation pump: Grundfos, bronze, model #26-96

Pump controller: iSolar model MX by Caleffi

Storage

Tanks: Trendsetter (atmospheric), TS-275, 275 gal.

Heat exchanger: Soft copper, finned Type K; two coils for space heat, two coils for DW preheat

Backup DWH: Daikin, Daikin SS, 52 gal., with 3 kW booster

System Performance Metering

Thermometer: Digital display on solar controller

Flow meter: 5-15 gpm, Pentair, LDF 359B

Pressure: Gauge, 10-20 psi

Radiant Floor System

Floor tubing: In-floor, PEX with O2 barrier

Boiler air-to-water heat pump: Daikin Altherma

Amount of tubing: 4,800 ft.

Number of zones: Six

Circulation pump: 15-55, Grundfos, Alpha ECM

Zone valves: 24 VAC actuator, Caleffi

Tempering valve: Caleffi

A Daikin Altherma Monobloc air-to-water electric heat pump works in tandem with the solar thermal system. This unit extracts heat from the outside air by passing it over a heat exchanger. A second heat exchanger "rejects" the heat into water, and the cooled refrigerant returns to repeat the cycle again.

Reducing energy for space and water heating was paramount, but several strategies helped reduce overall demand. All appliances are Energy Star-rated or better. Light fixtures utilize LED lamps. Kill switches on the entertainment centers turn all components off at once, so they are not phantom loads while not in use.

Working with Hot Air

Four SolarSheat hot air panels heat air that circulates through an Evapotron, which evaporates the water in a blackwater composting system housed in the ground floor of Desert Lookout—one of the five buildings that make up the Desert Rain "compound."

A fan draws air into the bottom of the panels, and blows heated air through ducts on the other side. For aesthetics, Scott and Elliott mounted the three panels on the south-facing exterior wall of Desert Lookout. Unfortunately, the eave overhang partially shades them in summer, hindering their performance. The representative from Advanced Composting Systems was concerned the three panels would not provide enough heat to evaporate the liquids at the required rate.

"There was a lot of head-scratching over the hot air panels," admits Elliott. The team decided to lower the panels and add a fourth one on the west façade. In addition, Timberline Construction (the general contractor for the project) trimmed the eave, which had already been finished with siding. Meanwhile, the HVAC installer had used a slightly smaller pipe for the hot air output, which means a smaller but hotter volume of air will reach the Evapotron. The fourth panel may not have been necessary, but any excess hot air can heat the composting room.

Above: Four solar hot air collectors provide evaporation for excess liquid in the blackwater composting system (inset, next to the composting chamber).

Lighting, By Design

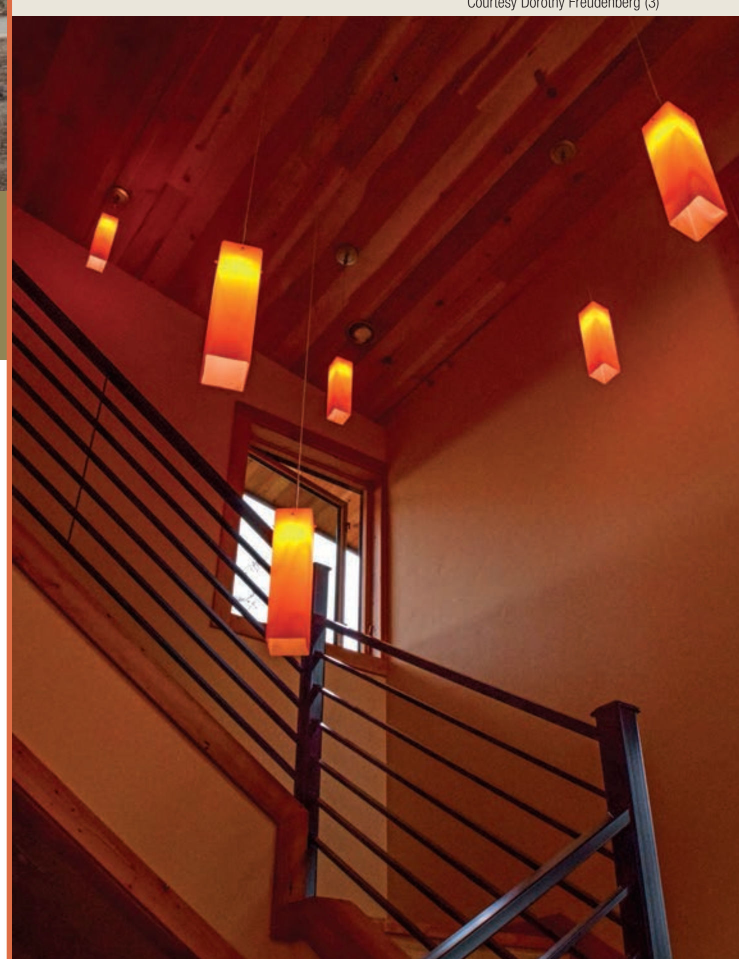
Light-emitting diodes, or LEDs, use half the energy of compact fluorescent bulbs, and a small fraction of the energy of incandescent lighting. Further, the bulbs have a much longer lifespan and contain no mercury. Scott and Elliott knew they wanted to use mostly LEDs, but at the time the availability and quality of LED fixtures and lamps was limited.

They observed that LED light output was low, and the lamps tended to create hotspots rather than diffuse, even light, and the color tended toward the cool end of the visible spectrum.

"We purchased many types of LEDs, both locally and online," says Scott. "We tried one bulb after another." They were concerned with not only choosing energy-efficient fixtures that provided warm, comfortable lighting, but finding efficient, low-voltage lighting controls. Given the many requirements, they decided to hire the Portland-based firm Luma Lighting, who was also working on the lighting design for another Living Building Challenge project.

Luma was able to source unique fixtures, such as the "flower" lights in the bathroom. Their design balances daylight with artificial light, and incorporates reflective and uplighting. "The lighting in our home is a delight," says Elliott. "It's a huge dimension of its beauty, comfort, and health."

Courtesy Dorothy Freudenberg (3)



The composter serves all three dwellings: Desert Rain (main residence); Desert Sol (ADU); and the upstairs Desert Lookout unit. Vacuum toilets, similar to those found in airplanes and cruise ships, funnel all blackwater to the composting system. Because Oregon graywater code does not allow waste from dishwashers to be treated as graywater, that wastewater is also directed to the composting system. This adds significantly to the proportion of liquid in the blackwater. The Evapotron reduces this volume so the Phoenix composting unit will function more efficiently (i.e., not go into "anaerobic mode.")

The Phoenix unit, manufactured and installed by Advanced Composting Systems, consists of a large chamber that is "charged" with wood shavings, peat moss, and water to create an environment conducive to biological decomposition. A shaft with tines within the unit rotates the mix to introduce oxygen and speed the process. The finished compost will be harvested about once a year.

Left: Forty-four Sunmodule 230 W PV modules from SolarWorld flank the solar thermal collectors on the main house's roof.

Below: Twenty-one more modules on the garage roof bring the total system to 14.95 kilowatts.

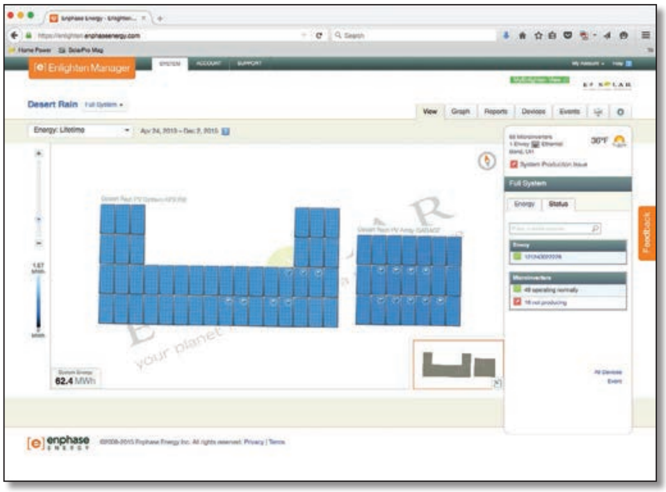
Courtesy Chandler Photography (2)

Harvesting the Sun's Power

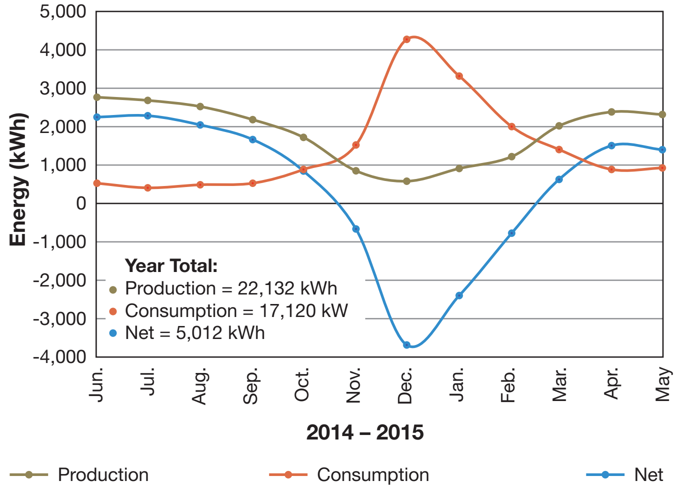
E2 Solar, based in Bend, performed the site analysis and the installation of Desert Rain's PV system, working with Matt Douglas's energy model to size the array. E2 Solar originally sized Desert Rain's PV array at 8.5 kW. But Scott and Elliott wanted to have enough energy to charge two electric vehicles, estimating 15,000 miles per year for each car—nearly doubling the system's capacity.

The 14.95 kW array consists of sixty-five 230 Sunmodule monocrystalline modules from the Oregon manufacturer SolarWorld. Forty-four modules cover the main residence's south-facing roof; the remaining modules are mounted on the detached garage. Enphase microinverters allow each module to function independently and to be individually monitored.

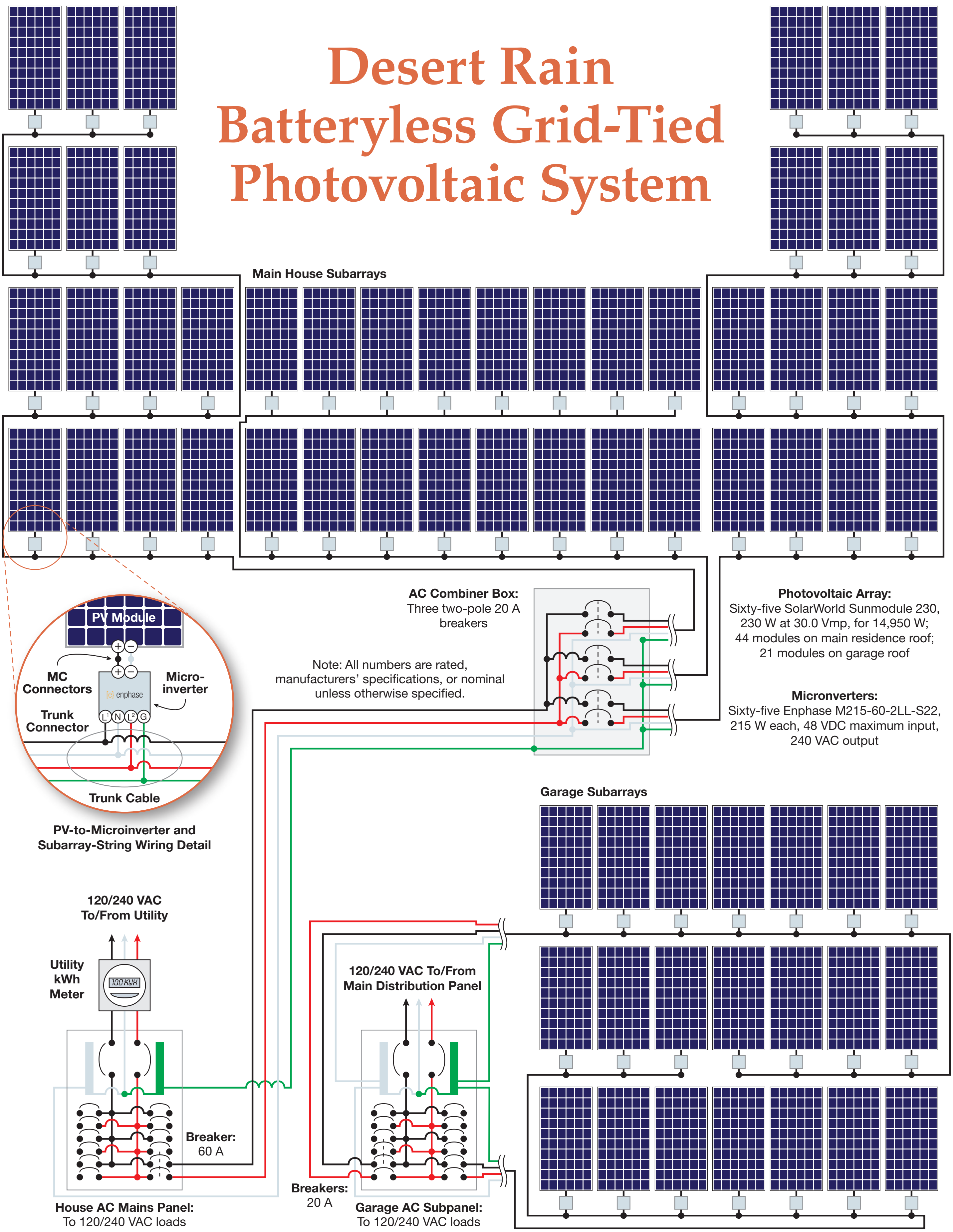
The Enphase Enlighten Web interface allows real-time and cumulative module-by-module performance monitoring.



Desert Rain Annual PV Production



Desert Rain Batteryless Grid-Tied Photovoltaic System



Batteryless Grid-Tied PV System Tech Specs

Overview

Project name: Desert Rain residence

System type: Batteryless, grid-tied solar-electric

Installer: E2 Solar

Date commissioned: March 25, 2013

Location: Bend, Oregon

Latitude: 44.05°

Solar resource: 5.14 average daily peak sun-hours

ASHRAE lowest expected ambient temperature: -2.2°F

Average high summer temperature: 91.4°F (average high, June through September)

Average monthly production: 1,844 kWh

Utility electricity offset annually: 129%

Components

Modules: 65 SolarWorld Sunmodule 230 monocrystalline (SW230 Mono 2.0), 230 W STC, 30.0 Vmp, 7.68 A Imp, 37.4 Voc, 8.16 A Isc. 44 modules on main residence roof; 21 modules on garage roof

Array: 14,950 W

Array installation: SnapNrack rails and mounting structure, installed on southwest-facing roof, 32° tilt (main residence), 24° tilt (auxiliary installation on garage)

Inverters: Enphase M215-60-2LL-S22 microinverters, 215 W rated output, 48 VDC maximum input, 27 – 39 VDC MPPT operating range, 240 VAC output

System performance metering: Enphase IEM6-01 Envoy Monitor

System Costs

Initial Cost: $69,678

Less Incentives, Rebates, Tax Credits:

Energy Trust of Oregon Residential Incentive = $5,000

Residential Energy Tax Credit ($1,500/year, capped at $6,000) = $6,000

Federal Investment Tax Credit (30% of net cost) = $19,403.40

Total of all investments, rebates, and tax credits = $30,403.40

Final installed cost: $39,274.60

Courtesy Chandler Photography

Despite the cold Bend winters, solar energy keeps Tom Elliott and Barbara Scott comfortable at their high-desert energy-efficient home.

Courtesy Ecotone Publishing

This article was adapted from *Desert Rain House: Resilient Building, Sustainable Living in the High Desert* by Juliet Grable (2015, Ecotone Publishing). **bit.ly/DesertRainBook**

Central Oregon is an excellent place to harness solar energy, with sunny summer days and cold, clear winter days. At Desert Rain, there were no issues with shading, but the slightly west orientation lowered its solar potential somewhat. E2 estimated that Desert Rain's array would generate 19,842 kilowatt-hours per year, just offsetting annual energy demand. However, the array was sized before Desert Lookout was accounted for, bringing in additional loads, such as pumps for the graywater wetland and composting system. Because there were so many variables, Scott and Elliott had Desert Lookout pre-wired to accommodate additional modules, if needed in the future.

Through the Enphase energy management system, Elliott and Scott monitor their PV system production, and their consumption. In December and January, consumption peaks and production dips; conversely, production is highest in July and August, when demand is lowest. Looking at June 2014 through May 2015, Desert Rain's PV array has performed better than expected, producing about 30% more electricity than was consumed during those 12 months. Given that during all of 2014 and January 2015 substantial energy was used for construction purposes, their system is expected to provide even more energy surplus in subsequent years. Scott and Elliott's home is demonstrating that a net-positive future—a future where buildings produce more than they consume—is now possible.

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Wiring Systems & the *NEC*

by Ryan Mayfield

The methods for wiring PV systems are relatively well-defined in the *National Electrical Code (NEC)*—acceptable methods are covered in Part IV in Article 690. This "Code Corner" covers the first section of Part IV, 690.31, "Wiring Systems."

This section first states that all wiring systems recognized by the *NEC*, both PV-specific and wiring in general, are acceptable for use with PV installations. This is both helpful and a minor burden for installers. Installers are not limited to the methods set in Article 690—but the burden is in digging into other *Code* sections to find the proper requirements. Fortunately, only a few wiring methods are typically used in PV systems, which limits the amount of *Code*-searching.

The second paragraph in 690.31(A) references PV conductors operating above 30 V and in readily accessible locations. The *Code* requires that PV source and output "circuit conductors shall be guarded or installed in a raceway." The most common scenario where this applies is in ground-mounted arrays when using standard racks. Solutions include installing a fence or other barrier to eliminate the ready access or elevating the conductors at least 8 feet above grade. Confer with your authority having jurisdiction (AHJ) on their interpretation of that definition. Rack manufacturers have been slow to provide a solution; however, at least one product is available (see solarscrim.com). Installing conductors in a raceway is generally not possible, since module junction boxes come with pre-attached module leads and no conduit knockouts.

The next subsections describe the grouping of PV system conductors. The conductors need proper identification at terminations and to be grouped together when they are routed through boxes and raceways. A significant change in this section refers to PV source and output circuits that are routed with non-PV system conductors. (This was covered in 690.4(B) of the 2011 *NEC* and was moved to 690.31(B) for 2014.) The 2011 *NEC* required a partition for separating non-PV from PV DC conductors sharing the same raceway, cable tray, or junction box, etc. However, a DC circuit could share the same raceway as an AC inverter output circuit since they were both circuits related to the PV system. In 2014, inverter output circuits were included in the list of circuits that require separation from DC source circuits. Both circuits can be run in a raceway, such as a gutter, as long as a partition is included to separate the circuits. Both AC and DC can be run in the same raceway, provided the two circuits are physically separated.

A common method for establishing this separation is a plastic partition that is mounted to the back of a box or gutter. These are available in various dimensions to match the box you are installing. Once they are attached to the back of the box, they create multiple wiring sections that are separated from each other. These partitions can be sourced from companies such as B-Line or Panduit.

Section 690.31(C) discusses conductor and cable types considered acceptable for PV applications. The first paragraph states that single-conductor USE-2 and PV Wire are appropriate for exposed exterior locations. This can be important when an inspector is unfamiliar with PV installations, since allowing exposed single-conductor cables is a rare occurrence in the *Code*. The most significant PV wiring change in 2014 is in 690.31(C)(2), which allows using cable trays to support PV source and output circuit wires of all sizes. (In Article 392, the cable tray section only mentions allowance of conductors 1/0 AWG and larger in cable tray, precluding the use of cable tray to support small PV source-circuit conductors.)

Unfortunately, this little paragraph doesn't provide adequate guidance for installing PV conductors in cable trays. Additional considerations required for cable tray installation are the conductors' ampacity and the allowable cable fill area. Article 392.22 sets the rules for the number of conductors in a cable tray.

Cable ties secure Solarscrim fabric panels to the array, keeping conductors from being readily accessible.

Courtesy Spiffy Solar

Ben Root

Here, both the inverter DC input wiring and AC output wiring are routed in a wiring gutter, which is compliant with the 2011 *NEC*. Under the 2014 *NEC* rules, a partition is now required to separate the DC and AC conductors.

Likewise, 392.80 discusses conductor ampacity when in cable trays. In both scenarios, the *Code* only considers conductors 1/0 and larger in the trays—there are still no direct rules addressing the use of smaller PV source-circuit conductors.

I have been involved with a few PV installations, both roof- and ground-mounted, that, under the 2014 allowance, have used cable trays. We applied the large-conductor principles to the smaller conductors, including using the total conductor area in calculating the cable tray width and ampacity correction factors. We brought this to the attention of the plans' examiners and inspectors to make sure everyone was in agreement.

Another addition to 690.31(D) affects wiring methods—allowing the output circuit of utility-interactive inverters not in readily accessible locations to use multiconductor cables outdoors. This is common in microinverter installations, although it could conceivably be used for string inverters that meet the requirements.

Section 690.31(G), which permits running DC conductors through the interior space of a building prior to a readily accessible disconnect, is an oft-cited *Code* section. Occasionally, an inspector will interpret this section to include AC circuits. But as the title indicates, only DC circuits inside buildings need to meet these requirements. In general, DC conductors are required to be contained in metallic raceways or use Type MC (metal clad) cabling listed in the section. The section concludes with some specifics based on the installation method used, including labeling and protection of the raceways. The final requirement lists requirements for raceway labels, including color, language, and character height.

The Wiring Methods part of Article 690 continues to cover the balance of the wiring methods, including connectors, ungrounded PV systems, junction boxes, and labeling. These additional requirements will be covered in future editions of "Code Corner."

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Solar Pioneer Party

by Kathleen Jarschke-Schultze

Harry Martin

A very long time ago, in a land not very far away, a very few people began to promote solar and other renewable energy. The industry itself was small and everyone knew or knew of each other. What would happen if all of these solar pioneers were to gather together, now that they've grown the industry into a mainstream technology?

Pioneer Party

Jeff Spies (now with Quick Mount PV) had a dream. He shared his dream with others. A Facebook event, The Solar Pioneer Party, emerged. Word spread and the group grew, some really fun old photos were shared, and people across the nation planned to travel to the California redwoods to celebrate.

Although the three-day gathering began in Redway, California, on the second day it moved to Beginnings School in Briceland, near the original 1970s location of then co-owners David Katz and Roger Herricks' company, Alternative Energy Engineering. David and his wife Anne were instrumental in making Jeff's dream come true.

As Jeff tells it, "In October 2015, a group of dedicated solar professionals gathered in southern Humboldt County for the first-ever Solar Pioneer Party. These incredible people assembled to celebrate the birth of the solar industry and recognize the contributions of those intrepid backwoods solar engineers and mad scientists that made solar home power possible."

Solar Reunion

My husband Bob-O and I prepared for the pilgrimage. We dug out all our renewable energy themed T-shirts from the early years. I even had a T-shirt from SEER 1990 that had been autographed by everyone I saw at that event. (It was fun to now see people find their name after all these years.) A resort near Redway offered a motel, cabins, tent sites, and RV sites. We prepped our 19-foot-long travel trailer for the trip. The trailer is a Pioneer model; we bought some vinyl lettering in the same font and color as the original logo and made it the Solar Pioneer trailer. We loaded up Lucea the Airedale and took off.

When we arrived at the resort, our site was next to John Berdner's (Enphase Energy) RV. I told him I still had my Sunny Girl T-shirt. John and his friend set up the coolest driving simulator next to their RV. Two stations, big screens, special chairs; it had the works. It was a popular pasttime in the evenings.

That very first afternoon at the park, we started seeing old friends arrive who we hadn't seen in many years. We were standing by our trailer when an RV with solar panels on the roof drove by. Bob-O said, "That looks like a Steve-and-Elizabeth-Willey (Backwoods Solar) vehicle." We followed it in and found Steve and Elizabeth getting settled. Steve was unloading his electric motorcycle that they use to get around when RVing. The Willeys also helped pull this shindig together.

The first of the weekend's Solar Pioneer events was planned for that evening at the PV-Cables facility in Redway. It was sponsored by Charlie Wilson, co-owner of PV-Cables, and his wife Cietha—the original artist for the Power to the People logo used for AEE and PV-Cables. As soon as we arrived, Allan Sindelar (Positive Power) gave us nametags. We found and talked to so many friends that we had not seen in way too long. We were able to snag our good friend Bill Battagin (Feather River Solar) for dinner in our trailer. We enjoyed catching up with each other in an unhurried flow of conversation.

The next morning the resort camp area was awash with solar bozos, coffee cups in hand, gathering in small knots of laughter. More Pioneers arrived.

continued on page 62


Courtesy Rachel Bujalski

The graybeards and graybuns of renewable energy meet to celebrate the good ol' days, and progress since.

web extras

See the party video and interviews with solar pioneers at **bit.ly/SolarPioneers**

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Midday found us all taking a scenic drive west through the redwoods out to Briceland. Jeff and his crew, Sequoya Cross (Backwoods Solar), Bryan Norkunas (PV-Cables), and David Katz had rented a small country school for the day. It was perfect—a beautiful setting, large deck, larger great room, and a small kitchen for the caterers.

As we all mingled and reminisced throughout the day, Bryan's wife, Vanessa Norkunas, and her kitchen crew kept refilling large tables with the tastiest finger foods. Fortified with food and drink, the day ran into the evening.

One thing I heard a lot was how great it was to be able to actually have a full conversation with old friends. In the early days, the places we would see each other were renewable energy fairs. Back in those days, we were all working hard to find customers. Any conversation with a friend could be, and usually was, interrupted by a potential client, or we were all relegated to staying in our booth to keep it staffed.

We saw Don Harris (Harris Hydro), who is still, in a word, adorable. I met Denis Ledbetter (Lo-Power Engineering) who is carrying on with Harris Hydro now that Don has retired. For years, I had spoken to Denis only on the phone—I had never met him face to face. I had known of Debbie Tewa (Tewa Energy Services) from the article featuring her in *Home Power* 62. And now I was able to meet her.

Richard Perez (Home Power) and Joe Schwartz (Home Power) were able to make the trip. It was exciting for the younger crowd to meet Richard and fun for all us old-timers to see him there. Richard got to autograph his battery book for Tony Diaz (Century Roof and Solar) as Tony's starstruck son looked on.

Not all conversations were nostalgic. Our friends Jennifer Stein-Barker and Lance Barker (Morning Hill Forest Farm) traveled from eastern Oregon. I had a really interesting talk with Lance. First, he told me how Bob-O had inspired him to happily retire. Then we spoke about how his root cellar, which is dug into a hillside, has not been cool enough to store root crops at the time they are harvested. He and Jennifer grow most, if not all, of their own food, and preservation of those harvests is essential to them. But Lance came up with an out-of-the-box solution for the root cellar temperature problem. He installed inside the root cellar a small (300 W) thermostat-controlled air conditioner. It does not have to run much to maintain a cool-enough temperature for their root crops. Being off-grid and running an air conditioner is unconventional, to say the least.

As the afternoon turned to evening and the conversations flowed quietly around us all, the feeling of belonging to a special group fell over us like the blanket of stars above our heads. Throughout the festivities, Bob-O on bass, Jeff Spies and Kelly Larson (SEI) on ukuleles, and Bruce Fiero (Willpower Electric) on blues harp provided intermittent music. I know we don't see each other often enough, but friends like Bob and Golda Maynard (Energy Outfitters), Johnny Weiss (Solar Energy International), Michael Welch (Home Power), Ray Barbee and Darren Emmons (both of OutBack Power), and my old palindrome-quoting buddy Wayne Robertson (Solar Electric Specialties) are friends forever. I can hear the bass and ukuleles playing now. As in Vera Lynn's 1940s song, "We'll meet again, don't know where, don't know when, but I know we'll meet again some sunny day..."

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Catching the Rain

Catching and using rainwater can be a useful sustainability strategy in many situations. Three factors are important in designing a rainwater collection system—collection, usage, and storage.

Collection.

To start, examine your roofs to see how much they can collect. One method is to calculate the square footage of the building, and then add the roof overhang area. With some online map applications, you can locate your buildings, click on their corners, and the areas are calculated automatically.

Annually, a 1,000-square-foot roof footprint can capture about 600 gallons of water per inch of rainfall:

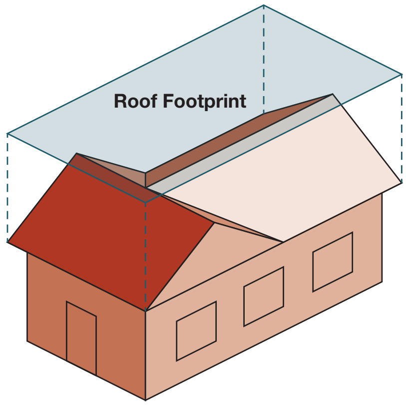
Area (ft.^{2}) × annual rainfall (in.) × 0.6 (collection factor) = Annual harvest (gal.)

Usage

United States residents use 80 to 100 gallons per person per day—but water conservation can shrink that. If your home is billed for water by the gallon, the usage amount is included on your bill. Alternatively, modestly priced meters can be added to measure water use. Partitioning your usage and metering (for example, measuring irrigation water separately) can give you even better data.

Once you know how much water you use, decide what portion of your needs rainwater will supply. Simple systems providing irrigation and other non-potable uses may avoid the issues and expense of filtering and water treatment. Also, you might not need your entire roof for collection. It could turn out that you only need one of a roof's sloping sides to meet your planned usage, which means less plumbing.

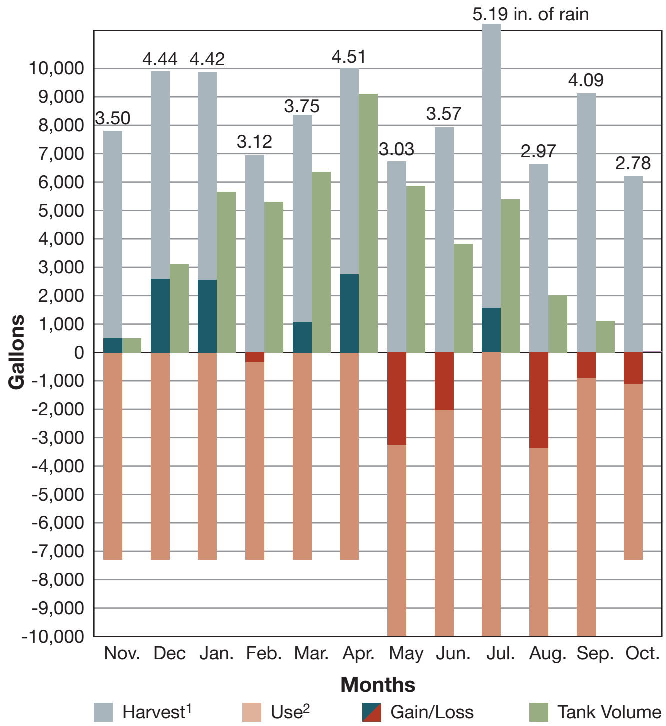
Determining Catchment Area



Area based on dimensions to eaves (dripline)

Meeting Water Needs

Example: Knoxville, Tennessee



Annual Rainfall = 45.37 in.
Annual Total Harvest[1] = 101,130 gal.
Annual Water Use[2] = 101,100 gal.
Minimum Storage Required = 9,131 gal.

1. Harvest based on 3,715-square-foot roof catchment area.
2. Usage based on three people at 80 gallons per day each, with extra consumption during gardening season.

Storage

It's worth looking at how wide the variations in annual rainfall have been in recent decades, so you can have realistic expectations. A crucial part of your analysis should be *when* rainfall occurs and *when* you need the water. From there, decide when your biggest rainfall time is, when your biggest times of use are, and how much storage it will take to bridge the gaps.

In most places and situations, it will take many thousands of gallons of storage, and a very large collection space to meet the entire needs of a family. But even meeting all of your nonpotable water needs is helpful. Once you get through this basic analysis, you'll be ready to move forward with planning and design for a rainwater collection system.

—Ian Woofenden

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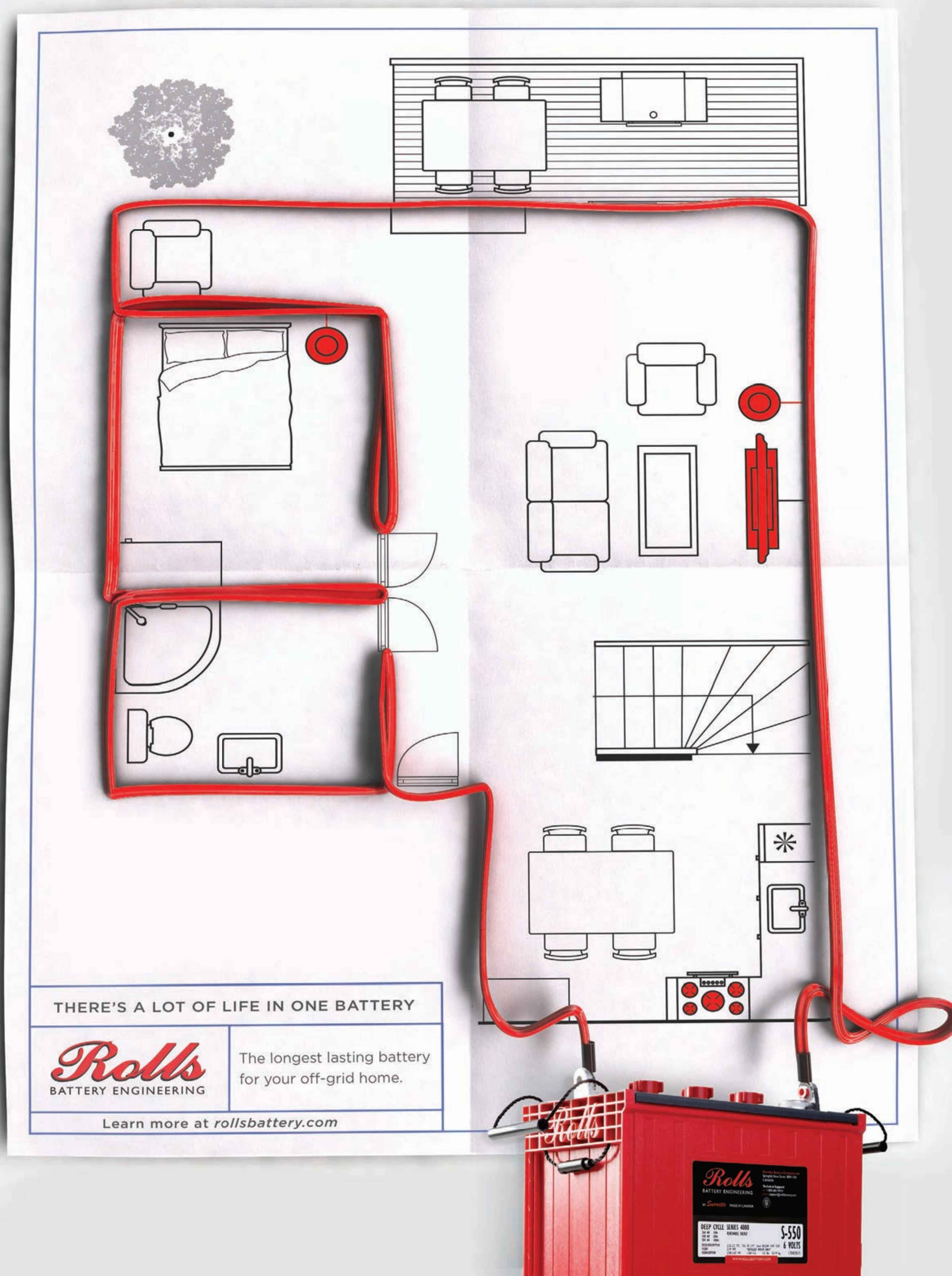
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