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Finding Resilience in Interdependence

Recently, Tara Cullis and David Suzuki's *The Declaration of Interdependence* came across my desk. Written for the 1992 United Nations' Earth Summit in Rio de Janeiro, it clearly addresses humans' dependence on and interconnectedness with the Earth and all of its inhabitants.

> *"We humans are but one of thirty million species weaving the thin layer of life enveloping the world.*
>
> *The stability of communities of living things depends upon this diversity.*
>
> *Linked in that web, we are interconnected—using, cleansing, sharing and replenishing the fundamental elements of life.*
>
> *Our home, planet Earth, is finite; all life shares its resources and the energy from the sun, and therefore has limits to growth.*
>
> *For the first time, we have touched those limits.*
>
> *When we compromise the air, the water, the soil and the variety of life, we steal from the endless future to serve the fleeting present...*
>
> *...We are learning from our mistakes, we are mourning our vanished kin, and we now build a new politics of hope.*
>
> *We respect and uphold the absolute need for clean air, water and soil.*
>
> *We see that economic activities that benefit the few while shrinking the inheritance of many are wrong.*
>
> *And since environmental degradation erodes biological capital forever, full ecological and social cost must enter all equations of development..."*

We humans need each other. The stronger our authentic community connections, the more resilient we are. The stronger and more diverse our communities, the more resilient *they* are. That goes for food security, local economies, and many other things, including, of course, energy.

That's why I try to invest myself locally—by joining food cooperatives, planting a garden, buying fresh food at the farmer's market, supporting local craftspeople, connecting with our neighbors, and investing in renewable technologies that contribute to a more livable planet Earth.

When I received Chris and Chom Greacen's article ("Common Ground—An Uncommon Energy-Efficient Community," page 36) in my Inbox, I felt more hopeful than ever before. Here was a workable, scalable model of interdependent success on many levels.

How resilient is your community? How interconnected? And what can you do to make it more so?

—Claire Anderson, for the *Home Power* crew

Think About It...

"Nobody's going to fix the world for us, but working together, making use of technological innovations and human communities alike, we might just be able to fix it ourselves."

—Jamais Cascio, American author & futurist


GRID-FREE
WATER
PUMPING
FH2OTON
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Franklin Electric

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Photos courtesy: Quick Mount PV; Eos

On the Cover

Chris (fifth in the lineup) and Chom Greacen (second), with their kids Isasa (front) and Ky (fourth), and friend Camille (third) at the Common Ground solar community on Lopez Island, Washington.

Photo courtesy Tracey Cottingham

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Brad Berman is the editor of PluginCars.com and HybridCars.com. Brad writes about alternative energy cars for *The New York Times,* Reuters, and other publications. He is frequently quoted in national media outlets, such as *USA Today*, National Public Radio, and CNBC. Brad is the transportation editor at *Home Power*.

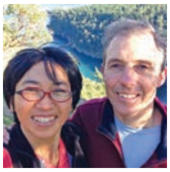
Thirty years ago, **Kathleen Jarschke-Schultze** answered a letter from a man named Bob-O who lived in the Salmon Mountains of California. She fell in love, and has been living off-grid with him ever since. *HP1* started a correspondence that led Kathleen and Bob-O to *Home Power* in its formative years,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

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

Drake Chamberlin became interested in photovoltaic technology in the 1980s, shortly after *Home Power* began publication. As an electrical contractor, he began working with solar, advertising in *Home Power*'s "Have Tools, Will Travel" department. This led to several jobs across the western United States, where he got his initial experience.

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*.

Michael Welch, a *Home Power* senior editor, is a renewable energy devotee who celebrated his 27th year of involvement with the magazine in 2017. He lives in an off-grid home in a redwood forest in Humboldt County, California, and works out of the solar-powered offices of Redwood Alliance in nearby Arcata. Since 1978, Michael has been a safe-energy, antinuclear activist, working on the permanent shutdown and decommissioning of the Humboldt Bay nuclear power plant.



Chom Greacen is passionate about nudging the evolving energy landscape toward peace, ecology, and justice. She enjoys working locally with schoolchildren on energy awareness, as well as in southeast Asia with policymakers, civil society organizations, and NGOs on energy policy and regulations. **Chris Greacen** got his start in renewable energy in 1989 working for *Home Power* on issue No. 10. After leaving *Home Power* in 1993, he earned his doctoral degree researching village microhydropower in Thailand. These days, he works in southeast Asia and Africa, implementing local renewable energy systems.

Hugh Piggott lives off-grid on the northwest coast of Scotland. He builds small wind turbines, writes books about how to do so, and has taught construction courses around the world. Hugh also installs hydro and PV systems, and writes about off-grid renewable energy systems.

Louis Woofenden has installed solar in Arizona since 2003. He's a NABCEP-certified PV installer, and has a bachelor's degree in engineering and a master's degree in solar energy engineering. When not on the roof, he volunteers internationally, advocates for sensible solar policy, and explores the southwest United States with camera in hand.

Courtesy SunPower

SunPower

Equinox System

SunPower's (sunpower.com) Equinox System is a complete residential PV system. It includes SunPower AC modules (with factory-installed microinverters); a low-profile InvisiMount rail-based mounting system; and an EnergyLink monitoring platform. SunPower's 96-cell SPR-X22-360-C-AC module has a 360 W STC rating with a +5/-0 power tolerance, and a 22.2% average module efficiency. On the AC side, the module has a 320 W maximum continuous power rating.

Up to 12 AC modules can be connected to a single 20 A, 240 VAC branch circuit. The InvisiMount has integrated grounding and bonding; the system as a whole carries a Class A fire rating. Because this system utilizes microinverters, it satisfies 2017 *National Electrical Code* rapid shutdown requirements for both outside and inside the array boundary. The EnergyLink system monitors both consumption and production. Equinox systems carry a 25-year combined product and power warranty.

—Justine Sanchez

Darfon Electronics

ACRak Integrated Microinverter & Rack

Darfon (darfonsolar.com) offers its G320 microinverter and cabling preinstalled on IronRidge XR pre-cut rails to reduce installation time. Three packages are offered: 1P for a single-module installation; 4P for four modules; and 24P for 24 modules. The 4P and 24P racks are precut into two-module sections for manageability. The packages can be combined to accommodate various system sizes. The ACRak can accommodate most 60- and 72-cell modules. The microinverters carry a 10-year warranty; a 25-year option is available. The rails have a 20-year limited warranty.

—Justine Sanchez

Courtesy Darfon Electronics

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E-Motorcycle

After many years of being absent, I finally renewed my subscription to *Home Power* magazine. In light of your recent article on electric motorcycles, I thought I'd share the system I came up with for charging my 2010 Zero Electric motorcycle directly with solar. The $30 DC-to-DC maximum power point charge controller charges the 55-volt lithium-ion battery pack directly from the solar module. The charge controller steps the solar module's voltage up or down to maximize the amount of solar going into the motorcycle's battery. To keep the battery from being overcharged, the PV array's output is automatically reduced when the battery's maximum voltage is reached.

The charge controller's output connects to the wires feeding the battery which is inside the motorcycle's Delta-Q battery charger. [Ed. Note: For safety and the health of a Li-ion battery, never bypass the battery management system. Also be sure to check to ensure that these modifications will not void the manufacturer's warranty.] The battery pack holds 4 kWh of storage, so it would take a long time to charge the motorcycle with a single 165-watt module, but the charge controller can handle two 165-watt, 36-volt modules connected in series, and then connected in parallel with two other modules connected in series.

My 2010 Zero uses about 0.11 kWh per mile (newer Zeros go farther on a charge). While 36 miles may not sound like much, it is plenty of range for all of my daily driving needs. And I love the feeling of riding on sunshine!

Jim White • Wenatchee, Washington

Courtesy Jim White

Battery-Charging Idea

Now that I'm retired from Bogart Engineering, I'm writing this to get reader reaction to a method I've thought about for awhile and have started to implement. I'm also writing because I want to put this idea into legal "public domain" so it can be used by anyone, without patent obstacles. After 25 years of living with an off-grid PV system, I've decided that the better way to charge batteries is by using a two-day charge cycle instead of just one day.

It's often thought that to charge a battery in one day, all you need is plenty of PV capacity—modules and sunshine. Of course, the chemical process of converting electrical energy to chemical energy requires enough amp-hours (Ah). But often people don't realize it's important to have enough solar time to charge them well. Lead-acid batteries—especially at the end of charge—absorb energy more slowly. One day just isn't enough time to completely charge them to preserve capacity. That's a fundamental limitation of the battery chemistry—similar to the logic that you can't bake a cake in half the time just by increasing the oven's temperature.

My idea is to use a two-day charging cycle: For example, instead of a 600 Ah capacity storage, divide the system into two 300 Ah battery sets. Discharge only one set the first day. The next day, switch to the other set, but continue charging the first set at a low finish-charge level. At the end of the day, switch to the well-charged set. This makes a two-day charging cycle using both sets.

It's generally regarded as good practice to discharge an off-grid system only to 80% SOC (state of charge). I'm now advising to discharge the "half-sized" system to 60% SOC—beyond what's normally recommended. How can discharging twice as much possibly be beneficial?

For the battery's health, leaving the smallest amount of uncharged lead sulfate per day as possible is good practice. If, in one day's charging, 5% uncharged lead sulfate is left, and, after charging for an additional day (without discharging), only 5% of 5% (or 0.25%), which is 0.125% per day, is left, that is a 20-fold reduction in unreacted residual per day. The result is that equalization cycles may not be needed as frequently.

With a typical one-day charging cycle, the productive afternoon sun can't be used efficiently because finish charging of the battery in the afternoon must be done at low amperage. With a two-day cycle, this lost solar energy can be accepted by the batteries. I estimate that this method could use 30% more performance from solar-electric arrays. Stay tuned for an update after I gather some data from my test system.

Ralph Hiesey •
retired founder of Bogart Engineering

PV-Direct Water Heating Vs. Solar Thermal

In Mailbox *HP179*, Hugh Piggott cited some advantages that make PV-powered water heating preferable to solar thermal technology. Here are a few more:

- Reliability—There's no heat-transfer fluid that can leak or deteriorate; and no circulating pump means no moving parts that can fail.
- Simplicity—The systems are easier to install, test, and commission. A tank water heater having one ordinary and one solar immersion element is no big deal, compared to a special "solar tank" with its necessary heat exchanger.
- Autonomy—Many solar thermal systems need grid electricity for the pump controller and the circulation pump. PV systems can be entirely self-powered—ideal for those in developing countries, as well as "off-gridders."
- Layout flexibility—It's easier and cheaper to run cables than plumbing. There are no airlock worries, either.


Courtesy Shel

A Willis style immersion heater is plumbed in parallel with a standard water heater to provide a small amount of hot water quickly, while also contributing to the main tank temperature.

- Guaranteed energy harvest—Lower solar input in early spring, late autumn, and winter, can compromise a solar thermal system—will the collectors achieve the necessary temperature to input heat to the tank? With PV, if there's any energy available, it'll be harvested. Plus, PV modules are more efficient in cold weather.

- High-temperature capability—Even if the available PV power is low, it can directly heat the hot water supply tank; there's no need for a preheat tank.

- Instant delivery—By using a Willis-type external immersion heater arrangement (popular in Northern Ireland, but universally applicable), hot water can be drawn almost as soon as your PV array starts generating a surplus.

- Greater end-use flexibility—With a PV-heat arrangement, you aren't just restricted to heating water. With a little creativity and electrical know-how, you can use conventional switches and relays to readily swap between water heating, background space heating (very useful in spring and autumn), or greenhouse soil heating. You can also cook with PV power—think of the deforestation, the fuel-collecting time, and the smoke-related illnesses this could prevent. Meanwhile, even Scots, Alaskans, or Canadians can—using a conventional AC hot plate fed from a dedicated "PV surplus" socket, on sunny days—be bulk-bottling fruit or juice, jam-making, or brewing beer in large batches, and enjoying full tanks of hot water!

Christopher Jessop • Pembrokeshire, West Wales, UK

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VAWT Commentary

I am a longtime subscriber and wind power, solar thermal, and solar-electric enthusiast. My rezoning application for a 6 kW horizontal-axis wind turbine (HAWT) was denied due to height restrictions in my semi-rural development. If I want a wind turbine, it needs to be mounted on a shorter tower. Turbulence is a problem here, so I have decided to try a vertical-axis wind turbine (VAWT). Using this will not require submitting a rezoning application.

Is there a viable 5 to 10 kW rated VAWT that has been installed in the United States in any appreciable volume in the last few years? I would consider purchasing a foreign product as long as it has a good track record and decent warranty.

Hans Sinkovec • Jefferson County, Colorado

A good measure of a wind turbine's worth is its annual energy output (AEO), defined as kWh of energy per year. This number depends on the annual mean wind speed, and the turbine's size (swept area) and efficiency. The standard "reference" site has a mean wind speed of 5 meters per second (11 mph). In most places where people live, you would need a tall tower to access this mean wind speed. Wind energy around buildings and trees will be much lower, and the wind is turbulent.

VAWT products are characterized by a high degree of marketing hype, and a high rate of failure. High-speed VAWTs have problems with startup and blade fatigue issues. Low-speed VAWTs have terrible efficiency. Comparing the kWh per year of energy produced on sites with the reference annual average wind speed of 5 m/s (11 mph), HAWTs produce 344 kWh per square meter, whereas VAWTs produce only 201 kWh—58% as much for their size.

Just as it's not a good idea to put a HAWT on a windy and turbulent site, because of the loads this puts on the blades, a VAWT is equally likely to fail on any windy site for the same reason. VAWTs are often sited too low to experience useful wind, so they do not fail.

Siting a VAWT (or any wind turbine) on a short tower, in low-speed or turbulent winds, is a recipe for wasted money and disappointment.

Hugh Piggott

Before you part with your money, find someone who already owns a VAWT and can show you measurement data proving that it does what it claims to do. Reliable VAWTs are rare, costly, and unproductive, and using a VAWT at low height is not a solution. More likely the best solution will be to install a PV system instead. A study published in the *Journal of Clean Energy Technologies* based on typical European solar irradiance concludes that PV energy is less costly than Darrieus-type VAWT energy in annual mean wind speeds of less than 7 m/s (15 mph) or Savonius-type turbines in wind speeds less than 10 m/s (22 mph).

Hugh Piggott • Scoraig, Scotland

Volt in Cold Weather

This summer I began leasing a 2017 Chevy Volt, which was supposed to go 50 miles on a full charge. I was pleasantly surprised to get up to 60 miles—until cold weather set in.

At below-freezing temperatures, the gas generator runs almost continuously, with mileage dropping as low as 19 mpg. Turning off the heating system to conserve battery power seems to help, but when the temperature is 15°F outside, there seems to be no way to force the Volt to use its battery storage below 70% SOC.

I have had the dealer check the vehicle and nothing seems to be wrong. A complaint to General Motors provided no further assistance. It seems that the Volt has been programmed to keep its battery charge above 70% SOC in subfreezing weather—but is there any workaround?

Peter John Moehs • via email

Your complaint is common among new Volt owners driving through a first winter in frigid regions. Volt drivers have long ranted, "The battery has juice! Why not use it no matter how cold it is?"

The answer is what General Motors (GM) calls "engine running due to temperature." An Internet search for the acronym "ERDTT" provides detailed explanations of this feature and reveals many debates about it in online forums. In a nutshell, GM engineers made their best attempt at balancing total system efficiency with the comfort and safety of its passengers. While a lot of EV aficionados take great pride in avoiding any gasoline use, the engineers apparently believe that periodic use of the engine to keep the cabin warm—by using the heat it generates—is a good compromise.

There are a few things you can do to correct this. First, use the Volt's dashboard menu to set the ERDTT temperature to 15°F, rather than the default 35°F setting. That should keep the engine off on all but the coldest days. Keep in mind that this is based on outside temperature, not cabin temperature. Start with home screen on the dashboard display, then go to Config > Vehicle Settings > Climate and Air Quality > Engine Assisted Heating. Then select "At Very Cold Outside Temperatures."

You can also preheat the Volt's cabin before a trip using grid or PV-produced electricity instead of the car's battery or engine. Set the

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ERDTT to be disabled while the car is plugged in. Then, preheat your car via the key fob or OnStar app. Consider combining trips to minimize the number of times in a day that you need to warm up a cold car.

If it's any consolation, the impact of cold weather on your Volt is relatively minor compared to what's experienced by drivers of pure electric cars. Freezing temperatures can reduce an EV's range by 40% or more. For drivers of first-generation EVs, the reduction can mean not being able to confidently complete a commute—and having to resort to driving a conventional gasoline vehicle. One of the reasons that GM installed a 60 kWh battery pack in its all-electric Bolt is to help commuters arrive at their destinations, despite the weather. Even with a 50% decrease, the car still has about 119 miles of range.

While it may look like your car has 70% of its battery charge remaining, that might not be the case. Dashboard systems displaying a state of charge—or estimated remaining miles—are notoriously inaccurate. That's how they earned the nickname "guess-o-meters." It's difficult to accurately measure the dance of electrons.

Finally, keep in mind that all cars—not just hybrids and EVs—take an efficiency hit on freezing days. Yes, it's annoying to see energy in your battery not getting used, but your Volt—even when cycling on the gas engine to warm up the vehicle—is among the most efficient vehicles on the road. Your annual consumption of gasoline is remarkably small, even if it takes an extra gallon or so to make it through the winter driving season.

Brad Berman • *Home Power* transportation editor

Courtesy Peter John Moehs (2)

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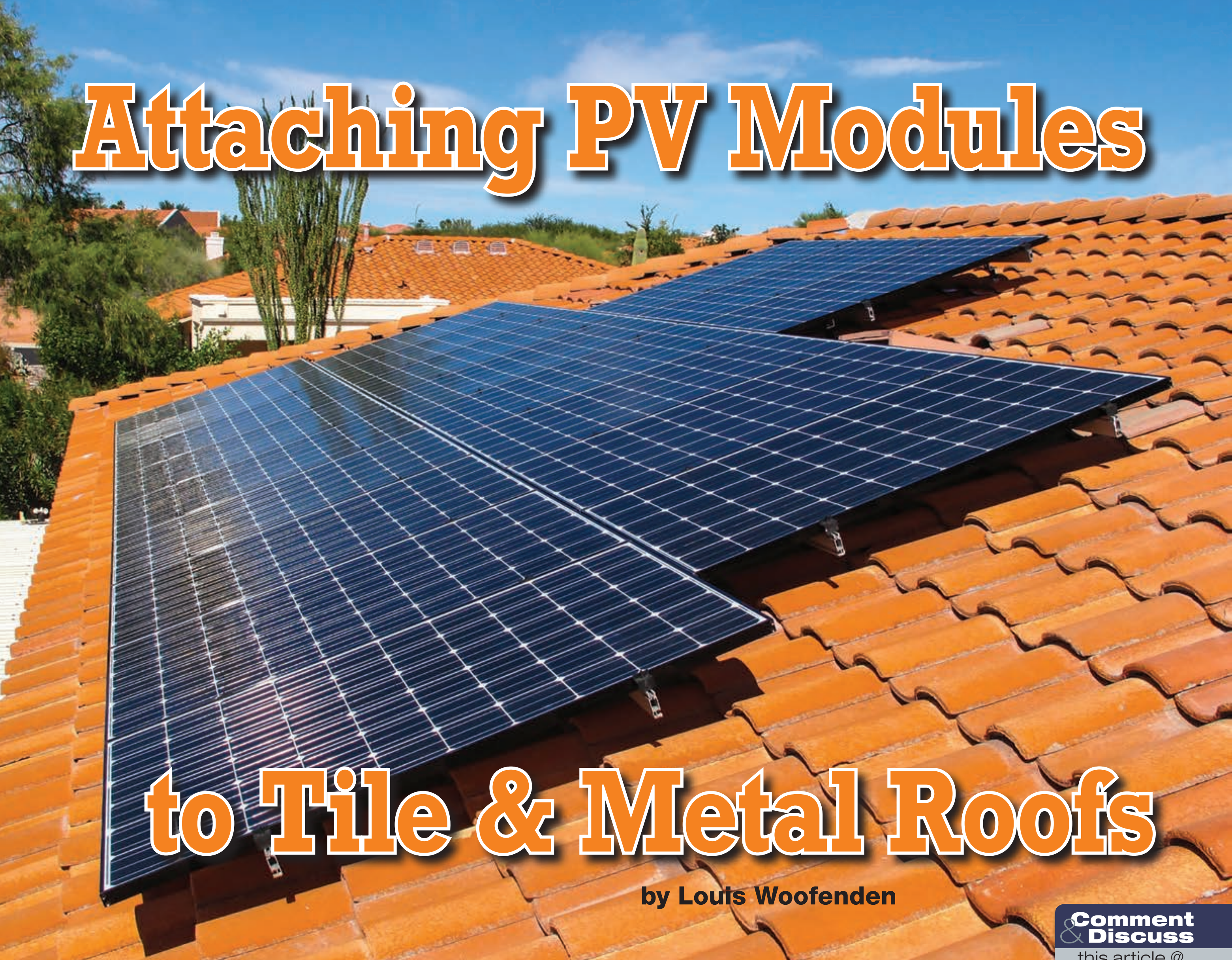
Attaching PV Modules to Tile & Metal Roofs

by Louis Woofenden



Courtesy Net Zero Solar

Comment & Discuss this article @ homepower.com/184.20

Over the past decade, solar rack design and manufacturing solutions have evolved to include tile and metal roof options that are attractive, well-designed, and long-lasting.

Four Things to Look For

As a solar installer, I evaluate four things when selecting an attachment method and rack system: strength, durability, aesthetics, and ease of installation.

A rack system has to be strong enough to safely support the PV modules and other equipment, such as microinverters or DC converters, and remain secure and in place under the stresses of wind or snow loads. Racks can be either rail-based or rail-less systems (see "PV Racks for Sloped, Asphalt-Shingled Roofs" in *HP181* for more information).

A rack system should last at least as long as the roof—preferably much longer. For some metal roofs, this could be more than 50 years. A quality tile roof may require major refurbishment every 25 years, but will last for decades.

Both consumers and PV installers appreciate an aesthetic rack solution. With the lower cost of today's solar-electric components, installers can design systems that perform well and look great. A rack and mounts that are easy to install can also save money by speeding up the installation.

Evaluating the Roof

When you install a rooftop PV system, you're asking more from your roof, since it will be supporting the additional weight of the rack and mounts, PV modules, wiring, electrical conduit, and wind (and, possibly, snow) loads. It must also support the weight of technicians and tools during installation and maintenance.

Before you add a PV system, assess (or hire a pro to assess) the condition of your roof from top to bottom. If the roof needs to be replaced, do so before installing a PV system. Otherwise, you'll have to pay twice for the system's installation (and also once for the system to be removed). If roof work is required, make sure your roofer and solar installer each understand their parts in the process and are communicating. You'll also want to know what warranties apply to your roof after your PV system is installed.

Tile Roof Options

Most modern pitched roofs have commonalities. There are structural members, usually trusses or rafters, which are attached to the walls and support the weight of the whole roofing system (and the PV system). Decking—either solid boards or plywood—is secured to the top of the structural members.

The topmost roofing layer is the roof's first line of protection from the weather. Tiles are made of concrete, clay, or a composite material, and formed into shapes that overlap each other. Concrete tiles are often referred to by the end shape they make when viewed from the ground: flat tiles, W-tiles, or S-tiles.

Starting at the bottom of the roof, these tiles are placed in rows and fastened to battens—thin strips of metal or wood that run horizontally across the roof to keep each row of tiles from sliding down the roof.

Between the roof decking and the battens is the tile roof's underlayment, which protects your home from moisture intrusion. Preserving this water-resistant layer is vital, and that means paying close attention to flashing and sealing around all penetrations, including plumbing and attic vents, and of course, any PV system attachments.

Tiles overlap the course below enabling water to flow from the top of one tile onto the next tile. It's still possible for some water to make it through to the also-protective underlayment, so it's important to flash any attachments that protrude through the tile layer to direct water onto the surface of the roof, not down to the underlayment.

Attaching to Tile Roofs

The essential goal for most PV attachments is to get down to the sturdy roofing trusses below the tiles, the underlayment, and the roof decking. Some tile attachments are engineered to attach to the decking rather than the roof's structural members. My preference is to attach to structural members. Three common methods are used to attach solar racks to tile roofs: standoffs and flashings; tile hooks; and tile replacement mounts.

Installing standoffs on a new roof, before tiling, is much easier than after the fact, as roofers can tile around mounting points, and flash as they go.

Courtesy Net Zero Solar

Standoffs like these by Unirac are secured by lags through sheathing and into rafters or purlin blocking. They are usually flashed at the deck level and again above tile level.

Courtesy Unirac

Standoffs & Flashings

A standoff is a metal post usually with at least two attachment holes at the bottom for lag-screwing into the roof's structural members. There's a threaded connection at the top of the post to connect to PV rack hardware. Some standoffs are a single piece of metal; others are made of multiple parts that screw together for easy installation.

Unirac's SM standoff pairs with its SolarMount rack system, which includes new Pro clips that reduce the visibility of the rack. SnapNrack, Zilla, and others also manufacture similar standoffs.

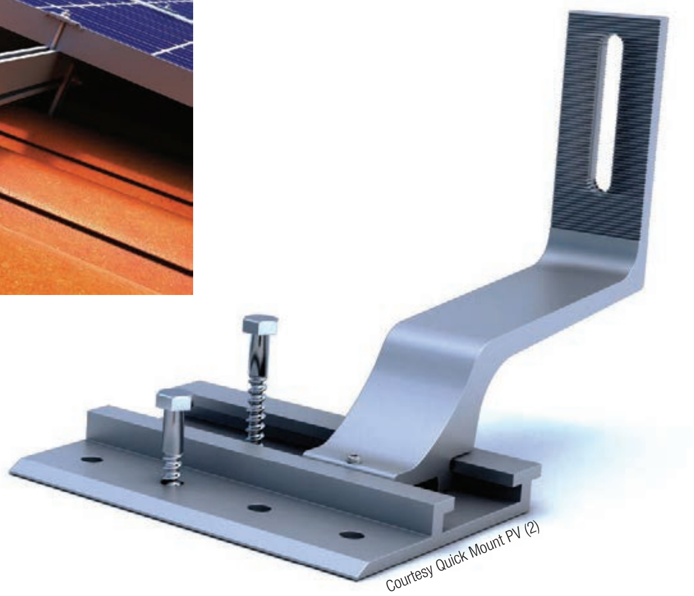
With this method, an installer has to drill pilot holes through the underlayment and decking, and into the truss or rafters. An appropriate sealant, such as typical asphalt roof cement, is applied to the pilot hole and the bottom of the standoff, and stainless steel lag screws are carefully tightened to affix the standoff to the roof.

After the standoff is in place, a deck flashing is usually installed and sealed, to direct water away from the lag-screw penetrations. Although not all building departments require installation of deck flashings, this method is required by the Tile Roofing Institute. It helps me sleep better at night, knowing the primary waterproofing layer of the roof is well-protected.

Next, the tile that was removed to place the standoff is drilled or trimmed to allow the standoff to protrude through it, and replaced. A flexible metal flashing is placed around the standoff to direct water to the next lower rows of tile.

IronRidge XRS rail

Courtesy IronRidge



Left & below: Tile hooks like these by Quick Mount PV are designed to mount under a tile. The mount hooks between the courses of tiles.

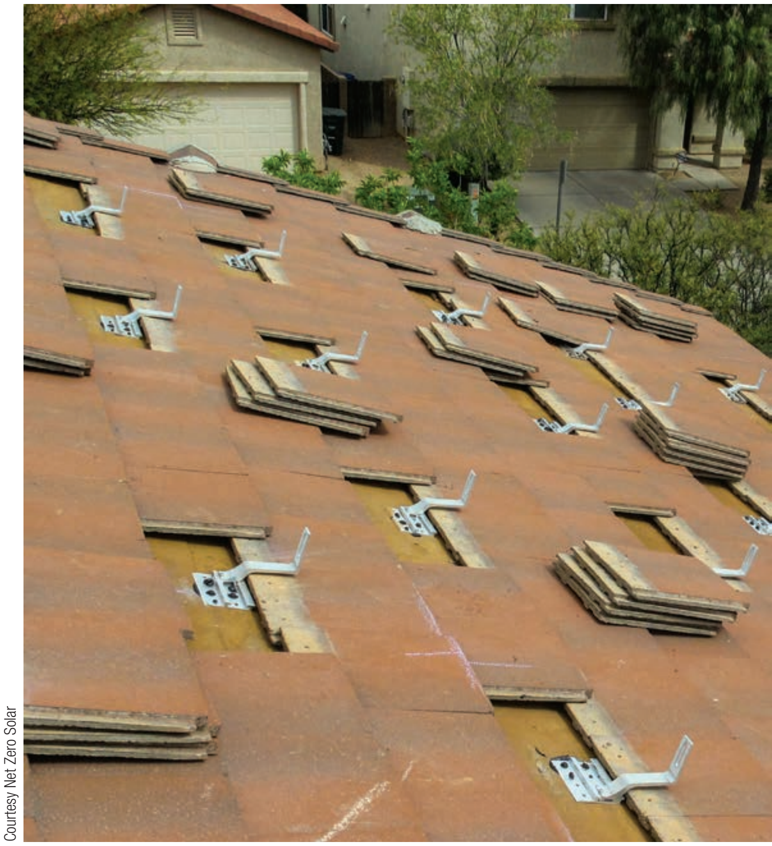
Tile Hooks

Tile hooks are a clever invention. Like standoffs, they have a base that connects to the roof trusses (or sometimes the decking). Most manufacturers also supply a deck flashing for tile hooks. But instead of poking through a tile, the curves of the tile hook exit between the bottom of one tile and the top of the next row of tile. This eliminates the need for an outer flashing for waterproofing the tile layer. To make this path possible, a small groove is made in the tile's underside.

Tile hooks protrude from under one tile into the valley of the tile directly below. If the roofing truss isn't located in a valley, the tile base should be wide enough to allow locating lag screws 5 to 7 inches in either direction from the tile valley, while the tile hook itself is located at the valley.

I use Quick Mount PV's QHook for my tile hook installations. They're sturdy and include deck flashings. Quick Mount PV doesn't make rail-based racks, but its attachments pair well with IronRidge's XR series racks, among others. Preformed Line Product's Easy Tile Hook is another option, as is Ecolibrium Solar's EcoX Tile Hook for its rail-free rack system.

Mounting tile hooks requires removing tiles. They are reinstalled after deck flashings, and prior to installing rails and PV modules.



Clay Tile & PV Systems

Some older or high-end homes may have natural clay tiles. They are attractive, but also very fragile, especially after they have been in place for a few years. It's not possible to walk on these tiles without significant damage.

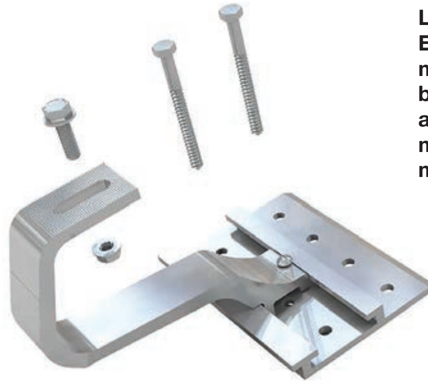
There are still ways to install a rooftop solar-electric system on these delicate roofs. One option is to replace the clay tiles with another roofing material only in the array attachment areas. Once the array is in place, it may be possible for the roofer to reinstall some of the clay tile around the PV array to help it blend into the overall roof structure, as long as maintenance access is preserved.

Tile Replacement Mounts

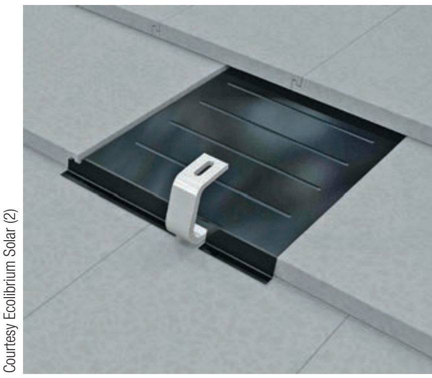
Working on a concrete tile roof without breaking tiles is an acquired skill. You have to be keenly aware of your every move, placing weight on the strongest parts of the tile—the peak of the bottom edge of the tile, where it's well-supported by the top of the next row of tile—not near the edge of a tile. Unfortunately, even the lightest of well-trained PV installers are probably going to break a concrete tile or two during a rooftop PV installation.

Tile replacement mounts can help solve this problem; plus, they have other benefits. A tile replacement mount's base is similar to a tile hook in that it allows the truss attachment to be offset from where the standoff will rise. But rather than trimming tile and using a flashing, the concrete tile is removed and the tile replacement mount installed in its place. These products are made of metal, and are designed with a sealable hole for the standoff to poke through, serving as both tile and flashing. The removed tiles can be saved for future breakage replacement.

SnapNrack's Tile Replacement is available for S-tile, flat tile, or W-tile, and works well with its Series 100 rack system. Quick Mount PV offers tile replacement options for each of these tile shapes, using an adjustable base and standoff, tile hooks, or a fixed standoff. The tile replacement needs to be very similar in shape to the existing tile, so carefully assess the product before purchasing.



Left & below: Ecolibrium Solar's mount is a cross between a tile hook and a tile replacement mount that uses a tile-matching flashing.



Courtesy Ecolibrium Solar (2)

A tile replacement mount like this one by SnapNrack uses flashings that mimic the shape of the tile it's replacing.

Courtesy SnapNrack

Like others, these Quick Mount PV tile replacement mounts are available for flat tile, W-tile, or S-tile, and in various base, standoff, or S-hook versions to match the needs of each installation.

Courtesy Quick Mount PV (3)

Rooftop PV on Slate

by Drake Chamberlin

When we decided to install a PV system on our house in southeastern Ohio, the rooftop seemed the best place because the house has a south-facing roof with a 35° pitch and good solar exposure. A 2.16 kW PV system would cover all of our household's electrical usage, and only take up 165 square feet. But the roof was covered in slates—a very brittle rock—and conventional rack attachment solutions for PV systems would not work with this type of roofing.

We could have (at considerable expense) removed all of the slate and installed a standing-seam or rib-style metal roof. Or we could have installed metal roofing under only the array's footprint and kept the rest of the slate in place.

But Paul Waltz, a slate roof expert, told us that, with a little maintenance, our roof should be good for another 100 years. We live in a post-Civil War-era house and wanted to preserve a piece of history. The roof had already survived 140 years.

I had never installed a PV array on a slate roof, so I turned to Paul for some advice. Although we found some equipment advertised as mounting hardware for attaching a PV rack to a slate-tiled roof, Paul felt that using this method would put too much compression on the tiles and risk cracking them. This method would have compressed the slate in the same way as an asphalt shingle mounting system would compress the shingle. Slate is very brittle and thus fragile.

It became apparent that we were going to have to get creative. Paul suggested that he could make some flashings out of sheet metal, but the problem of sealing the standoffs would have remained. Upon further discussion, the major issue seemed to be that the dimension of available flashings was too small.

I started calling rack system manufacturers to see if any solutions were available for slate tile installations. A breakthrough came when Quick Mount PV said they could make some custom flashings to modify one of their existing products. The flashing included a round metal base, standoffs, and a rubber boot. A standard L-foot would mount on top of the standoff, to which any rails using a standard L-foot configuration could be attached.

Our 140-year-old roof's structure needed to be considered. The roof had been constructed by nailing 6- by 7/8 -inch hardwood purlins across the rafters, and the slate was nailed to the purlins. The Quick Mount bases would attach to the purlins with four 5/16-inch-diameter lag screws, thereby exceeding the required pullout strength for the wind loading in our area. On Paul's recommendation, we first added bracing made of 2-by-4 dimensional lumber to the attic rafters to prevent any possible stresses caused by lateral wind load on the array, which could crack the slate. The braces were nailed perpendicular to the rafters.

The bases were round metal plates with four holes for mounting screws, and the standoffs screwed into the bases. Mounting the bases directly on top of the slate would have cracked it. We cut 4-inch holes in the slate where the bases would be placed, and attached the bases directly to the purlins. We used a carbide grit hole saw to cut through the slate. Once the bases were in position, we bolted the standoffs to the bases and slid the flashing over the top of the assembly. The flashing was then capped with a rubber boot.

This was a labor-intensive process. For every flashing, three slate tiles needed to be removed, and reattached. A fourth tile needed to have a 4-inch hole cut into it, directly over the purlin, so that the base could be screwed directly into the wooden purlin.

Care had to be taken to not walk directly on the slate. We laid ladders with peak hooks on the roof to obtain good footing and to keep our feet off the slate. The main trick was to be sure to keep our feet on the ladder and not contact the slate through the rungs. Although the roof was steep, our system of ladders and roof hooks made it easy to stay secure. With scaffolding, the roof was readily accessible from a stable platform. There was a lot of climbing up and down, and hoisting tools and materials up to the eaves (20 feet off the ground) with buckets and ropes. Fortunately, the installation crew was highly skilled and comfortable working on high roofs. This was not a project for amateurs.

Having an experienced slate roof installer on the job through the entire process was essential—no matter how much care is taken, it is likely that some slates will break during the installation. (We replaced three during this installation.) All in all, the roof was left in better condition, since we replaced worn tiles as we went along and reinforced the rafters in the attic. In most cases, the extra cost of working with the existing slate roof is less than the cost of replacing the roof, and well worth the effort of preserving a historic, long-lived, durable roof.

Slate tiles were drilled with a carbide hole saw.

Bases were mounted through the slate, then flashed.

Drake Chamberlin (2)

PV Hardware for Tile & Metal Roofs

Manufacturer	Tile	Metal: Standing Seam	Metal: Corrugated	Metal: Trapezoidal
EcoFasten Solar ecofastensolar.com	Rack & Attachment*	Rack & Attachment	Rack & Attachment	Rack & Attachment
Ecolibrium Solar ecolibriumsolar.com	Rack & Attachment	Rack & Attachment	–	Rack & Attachment
Everest everest-solarsystems.com	Rack & Attachment	Rack Only	Rack & Attachment	Rack & Attachment
IronRidge ironridge.com	Rack Only	Rack Only	Rack Only	Rack Only
Mounting Systems mounting-systems.us	Rack & Attachment	–	–	Rack & Attachment
Orion www.orionsolarracking.com	Rack & Attachment	Rack & Attachment	Rack & Attachment	Rack & Attachment
Pegasus Solar pegasussolar.com	Rack & Attachment	–	–	–
Polar Racking polarracking.com	Rack & Attachment	Rack Only	Rack Only	Rack & Attachment
Preformed Line Products preformed.com	Rack & Attachment	–	Rack & Attachment	Rack & Attachment
ProSolar prosolar.com	Rack & Attachment	–	–	–
PV Racking pvracking.com	Rack Only	Rack Only	Rack Only	Rack Only
Quick Mount PV quickmountpv.com	Attachment Only	–	–	–
Roof Tech roof-tech.us	–	–	–	Rack & Attachment
Schletter schletter.us	Rack & Attachment	Rack & Attachment	Rack & Attachment	Rack & Attachment
S-5! s-5.com	–	Rack & Attachment	Attachment Only	Attachment Only
S:Flex sflex.com	Rack & Attachment	Rack & Attachment	Rack & Attachment	Rack & Attachment
SnapNrack snapnrack.com	Rack & Attachment	Rack & Attachment	Rack & Attachment	Rack & Attachment
Spice Solar spicesolar.com	Rack Only	Rack Only	Rack Only	Rack Only
SunModo sunmodo.com	Rack & Attachment	Rack & Attachment	Rack & Attachment	Rack & Attachment
Unirac unirac.com	Rack & Attachment	Rack & Attachment	Rack Only	Rack Only
Zilla zillarac.com	Rack & Attachment	–	Rack & Attachment	Rack & Attachment

***Rack:** System to secure PV modules to roofing attachments. **Attachment:** Hardware connecting roof structure to racking.
Rack & Attachment: Complete systems to support and secure PV modules to roofing system. Includes rail-free options.

Metal Roof Options

For long-term durability and attractiveness, it's hard to beat a metal roof. Metal roofs can last 30 to 50 years, depending upon the product and on local weather conditions.

My favorite metal roof is standing-seam. These roofs have flat sections that are 12 to 18 inches wide and are joined together at a raised seam. Corrugated metal roofing has a regular succession of waves and troughs, usually ranging from 1.25 to 2.5 inches in height. Trapezoidal profiles usually have a flat section that's 12 to 24 inches wide between raised trapezoidal ridges that are 1 to 4 inches tall.

Each of these roof types provides a way to attach each section by overlapping with the neighboring section. On homes, these roofing panels are attached to the underlying roof structure using screws fitted with special waterproof gaskets—commercial roofs may require different methods.

Attachment Issues

A well-installed metal roof relies on attachments of the roof panels to the decking or purlins below, and their attachment to the trusses. Any problems with the connections between all parts of the roof could compromise the security of the PV rack.

The first step is to determine the brand, model, and thickness (gauge) of the metal roof. Check how everything was supposed to be fastened from plans or manufacturer instructions and whether the plans were followed. Red flags are too few fasteners on the roof, or many roofing fasteners in your attic that missed the structural members. Experienced solar installers and roofers might also be able to help you determine the strength of your metal roof by feel.

Courtesy EcoFasten Solar

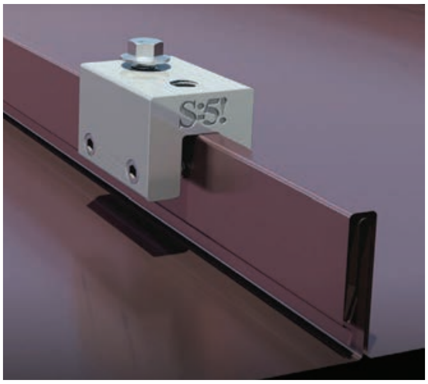
The advantage of standing-seam metal is that the standoff hardware attaches to the roof without any penetrations.

Standing-Seam Products

My first choice for standing-seam roofs is a nonpenetrating clamp that fits over and is tightened onto the seam, usually with two set-screws. The correct clamp must be used to fit the shape of the seam, the thickness of the metal roofing, and how much force can be applied to the clamp without failure.

S-5! manufactures clamps that accommodate a variety of standing seam roof profiles. Ecofasten, Orion Solar, and SnapNrack also have products to fit standing-seam metal roofs.

Right & below: S-5! is a longtime provider of metal roof attachment products, producing clamps to match several standing-seam profiles.



Courtesy S-5! (2)

Above & right: EcoFasten Solar's standing-seam clamps also function as rail-less racking by including a base to support module frames and a top clamp.

Courtesy EcoFasten Solar (2)

Orion Solar Racking seam clamps

Courtesy Orion Solar Racking

Metal Roof Pitfalls

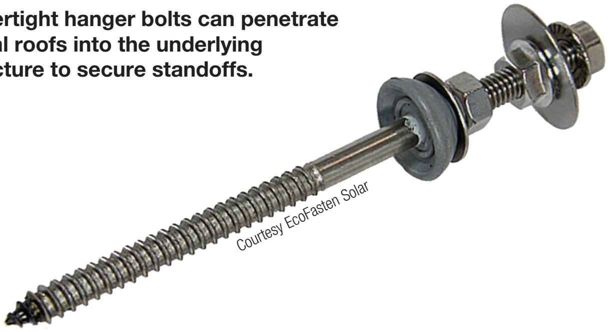
If installed properly, a PV system on quality racks mounted to a sturdy metal roof can be an extremely long-lasting installation. Here's what you can do to make your installation stand the test of time.

- Select the correct products that are designed and tested for your particular roof type, brand, model, and gauge.
- Install them according to the manufacturer's instructions.

Even the right product can fail when installed incorrectly. Most metal roofing solar attachment solutions have very specific torque requirements. If screws or other fasteners aren't tight enough, the product may not stay attached to the roof. If the fasteners are overtightened, the fasteners might pull out or the roof could be damaged. Use torque wrenches and/or torque-limiting extensions with an impact driver for tightening this hardware.

If no clamp is available for your standing seam roof, you can use penetrating options called hanger bolts, such as Ecofasten's Simple Seal Hanger Bolt Assembly. Hanger bolts are designed to penetrate the metal roof and connect to roof trusses. They work well as long as trusses aren't located directly under the seams.

Watertight hanger bolts can penetrate metal roofs into the underlying structure to secure standoffs.



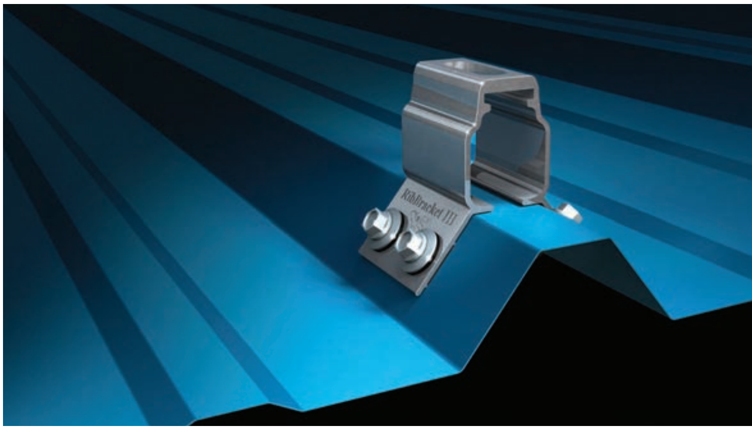
Courtesy EcoFasten Solar

Trapezoidal-Profile Products

A trapezoidal roof panel is similar to a standing seam roof. Both a have a flat section to channel water to gutters below and a raised profile at each edge to allow one panel to overlap the next. What's different is the shape of those raised edges. Non-penetrating clamps are made to fit a trapezoidal profile, but a variety of brackets can fit snugly to the profile, using self-tapping screws to securely connect to the roofing panels.

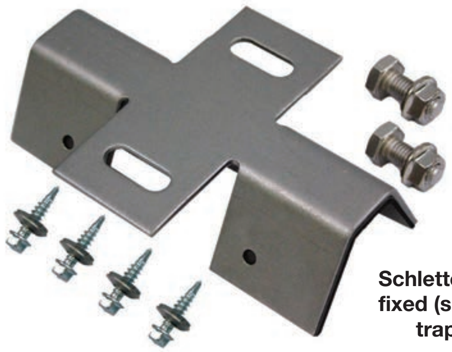
These attachments can be one-piece and tailored to your particular roof profile, such as Schletter's Fix2000 or S-5!'s RibBracket. These products contact both the sides and the top of the trapezoidal profile and are secured with four screws. S-5!'s adjustable ProteaBracket works with a variety of roof profiles, and doesn't have to be custom-ordered. A third bracket option, such as Everest Solar's XpressClip and Mounting Systems Tau+ product, mounts to the flat top of the ridge profile and attaches with self-tapping hardware.

If these three options don't work for your roof profile, Roof Tech's RT- Mount [E] or E Mount AIR rail-free products may be a viable solution, These products have brackets that attach to the roof decking using wood screws. If your roof doesn't have decking, you can use hanger bolts or self-sealing standoffs, such as SunModo's EZ Metal Roof Mount Kits.



Courtesy S-5! (2)

Top & above: S-5! fixed and adjustable trapezoidal-profile mounting products.



Courtesy Schletter

Schletter manufactures both fixed (shown) and adjustable trapezoidal attachments.

Courtesy Roof Tech

Left: Roof Tech's RT-[E] mount attaches through the flat area of roofing to the sheathing below.

EcoFasten Solar's Corruslide adjustable attachment is appropriate for trapezoidal and corrugated roofing.

Courtesy EcoFasten Solar

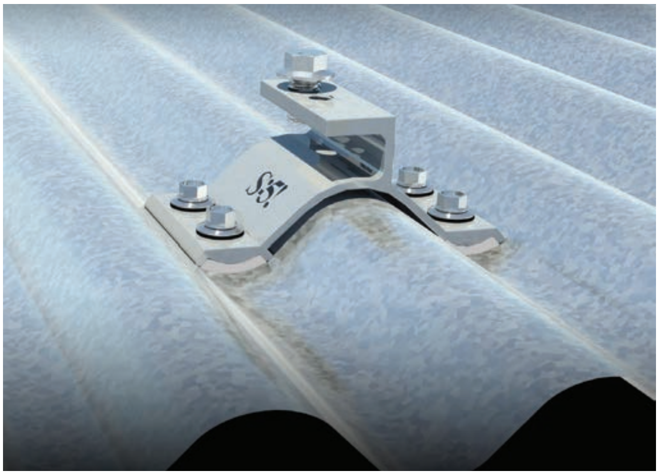
Mounting Systems' Tau+ product mounts to the top of the trapezoid.

Courtesy Mounting Systems

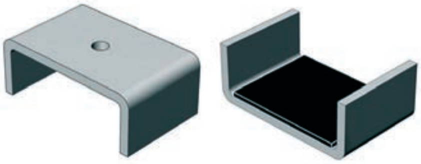
Courtesy SunModo

SunModo's self-sealing standoff can be used on metal roofs without sheathing but must penetrate into the roof support structure.

Courtesy S-5!



S-5!'s corrugated roof mount attaches through the valleys.



Courtesy PLP

Preformed Line Products' simple mount penetrates through the ridge, but bears weight in the valleys.

Corrugated Roof Solutions

Options for these roof profiles are similar to those for other metal roof types. Preformed Line Products' Corrugated Mounting Bridges, the SunModo EZ Corrugated Metal Mount Kit, and the S-5! CorruBracket work by bridging the top of the corrugations and securing to the purlins or decking. EcoFasten's CorruSlide attaches to the roofing panels themselves. If none of these options work well for your roof, you can always use hanger bolts or standoff products.

Making Your Best Choice

In my PV installation career, I've tried many new products. Innovation is generally good. But innovation without testing and experience can be costly. If you're hiring a pro to install your system, ask what products they've used before.

Whatever your roof type, you can be sure that a properly selected and installed PV rack system will provide the support needed, for years of trouble-free clean energy production.

web extras

"PV Racks for Sloped, Asphalt-Shingled Roofs," by Garrison Riegel in *HP181* • **homepower.com/181.22**

"Railless PV Array Mounting," by Justine Sanchez in *HP171* • **homepower.com/171.40**

"PV Racks with Integrated Equipment Grounding," by Justine Sanchez in *HP166* • **homepower.com/166.36**

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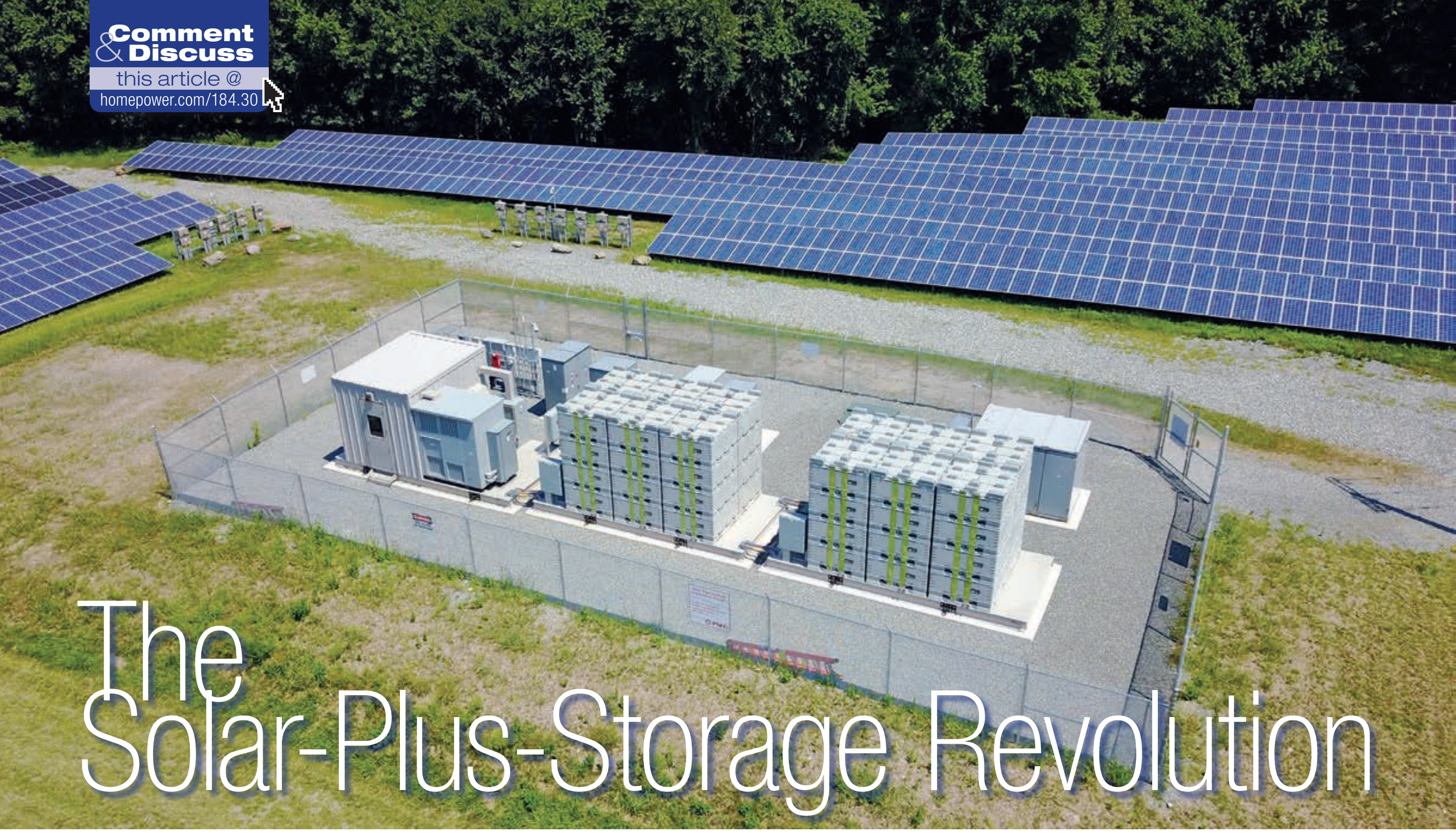


The Solar-Plus-Storage Revolution

Courtesy Eos

by Justine Sanchez

PV systems were born out of a need for power in remote locations. As such, the PV industry established its roots in battery-based systems. Today, it is trending back toward that direction.

Decreasing module and battery prices; changing market dynamics; regional resiliency goals; and additional system benefits gained from residential, commercial, and utility-scale photovoltaic (PV) systems are spurring on the solar-plus-storage "revolution."

The growth of the solar-plus-storage market is on an impressive trajectory. According to researchers from Greentech Media (GTM), the annual deployment of U.S.-based solar-plus-storage systems tripled—from 18 MW in 2015 to 47 MW in 2016. By 2022, annual solar-plus-storage installations are projected to exceed 1.4 GW.

Courtesy NASA

Benjamin Root

The PV industry got its start providing power in remote locations—like in space and the backcountry. Both require energy storage.

> "Solar-plus-storage…In 2016, it might be once a quarter [that] we'd get an inquiry…now, it's once a week, in the 10s-of-megawatts scale."
>
> —Craig R. Horne, Vice President Business Development, Energy Storage, Renewable Energy Systems Americas Inc. (RES). From a panel discussion at the GTM "2017 Energy Storage Summit"

Primary Factors Increasing Deployment

Price Drops

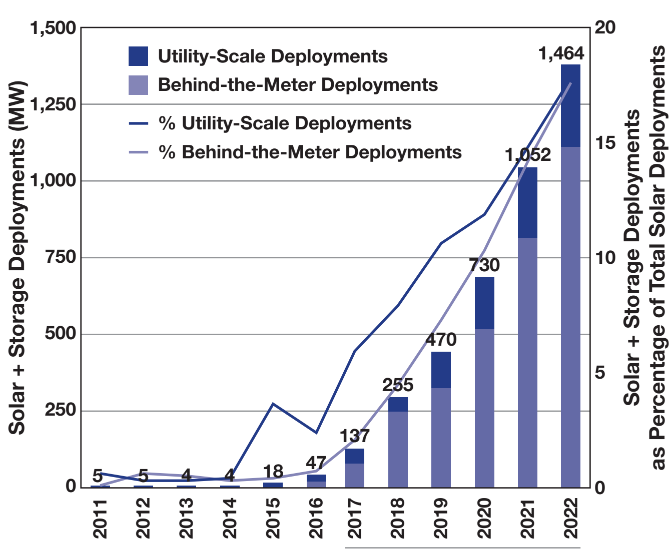
Unsubsidized solar is now competitive with conventional power. In November 2017, Lazard, a financial advisory firm, released its 2017 figures comparing the levelized cost of energy (LCOE) of utility-scale PV systems with that from conventional fossil fuel and nuclear power generation. The low-end cost of electricity from utility-scale PV was $0.04 to $0.06 per kWh, depending on whether the location was sunnier or cloudier, versus $0.06 to $0.07 for coal or natural gas. The cost of electricity from utility-scale wind farms was $0.03 per kWh.

If you account for the federal tax subsidies (ITC and PTC), then LCOE pricing comes down to $0.035 for utility-scale PV-generated electricity and as low as $0.014 for wind-generated electricity. Costs rise when storage is added—the report stated that solar-plus-storage systems generate electricity at $0.082 cents per kWh (unsubsidized). If the storage is placed into service at the same time as the PV is installed, it too can qualify for the 30% tax credit, thus reducing the cost per kWh.

However, since those numbers were published, Xcel Energy released new pricing from bids for future energy generation in Colorado. Out of 87 bids, the median bid for solar *plus storage* was $0.036 per kWh. While there are some unknown details and these projects aren't expected to go online until 2023, the news is compelling. The lowest previous contracted solar-plus-storage bid was in May 2017, for Tucson Electric Power (TEP) in Arizona at $0.045 per kWh.

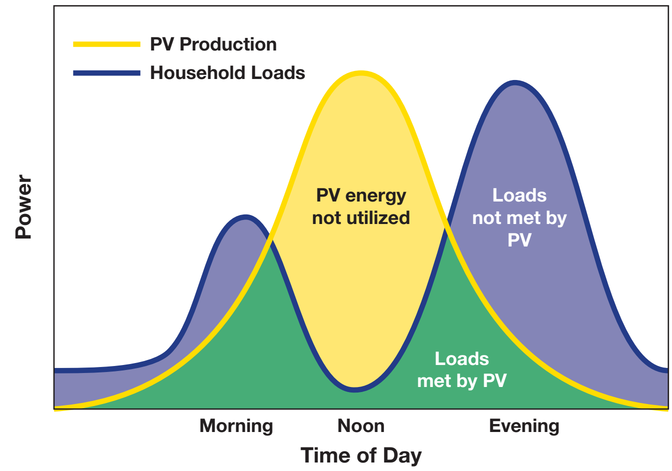
While much of the news concerns utility-scale deployment, residential installations are also cost-competitive in some areas. A panel discussion at the GTM 2017 Energy Storage Summit noted that a residential solar-plus-storage system installed in California's San Diego Gas & Electric, Pacific Gas & Electric, or Southern California Edison's service territory can break even within seven years—even without the self-generation incentive program.

Solar + Storage System Past & Projected Deployments



Source: GTM Research

Peak PV Production vs. Peak Loads



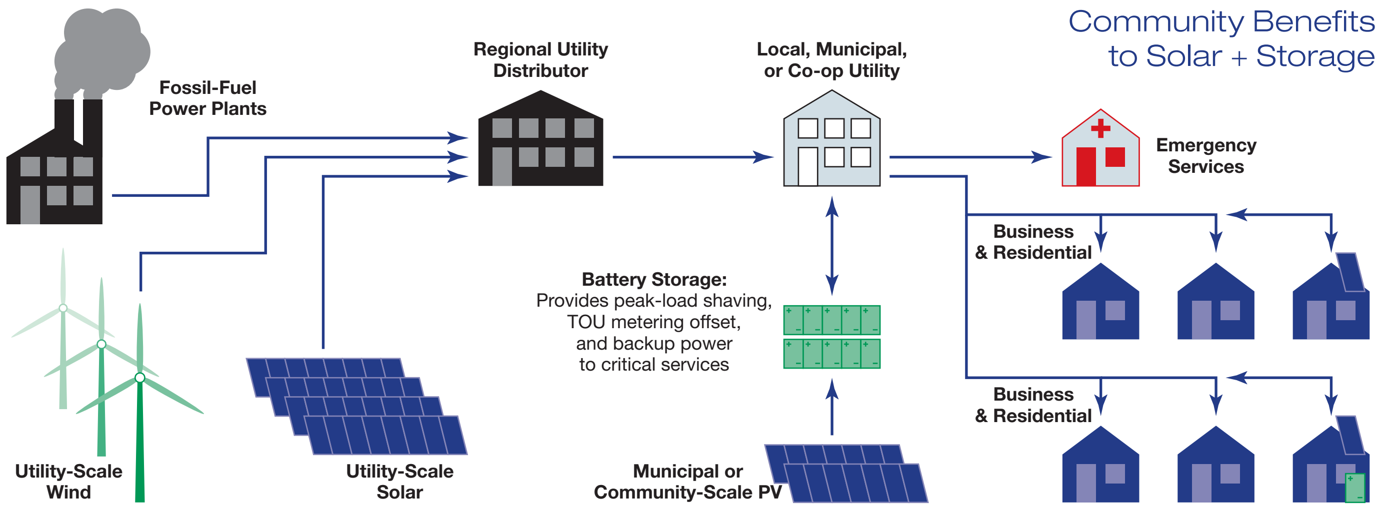
Dispatchable

"Dispatchable" solar is more useful than energy produced by batteryless PV systems, which is only available during the daytime. Peak solar hours are usually from 9 a.m. to 3 p.m., but this doesn't necessarily correspond to the highest demand for electricity. Different utilities have various peak demand times depending on the region, the season, and the common electrical load profile. For example, a utility may experience peak demand from 5 p.m. to 9 p.m.

Adding energy storage provides the flexibility for charging and discharging the battery when it makes the most sense—or cents. This advantage plays out across each market, in various but similar ways. For example, in a residential installation with time-of-use (TOU) metering, charging the battery bank when kWh rates are low and sending those stored PV kWh to the grid when rates are high can maximize the PV system's financial return.

> "Xcel Attracts 'Unprecedented' Low Prices for Solar and Wind Paired With Storage. Bid attracts median PV-plus-battery price of $36 per megawatt-hour. Median wind-plus-storage bids came in even lower, at $21 per megawatt-hour."
>
> —Headline from Greentech Media 1/8/18

Community Benefits to Solar + Storage



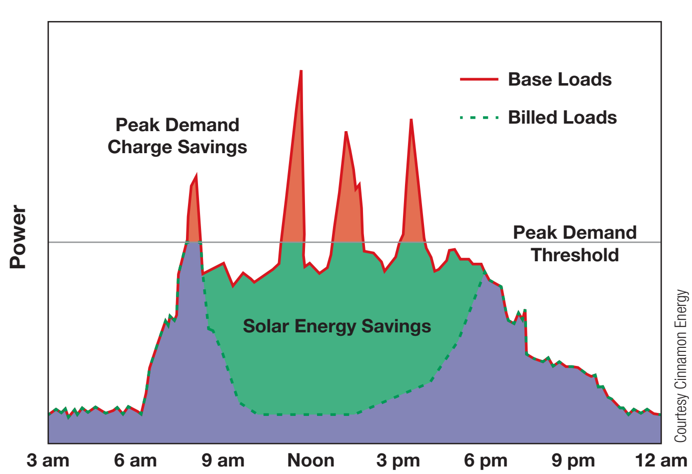
In addition to TOU metering, where energy (kWh) rates vary, power demand charges (watts or kilowatts) are large factors for utilities that purchase electricity from a regional supplier and for commercial customers. Solar-plus-storage provides a way to significantly reduce those peak-demand power costs. A paper by the National Renewable Energy Laboratory (NREL) and Clean Energy Group estimates the potential size of the commercial battery-storage market in the United States. They analyzed representative building load profiles against more than 10,000 utility tariffs, and found that more than 25% of commercial customers may be able to cost-effectively reduce their utility bills by having energy-storage systems (see “Commercial Energy Storage” sidebar).

In the utility sector, peak-demand charges can be an economic hurdle. A local utility may pay monthly and annual fees to its regional grid operator and, in many regions, these charges can be a large portion of the cost of doing business. Having an energy-storage system in which the batteries can be discharged during hours of peak electricity demand allows a utility to significantly reduce its costs for electricity capacity and transmission services.

Greater penetration of distributed RE onto the grid and how to integrate are also issues facing utility operators. Including energy-storage systems can mitigate this. Before PV systems started to significantly contribute energy to a local grid, a utility’s daily load profile was characterized by two peaks—a morning peak (when people wake up and start using electrical appliances) and a larger evening peak (when they return home from work). This two-humped “camel load curve” varies depending on the region and the season. During some times and in some places, the peaks are more pronounced. In temperate climates with fewer heating and cooling loads, the peaks are less extreme. Between the peaks, demand (aka “base load”) was fairly flat and predictable—and primarily met with coal or nuclear power plants that run 24/7, as they are slow and expensive to start or stop. To meet peak loads, natural gas “peaker plants” are commonly used—they are expensive to run, but easier to ramp up or down quickly.

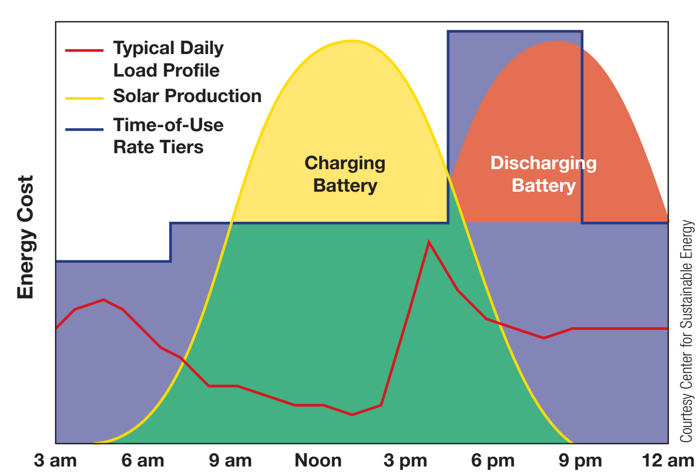
In places where PV system capacity contributes a higher percentage of the overall daytime energy on those grids (such as in California and Hawaii), the shape of the daily load curve

Peak Demand Charge Savings with Solar Plus Energy Storage



Courtesy Cinnamon Energy

Time-of-Use Charge Savings with Solar Energy Storage



Courtesy Center for Sustainable Energy

"In California, I don't know when we will build our next natural gas plant—maybe we are there already."

—Vibhu Kaushik, Director of Grid Technology & Modernization, Southern California Edison. From the panel discussion at the GTM "2017 Energy Storage Summit"

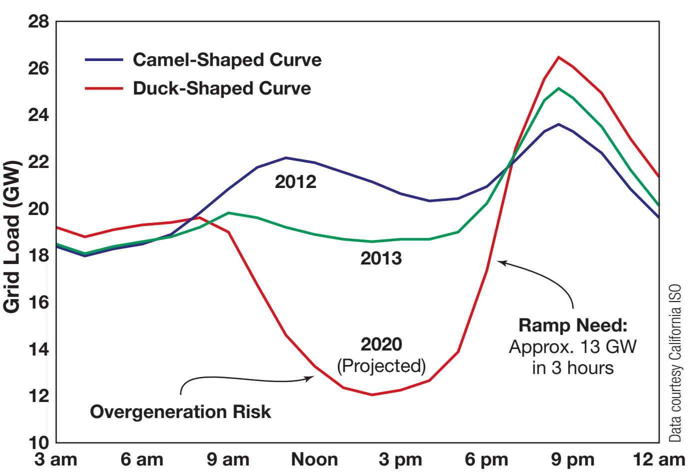
Large-scale facilities are often susceptible to peak demand charges, making energy storage a cost-effective addition to a PV system. Here, a Primus Power 250 kW and 1 MWh Primus EnergyPod are integrated with an existing 230 kW PV system. The combined microgrid system provides several functions, including reducing peak electrical demand typically experienced during weekday afternoons and providing power to critical military systems when grid power is not available.

Courtesy Primus Power

in those areas is different. Instead of a flat base-load in the middle of the day, a downward curve results, since the PV systems are generating their maximum output then. Once the sun starts to set, which also coincides with the evening peak, the curve takes a steep turn up, and is now referred to as a "duck curve."

Historically, natural gas peaker plants met this immediate, steep peak demand. These plants also are used to make up for reduced PV system output due to cloud cover. However, outside of those events and meeting peak demand, peaker plants are not utilized very much, resulting in low "capacity" factors (commonly less than 10%). Additionally, the task of being quickly ramped up and down increases operation and maintenance costs for those plants. The result is that the utilities have an asset that is being unused 90% of the time.

Net Loads: Camel & Duck Curves



Commercial Energy Storage

For the past 15 years and more, companies have been installing PV systems to reduce their energy costs. But PV systems only reduce a company's energy costs, measured in kilowatt-hours (kWh); many companies also incur peak power demand charges. These demand charges are measured in peak kW per month, and can be as high as $20 per kW peak per month. For example, if a company has a 200 kW peak demand and is on an electric rate with a $20 per kW demand charge, they would owe $4,000 per month, just for the peak demand. In some cases, these peak demand charges comprise 50% or more of a company's total electricity bill.

Although a PV system does not significantly reduce these demand charges, a battery storage system can. Battery storage systems can be designed to automatically discharge energy in the battery during peak times, thereby reducing a company's peak demand charge. In the above example, when the battery storage control system senses any demand over 100 kW—perhaps from machinery being started or the HVAC system turning on in the morning. The battery power is used to meet the next 100 kW of demand. The battery can then be recharged from a PV system, or even the grid during non-peak times.

This PV and storage system reduces both kWh and peak kW costs, and can also provide emergency backup power. Backup capability is especially important for companies that are dependent on consistent manufacturing processes or companies that require power for credit-card processing (retailers), communications (service providers), or refrigeration (convenience stores).

—Barry Cinnamon, Cinnamon Energy

"PG&E Will Consider Storage to Replace 3 Gas Plants. The [CA Public Utilities] commission passed an order directing PG&E to solicit bids for clean energy resources to replace three expensive gas plants in Northern California, and to specifically consider storage…Energy storage to replace generation is a strategy California is familiar with. In 2016, the commission directed Southern California Edison (SCE) to conduct an expedited procurement to address the Aliso Canyon gas leak and resulting generator shortages. Three years before that, the commission required the utility to procure some storage and other alternative resources, related to the closure of the San Onofre nuclear plant. SCE wound up far exceeding the target, procuring 260 MW of storage when it was directed to find 50 MW."

—*Utility Dive* 1/12/18

Courtesy Jim Sicile

Battery systems aren't just for balancing surges in supply and demand, but can help in times of no supply, too.

"Three Months After Maria, Roughly Half of Puerto Ricans Still Without Power."

—*The New York Times* 12/29/17

Courtesy LG Chem

Courtesy Iron Edison

Residential systems can benefit from solar-plus-storage systems for many of the same reasons that a municipal utility or business can.

Above: A lithium-ion storage battery system by LG Chem.

Right: A residential nickel-iron storage battery by Iron Edison.

But energy-storage systems can be discharged to supply power during peak demand, solving the same issues that have historically been met with natural gas peaker plants. Energy-storage systems also have the ability to smooth and shape PV system output (for example, when there is variable output due to clouds) and provide backup electricity during utility outages. They also provide ancillary grid services, such as grid voltage and frequency regulation/support, transmission congestion relief, and, in some cases, reduce the need for upgrading transmission and distribution lines. Declining costs for energy storage coupled with its higher capacity factor means that, in some areas, these systems are now cost-competitive with natural gas generation facilities.

Backup Power

Backup power offered by solar-plus-storage increases energy resiliency. According to the National Oceanic and Atmospheric Administration (NOAA), in 2017, the United States was impacted by 16 separate billion-dollar disaster events; the total cost due to damage from these events exceeded $300 billion.

The intensity of last year's hurricanes and subsequent power outages have increased awareness about local disaster and outage preparedness. As of this writing, parts of Puerto Rico, the U.S. Virgin Islands, and Dominica are still without grid power. *The New York Times* reported that, at the end of 2017, about 50% of Puerto Ricans still did not have power; a separate article on December 23, 2017, stated that power might not be fully restored for another four months.

Solar-plus-storage allows PV system owners to access backup power for specified circuits and loads during utility outages, especially helpful if fossil fuel is in short supply for backup generators. Homes and businesses can benefit by having backup for lights, communication equipment, and refrigeration. Utility (or community-scale) systems can provide emergency backup power services for essential circuits—for example, powering communications equipment at police and fire stations, emergency dispatch centers, and hospitals.

The business of generating, storing, and moving electrons is shifting during this energy revolution. It's a "revolution" in two senses—a wide-reaching change in how RE systems are designed and operated, and a reconnection to RE system origins.

RE is being deployed in large quantities, as it is now cost-competitive with conventional fossil-fuel energy sources. Coupled with energy storage, it offers the same benefits of—and several more than—its fossil-fueled counterparts, making this revolution a win for our pocketbooks, a win for our resiliency, and a win for our planet.

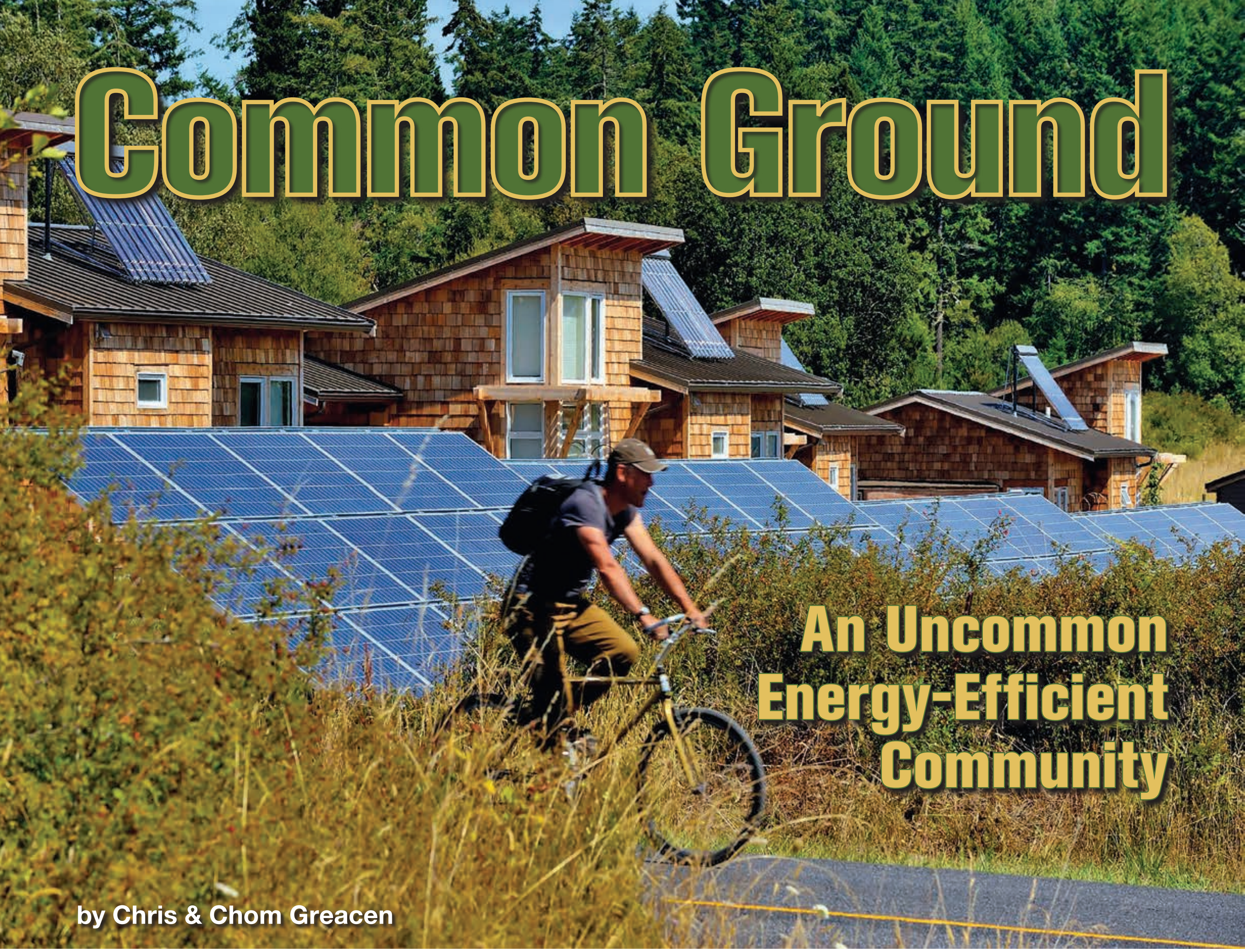
Courtesy Tesla

Kauai Island Utility Cooperative provides a good example of the advantages of energy storage. These systems store renewably generated energy from the island's utility-scale and residential grid-tied PV systems, significantly reducing the need for diesel fuel.

Common Ground

An Uncommon Energy-Efficient Community

by Chris & Chom Greacen



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In 2006, a group of local residents set a goal of creating net-zero-energy (NZE) straw-bale homes as part of the Lopez Community Land Trust (LCLT), an affordable housing project on Lopez Island in rainy Washington State. By 2007, we had architectural drawings and engineering designs. In 2008, we became a part of the resident-builder construction process of 11 homes, and have lived in one of these cozy homes since their completion in March 2009.

Chom Greacen

Project Origins & Objectives

In 1989, home prices on the island rose 189%. Locals found it increasingly difficult to find affordable housing. A group of Lopezians came up with the idea of a community land trust (CLT) housing development as a possible solution. In a CLT, land is held in trust by a nonprofit organization and removed from the speculative real-estate market for perpetuity. The homes are owned by individuals through cooperatives. LCLT homes are allowed to increase their value only 3% (noncompounding interest) per year, thus ensuring permanently affordable housing. There are roughly 250 land trusts in the United States.

By 1992, LCLT had finished seven homes in Morgantown, the first affordable housing project in Washington State. The homes were built with resident sweat equity, working with volunteers, LCLT interns, and contractors. After Morgantown, the LCLT completed Coho (seven homes, 1995); Innisfree (eight homes, 2003); Common Ground (11 homes, 2009); Tierra Verde (four homes, 2012); Salish Way (three homes, 2015); and is working on three additional homes.

Site Design

1 Evacuated-tube solar hot water collectors
2 Potable water tank & pumphouse
3 Rainwater catchment tank & pumphouse
4 Pond for storm-water control & irrigation
5 Rain gardens
6 Bioswale
7 PV arrays

Many who turned to the LCLT for housing did not qualify for traditional mortgages, which usually require excellent credit history and reliable, consistent income history. LCLT negotiated a group mortgage on behalf of the homeowners who formed the cooperative. The cooperative makes mortgage payments to the bank, and each co-op member pays their share of the mortgage to the co-op. Ownership of one share in the cooperative entitles the shareholder to reside in one of the homes. If a shareholder is unable to pay, the co-op tries to work with the shareholder to address the payment issue, taking into account the shareholder's circumstances. A backstop for the first few months of delinquency is to deduct the monthly assessments from the shareholder's equity. Continued nonpayment can be grounds for being asked to leave the cooperative. In that event, the share is sold at full value, but the shareholder receives a reduced amount, reflecting the amount withheld by the co-op for nonpayment.

Built in 2008, the Common Ground community on Lopez Island, Washington, is a showcase of energy efficiency and social collaboration to provide an oasis from rising housing costs.

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The 11 energy-efficient homes use both active and passive solar energy strategies.

Pioneering Affordable Homes

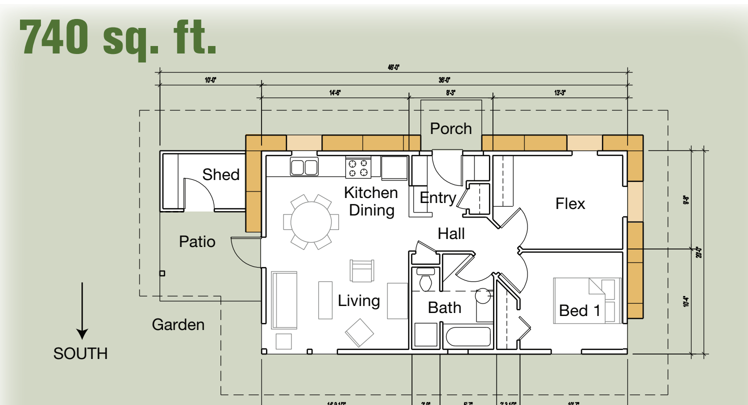
Inspired by a speech by William McDonough, the author of *Cradle to Cradle*, a manifesto calling for transformation of human industry through low-waste and ecological design, LCLT members focused on developing an NZE neighborhood called Common Ground, with a project concept of superinsulated, passive solar, solar-powered, straw-bale homes, with water catchment and permaculture landscaping.

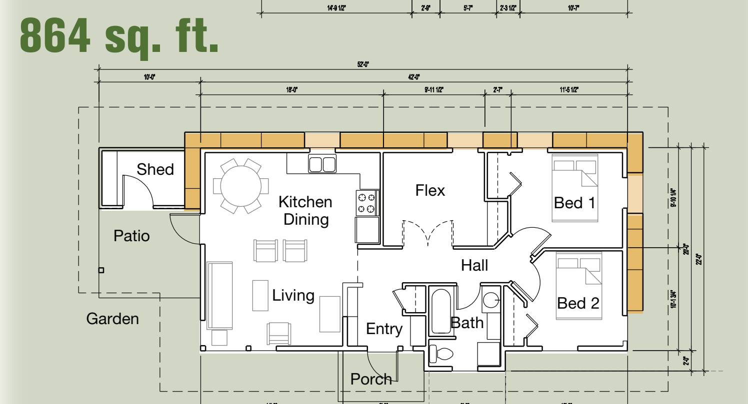
LCLT contracted with solar installer Dana Brandt of Ecotech Energy Systems to further evaluate the NZE concept. Ecotech used recorded data from the three existing LCLT communities of 22 homes and information from existing NZE home projects to estimate the energy requirements for Common Ground homes. Seattle-based architectural firm Mithūn was selected to guide the homes' design. The designs evolved as LCLT and Mithūn made revisions based on available budget, skills, and timeline. The final design called for 11 homes in three different sizes: 740, 864, and 1,160 square feet.

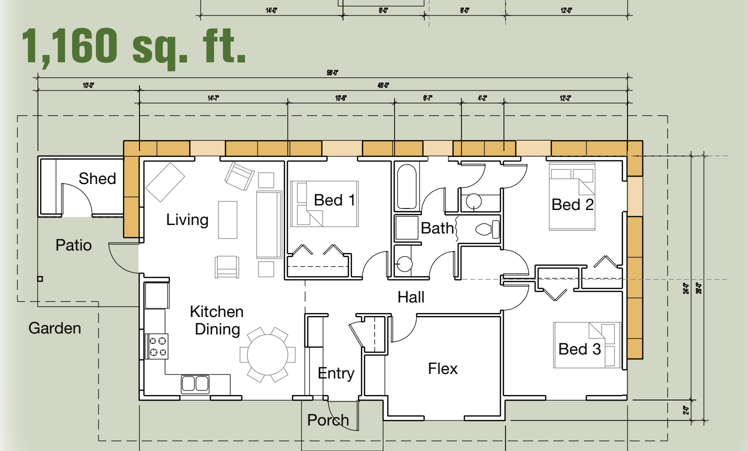
Building Efficiency First

Solar siting and an efficient envelope. With excellent solar exposure from horizon-to-horizon, the homes are oriented with east-west lengths and substantial south-facing glazing for maximum solar gain in the winter. A high south-facing clerestory with operable windows assists with passive, stack-driven ventilation. The floor of each house is a 4-inch concrete slab above a 2-inch layer of R-10 rigid foam insulation. This provides thermal mass for absorbing daytime solar gain. When inside temperatures start to fall, this stored heat is released to heat the space. Several layers of earthen (interior) and lime plaster (exterior) finish over the straw bales provide additional thermal storage.

The north, east, and west walls are nonload-bearing straw bale (timber-frame structure) providing R-34 to R-42—double the level required by local code. The south walls are 2-by-6 studs, with blown in cellulose for R-21. A cathedral







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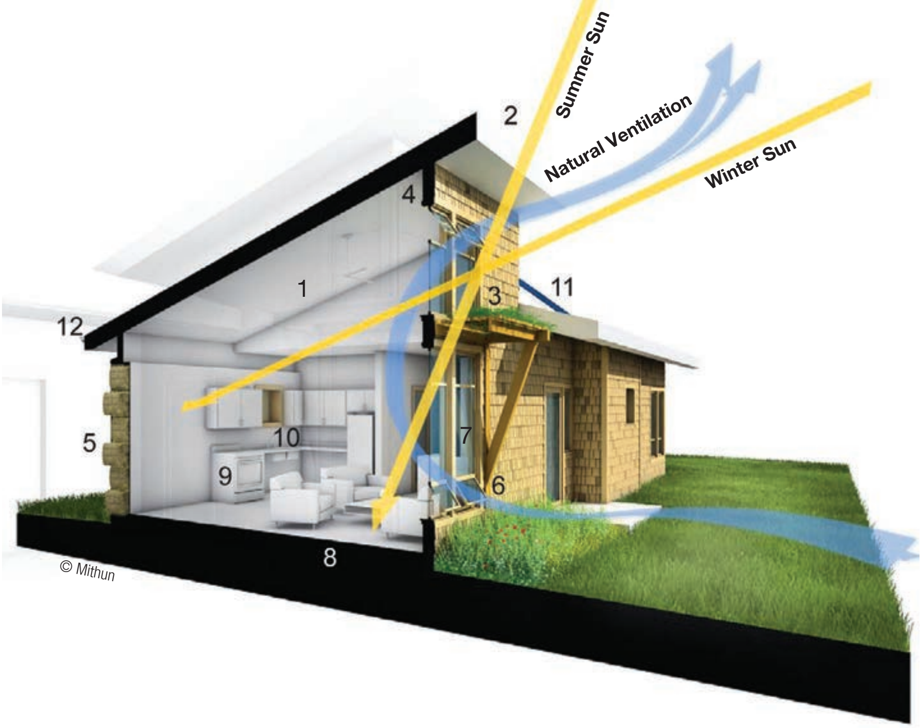

House Systems

1 Home sizes are small to reduce energy and resource use.
2 Overhangs were sized to allow heat gain in winter and provide shading in summer.
3 Vegetated trellis shades lower windows.
4 Superinsulated roof and walls.
5 Straw bales at north, east, and west walls provide insulation.
6 High-efficiency operable windows optimize solar performance, natural cooling, and ventilation.
7 Solar shades on window interiors.
8 Concrete floor provides thermal mass.
9 Energy Star appliances & lighting.
10 Water-saving plumbing fixtures.
11 Rooftop solar water heating system.
12 Rainwater catchment system provides water for toilet flushing, washing machines, and storm-water control.

ceiling above the kitchen and living room is insulated with spray foam for R-50. All other rooms have a dropped ceiling insulated with 14 inches of blown-in cellulose, also R-50. All windows are argon-filled, low-e coated, and double-pane. Windows on the south, west, and east walls have a 0.31 U-factor, an SHGC of 0.61, and a VT rating of 0.63 with double glazing and insulated spacers to maximize solar insolation. The windows on the north walls have a 0.27 U-factor, an SHGC of 0.28, and a VT rating of 0.49 with double glazing and insulated spacers to maximize heat retention.

Space heating & ventilation. Our initial building performance calculations suggested that passive solar gain could provide 40% to 50% of heating needs. At the time, minisplit heat pumps were not available, and ground-source heat pumps were cost-prohibitive, so we chose electric resistance heaters for backup. Since their initial occupancy, five of the homes have been retrofitted with minisplit ductless heat pumps. These work extremely well in the Pacific Northwest, where temperatures hover around 50°F much of the winter, and rarely fall below freezing. Whole-house fans provide supplemental ventilation. We retrofitted our house with a heat recovery ventilator (HRV), which uses a heat exchanger to preheat fresh outside air using outgoing stale air. The homes' performance were tested using a blower door test and infrared camera. During the blower-door test remaining leaks were identified and the house sealed for less than 2.5 air exchanges per hour. (Passive House standards dictate an ACH@50 Pa of 0.6 or less.)

Appliances. Lighting was initially all CFL, but since 2013 has transitioned to LEDs. Refrigerators are Energy Star-qualified models. Washing machines are low-water, front-loaders. All homes were equipped with electric clothes dryers, though many occupants choose to hang their clothes. Kitchens in

Inside, natural, nontoxic finishes help ensure good indoor air quality.

© Mithun | Juan Hernandez (2)

Thick straw-bale walls offer good insulative value. The earthen plaster walls and concrete floors provide thermal mass.

Courtesy LCLT

Evacuated-tube solar water heating systems offset up to 75% of each household's domestic hot water.

most of the homes were outfitted with conventional electric ranges, though two homeowners chose to use propane. Only one house has a dishwasher (added several years ago).

Water systems. Three sources of water serve the LCLT. The first is conventional well water, with a class-A treatment system (chlorinated, with arsenic removed) and a 23,000-gallon storage tank. This is used for all potable water, for the kitchen, bathroom sink, and shower/bath. The second water system is rooftop rainwater catchment, plumbed on separate lines into each house for nonpotable uses, including toilet flushing, clothes washing and outdoor spigots. Water that falls on the metal roofs is collected using gutters and flows to a 34,000-gallon metal storage tank located at the edge of the Common Ground neighborhood. We had hoped to have the rooftop catchment system be the only water source used for all household purposes, but San Juan County required the well and class-A system, which has proven to be a considerable expense for the LCLT. The third system is pond water, collected as runoff from the site via a swale and ditch, which is used for three household gardens. Water is conserved in the houses through the use of low-flow showerheads and low-flush toilets.

Courtesy LCLT

The solar water heating system includes an 80-gallon SuperStor tank with built-in heat exchanger and a FlowCon FA glycol pump station. The glycol is heated by rooftop-mounted Thermomax evacuated-tube collectors.

Active Solar Energy

Solar water heating. Twenty rooftop-mounted Thermomax evacuated-tube solar collectors provide up to three-quarters of each household's domestic hot water. When the temperature in the solar manifold on the rooftop exceeds the temperature of the water in the solar storage tank, a pump circulates solar-heated propylene glycol through a heat exchanger built into the lower portion of the HTP brand water tanks. Larger homes have 80-gallon tanks; smaller homes use 50-gallon tanks. A 240 VAC heating element in the uppermost portion of the tank provides backup heating. Thanks to the physics of thermal stratification, this means that the electric element heats the water in the top tank, leaving cooler water at the bottom of the tank that the solar system, when available, can heat.

Starting in early April, several households (ours included) turn off the circuit breaker to the tanks' heating elements to heat entirely with solar. When daylight hours grow shorter in October, we flip on the breaker. But we're convinced that solar-heated showers feel better.

When the CG homes were built, evacuated tubes were the best option for solar water heating. In subsequent years, the price of PV has plummeted, and affordable heat-pump water heaters have become available. In Tierra Verde, built after CG, instead of evacuated-tube collectors, the LCLT elected to add another kW of PV modules and use heat-pump water heaters instead.

This has several advantages. First, it works better with the seasonal availability of sun in our climate. We get a lot of sun in the summer—so much that CG's water tanks need to be monitored to ensure that they don't overheat. Overheating triggers the water tank's pressure-relief valve, losing hot water. This is dangerous, as pressure-relief valves are not designed for routine use, and venting hot water outside—near straw-bale walls—is exactly what they do not need. During the summer, some households, ours included, turn a portion of the evacuated tubes away from the sun to reduce system overheating. During the winter, when the number of sun-hours dwindles, the evacuated-tube systems don't typically generate enough hot water and we have to turn on the tanks' electrical heating element.

Another advantage of using a PV array and heat-pump water heater is that there is less plumbing. Our solar water heaters have worked pretty well, but we have piping and circulation pumps and propylene glycol that needs to be replaced every few years. Wiring takes much less maintenance.

Solar electricity. From its inception, we wanted Common Ground to use renewable electricity. Lacking falling water and biomass, the two options we considered were wind and solar. A comparative feasibility study conducted by A World Institute for a Sustainable Humanity (AWISH) investigated both options, making use of a loaned anemometer mounted on a 100-foot tower. The results of the study were conclusive—we had a good solar site and a marginal wind site. Even in 2007, PV modules would be cheaper for us than wind turbines, and it was a pretty easy choice to go with PV technology.

The utility didn't allow LCLT to install one large community array. Instead, 11 individual 3 kW grid-tied systems were installed, one for each home. This cost more but also triggered a larger subsidy.

Courtesy LCLT (2)

The next decision was whether to have a single, large shared array or a collection of 11 smaller arrays, one for each house. Our preference was one single array and also to have the entire cooperative served by a single utility revenue meter. Installation would be less complex and the system less expensive to install. If Common Ground were to have a single utility revenue meter, we would have had to pay only a single base meter rate, saving about $4,900 annually at today's rates. But the day we were prepping the groundwork for the electricity installation, three yellow utility trucks pulled up, with the general manager of the local cooperative electricity utility, Orcas Power and Light Company (OPALCO), who informed us they had changed their minds. We weren't sure why, but we guessed it had something to do with the $4,900 per year they would gain by having the monthly meter charge from 11 meters instead of one. By then it was too late to appeal. On the bright side, OPALCO offered subsidies for customer-owned, grid-intertied PV systems at $1.50 per watt, peak. The subsidy was capped at $5,000 per system. This helped soften the blow of having to change our plans—we received $49,500 in subsidies from OPALCO after the systems were commissioned.

With help from NW Seed (now NW Spark), a Seattle-based RE advocacy group, a request for bids (RFB) was issued. The RFB instructed companies to submit bids that included cost savings by using local resident and volunteer labor. After reviewing proposals from several companies, Power Trip in Port Townsend was chosen because it met technical specifications, had an attractive price offer, and had a great reputation. Power Trip designed and procured equipment for 11 identical 3.075 kW batteryless GT PV systems. Their bid included labor only to install the first two, which would serve effectively as reference model systems. Washington law allows homeowners to pull their own electrical permits. Making as-needed visits to the professionally installed system to examine how the installers treated certain details, homeowners and interns installed the remaining nine systems.

Each PV system has 15 Evergreen 205 W PV modules feeding a SMA Sunny Boy 3000 inverter. Electricity production is metered with a utility AMR meter that is read remotely by OPALCO. PV production is compensated through Washington State's RE production incentive. For the first few years, we were compensated $0.15 per PV kWh produced, but in 2017, this dropped to about $0.081—OPALCO's quota under the Washington RE production incentive is heavily oversubscribed and is parsed out pro-rata.

OPALCO provides an annualized net-metering, earning monetary credit for surplus solar energy produced during the summer and drawing on these credits when PV production is less than consumption. Homeowners whose homes are net-positive energy producers are compensated by OPALCO for their surplus electricity in July of every year at $0.04 per kWh, a rate roughly equal to the utility's wholesale electricity cost.

Wide-open solar exposure on the site's southern boundary made a ground-mounted array preferable.

Courtesy LCLT

Community members and volunteers worked together to build the straw-bale homes.

Courtesy LCLT (2)

Community & Home Building

Residents put in "sweat equity" to complete the project. We were a diverse crew, ranging in age from early 20s to over 70 years old. For our family, the quota was 26 hours per week, calculated based on the square footage of the home. In addition to future residents, construction labor was also provided by "building partners" (friends and family) of future residents to help meet their respective sweat equity requirements, and by a wonderful cohort of national and international interns. Many of the interns were recently graduated from college and, after four years of sitting at desks, were eager to work with their hands on a sustainable construction project. Others were retirees and folks in career transitions who dedicated several months of their lives to participate in a meaningful project.

Interns boarded in the homes of Islanders, typically exchanging eight hours of additional labor per week at their hosts' homes for a room—all arranged by LCLT. Additionally, the project accepted walk-in volunteers once they had been checked out on tool safety. Professional carpenters worked side by side with the interns and volunteers, providing hands-on training when necessary. Each weekday began at 8 a.m., rain or shine, with a safety talk and discussion of the days' activities. A local restaurant, Vitas, provided hot soup most days at lunchtime, and a local bakery, Holly B's, provided goodies consumed during the workday's two 15-minute breaks. Residents, interns, and volunteers did most of the construction, but LCLT hired contractors for the rough framing, drywall, plumbing, and electrical.

The straw-bale building process was perfect for an untrained volunteer workforce on a budget.

Courtesy LCLT (3)

Straw-Bale Construction in the Pacific Northwest

Straw-bale buildings require “good boots and a good hat.” The “good boots” means a foundation sufficiently high off the ground to protect the plaster and bales beneath from rain splatter, and keeping the walls free from moisture from plants. A “good hat” means sufficiently deep eaves to protect the plaster-and-bale walls from wind-driven rain.

Our hat initially wasn’t so good. Engineering, architecture, and cost decisions led to relatively small eaves. After three years of residency, water damage was causing mold growth in some straw-bale walls, particularly those exposed to our island’s strong southeast winds that bring driving rain. The primary factor was the quality of lime plaster used, which ended up acting more like a sponge and less like a raincoat. Many problem areas were transitions between materials—for example, where lime plaster interfaced with wooden windowsills.

Fixing the problem was expensive, time-consuming, and anxiety-producing. LCLT purchased specialized moisture removal equipment and we drilled dozens of holes in each wall and attached tubes that siphoned moisture from deep in the walls. We built generous awnings over east- and west-facing straw-bale walls. Two of the straw-bale walls had to be completely rebuilt. We have implemented an annual inspection process in spring during which we take moisture readings with a long straw-bale probe, and, over the years, have applied layers of additional lime-wash using a higher-quality lime. The problem that once loomed large seems to have been remedied.

While the straw-bale walls are beautiful—people love the gentle curves in the spaces—they’re a lot of work in this climate. Subsequent LCLT building projects chose other insulation materials.

Courtesy LCLT

Cooperation and camaraderie during the building process made for an emotional investment in the community.

“My heart grew three sizes,” says one resident of the construction process. The homes were built in concert with each other, with everyone working on each of the homes as needed. Working side by side, we shared stories, music, laughter, and developed a deep trust in each other. When challenges emerged, this bedrock of trust held us together. The alchemy of working together fostered an atmosphere in which everyone’s contributions were valued. Those who were highly skilled in the trades often handled more difficult tasks, or accomplished them more quickly. But those learning carpentry were encouraged to move at their own pace, prioritizing safety and following the carpenter’s maxim: “Measure twice, cut once.”

In CG, NZE Relies on End-User Behavior

We found that user awareness and behavior accounts for huge differences in electricity consumption. After move-in, residents took weekly meter readings of electrical consumption. By sharing this information and nurturing awareness of energy conservation, we achieved the largest reduction in electricity usage among the outlier households with high consumption levels.

The monitoring continues, albeit now on a monthly basis. Despite the initial decline in usage by the largest electricity users, differences remain. Compared to the homes with the lowest usage, the homes with the highest consumption use roughly three times as much electricity each year. This is not due to the number of people in the household: one of the households with the lowest annual consumption has four people. The difference in consumption patterns can be attributed to user behavior. Do you like to keep your house really toasty most of the time? Do you take long baths in the winter? Do you use the electric clothes dryer or hang-dry your laundry?

Notwithstanding the differences between households, our average annual consumption per household is 5,900 kWh—about 47% of the Washington State average and 54% of the U.S. average household electricity use. Our average PV production per 3.075 kW array is about 3,730 kWh per year. As a community, we are not NZE—an average household at Common Ground generates 63% of its own electricity from PV while importing the remaining from the grid—but four CG households have been certified as NZE by the Living Future Institute, with two households meeting the NZE goal year after year.

LCLT Home Stats

Total LCLT homes completed in 2015	42
Local businesses owned or run by residents of LCLT homes	16
Total land trust homes with on-site PV production	20 (48%)
Average monthly LCLT household electricity consumption	492 kWh
PV system size	3.075 kWp
Average annual PV production per Common Ground Home	3,730 kWh
Lowest annual household energy consumption at Common Ground (Nov. 2016 to Oct. 2017)*	2,737 kWh
Highest annual household energy consumption at Common Ground (Nov. 2016 to Oct. 2017)*	8,401 kWh
Number of households that have met the NZE annual goals	2*

*These two households have the same number of occupants (4).

Chris Greacen

Choosing to live in community takes commitment, but the work is empowering and fruitful.

Courtesy LCLT

Smaller Footprints, Larger Lives

Common Ground is about reinventing the American Dream. In the coming years, Americans will do well to shed entrenched habits of consuming stuff. We can embrace these adjustments if we are confident that our country is headed toward a more fulfilling transformation. We believe this transformation is really about revealing what it means to be truly human, not as "consumers," but as friends, neighbors, citizens, and co-creators of a compelling new story that supports a healthy planet and social justice. Our community is about smaller footprints and larger lives.

Resources

Ecotech Energy Systems • ecotechsolar.com • Energy systems design

Mithun • mithun.com • Home design

PowerTrip Energy • powertripenergy.com • PV systems installation

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Load-Side Connections

by Ryan Mayfield

Article 705 in the *National Electrical Code* covers the interconnection of electric power production sources to a primary power source, typically the utility. This *Code* article is not specific to PV systems; it applies to any power production equipment that interconnects with the primary source of electricity. In the "Scope" section, 705.1, an informational note indicates that primary power sources can include a utility supply or on-site electric power source.

In 2017, notable changes in Article 705 took place. First, a few definitions have been added with respect to microgrids, defining what a microgrid is in addition to a microgrid interconnection device. Second, the definition for inverter output circuits no longer includes "utility," given that the inverter can interconnect with a source other than a utility. The term "inverter output connection" has been replaced with "power source" within the text of 705.12(B). While the changes in definitions and section titles likely don't affect any PV system interconnection, the language within this Article is more inclusive of other systems that may interconnect to a primary source of electricity.

Beyond the definitions and terms, the focus of this "Code Corner" is Article 705.12(B) [705.12(D) in 2014]—load-side connections. The point of interconnection is allowed at the load side of service disconnecting means at any distribution equipment on the premises. Making a connection in the main service panel is not required—downstream subpanels are perfectly acceptable for interconnection points.

To make a connection on distribution equipment, five subsections of the 2017 *NEC* must be met, one less than in 2014 (Tentative Interim Amendment 14-11 deleted 705.12(D)(6) in its entirety and in 2017 it was omitted). Read each of these subsections carefully—in some cases, the calculations are based on 125% of the power source's output circuit current; in others, the calculations are based on the overcurrent devices' ratings.

The first requirement is that "each source interconnection of one or more power sources installed in one system shall be made at a dedicated circuit breaker or fusible disconnecting means." This does not necessarily require an interconnection circuit breaker for each individual inverter, but rather one for the entire system per the manufacturer's instructions. For microinverter-based installations, this will result in having multiple microinverters on a circuit; string inverters will typically have a dedicated circuit breaker or fusible disconnect.

The first subsection in 705.12(B)(2) covers connections directly to feeders. In this case, the power source output would be connected to a feeder that is not at the opposite end from the overcurrent protection device (OCPD) that protects that feeder. When this output connection is not on the opposite end of the OCPD, there is a risk of overloading the feeder. Thus, to meet the requirements of 705.12(B)(2)(1), the feeder conductor being connected to must either be sized such that the conductor's ampacity is large enough to handle the sum of the primary source OCPD and 125% of the power source's output current, or there must be an OCPD on the power source connection's load side that is not larger than the feeder's ampacity. Meeting either of these two requirements will ensure that the feeder conductor does not have an excessive amount of current on it from the two power sources.

The section that follows addresses the typical taps that electricians are accustomed to. When a tap is made on the same feeder that is connected to a secondary power source, Section 705.12(B)(2)(2) requires that the methods used to size the tap conductors—as calculated in 240.21(B)—include both the rating of the OCPD protecting the feeder and 125% of the power source's output current. As with the feeder calculations in the above section, this ensures the tap conductors installed will be sized for all the power sources present.

The third subsection deals with connections made to the busbars in panelboards. This is likely the one that most installations on the load-side of the main OCPD will refer to. The first subsection, 705.12(B)(2)(3)(a), allows a power source connection anywhere on a busbar as long as 125% of the power source's output circuit current plus the OCPD rating

A PV source interconnection made at a subpanel. The interconnection breaker is at the opposite end from the main feed, and is marked not to be moved.

Benjamin Root

protecting the busbar do not exceed the busbar rating. For example, if you have a PV system with 16 A of rated inverter output and a residential panelboard with a 225 A busbar rating protected by a 200 A main breaker, the sum of the main OCPD and 125% of the inverter output (200 A + (16 A × 1.25) = 220 A) does not exceed the busbar rating. Therefore, there would be no restrictions on the PV system breaker's location.

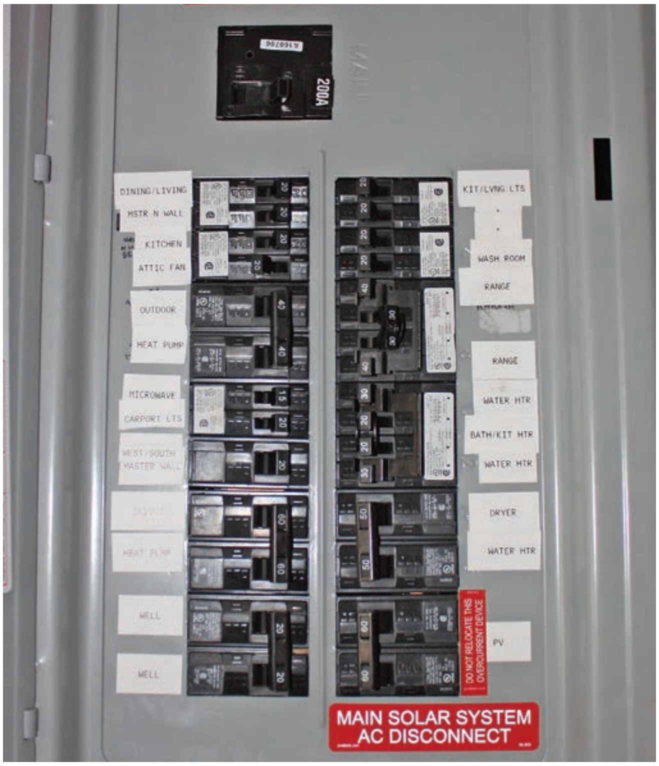
While that example is uncommon, the next section, 705.12(B)(2)(3)(b), covers one of the most common scenarios—often referred to as the 120% rule. In this case, the sum of the main OCPD protecting the panel and 125% of the power source's output current can exceed the busbar's rating, but by no more than 120% of the bus's rating. In addition, the two power source breakers must be at opposite ends of the busbar. A residential service panel rated at 200 A and protected by a 200 A breaker can support a PV system with a continuous output current from the inverter that is 32 A or less, as long as the breakers for the two power sources are located at opposite ends of the busbar.

This 200 A busbar can support 120% of its rating per *Code*, or 240 A. In this case, the main breaker is 200 A, leaving up to 40 A for the PV connection. However, 125% of the output current needs to be used in this calculation (32 A × 1.25 = 40 A). By no coincidence, many inverter manufacturers offer inverters rated at 7,680 W to match this limitation. This type of connection requires a label at the PV system's point-of-interconnection breaker; the *NEC* requires specific language on the label indicating that the breaker cannot be relocated.

The third busbar subsection is commonly applied when multiple inverter circuits are aggregated prior to making the interconnection, although it can be applied to point of interconnection situations as well. The subsection requires that the sum of the breakers in a panelboard (load and source) is less than or equal to the busbar's rating. In this calculation, the rating of the OCPD protecting the panelboard does not need to be used, but the main OCPD's rating cannot exceed the panelboard rating. As with the above section, specific labeling must accompany this option.

Let's say there's a 100 A subpanel protected by a 100 A breaker in the main panel. If the existing subpanel only had load breakers that add up to 60 A, you could interconnect PV breakers that sum up to 40 A or less. A more common scenario is a situation in which multiple inverter circuits are aggregated before making the interconnection. This section essentially dictates the sizing of this AC aggregation panel, making the panelboard ampacity rating greater than or equal to the sum of the breakers contained within it. One of the great functions of this section is the ability to add a small monitoring load in that same panel without having to oversize the panelboard, as older *Code* cycles were often interpreted to specify.

For some installers, the addition of 705.12(B)(2)(3)(d) is a big improvement for interconnections, since it allows a power source's interconnection to center-fed panelboards. The requirement specifies that a connection be made at one end of the busbar only and that the 120% rule is not violated for the busbar rating. The next subsection requires



Benjamin Root

A PV source interconnection made at a bottom breaker of a top-feed main distribution panel. The breaker is marked as PV input and not to be relocated.

engineering supervision for interconnection on multiple-ampacity busbars. These are most commonly found in commercial applications and because there are busbars with different ampacity capabilities, it is necessary to engage an engineer for proper interconnection.

The next two subsections in 705.12(B) have undergone no changes from 2014. It still specifies that the breakers used shall be suitable for the application, meaning they must allow backfeeding. In general, unless a circuit breaker has "line" and "load" markings, indicating a required current flow, circuit breakers used in typical panelboards will meet this requirement.

Finally, the last subsection states that the breaker used for interconnection does not need to meet the fastening requirement of 408.36(D) when interconnecting with a power source that is listed as interactive. This applies to the grid-direct inverter output since they cannot produce power with the absence of the utility. However, a fastening kit may be needed for battery-based inverter output since this equipment can continue to operate when the grid is down.

The section addressing interconnection of power sources to the utility can get tricky in some cases, so careful examination of your approach and all the specific rules that apply should be reviewed prior to installation. Also be aware of the disconnect requirements in 705.22 and rapid shutdown initiation requirements in 690.12, as these can add to the equipment required for interconnection.

On the Fence

by Kathleen Jarschke-Schultze

For the most part, I grew up in the country. I had country-kid skills. I could slip through a barbed wire fence without getting snagged. I herded cows to the milking barn on my Auntie Bea's dairy. I knew the Pasture Prime Directive: When you come upon a gate, open or closed, leave it how you found it.

When my husband Bob-O and I lived at the edge of the forest, our whole county was open range, but nobody ranged their cattle in the woods. Moving to our current homestead was my first experience being surrounded by open range and dealing with roaming critters.

Our parcel of 10.2 acres held the roundup cabin, hay barn, and corral and chutes for the large cattle ranch that had been subdivided and sold off. About 5 acres around the cabin were fenced with the typical four strands of barbed wire attached to cedar posts, but the fence was old and run down in places. There was a metal gate across the road at the bottom of the property and a wooden plank bridge over the creek with gaps that served as a cattle guard.

That first autumn, Bob-O and I realized we would have to fence the area we wanted to grow vegetables in, since the deer jump right over barbed-wire fences. Ever resourceful, we cut and used lengths of irrigation pipe as fence posts. The pipe had once been used to transport water from a now-defunct water ditch on the hillside above our house. We bought 6-foot-high "rabbit" fencing to attach to the posts. The horizontal spacing is smaller toward the bottom of the fence—where protection against rabbits and varmints is needed most. Toward the top, the upper spacing allows your hand (or as we found out, a raccoon) to pass through. We fenced the only piece of flat ground within the 5 fenced acres for our vegetable garden. At one end, we installed a 4-foot-tall gate with a PVC arch over it to deter the deer from jumping over it. The back of the garden area was covered in brush; the side along the road I planted with lavender and rosemary shrubs.

While our garden was protected from deer, that still left the rest of the land—and the shaggy range cattle that would jump the barbed wire fence almost as easily as the deer. When the cows jumped the barbed wire, my trusty canine companion Amelia Airedale and I would go shoo them back over the fence. If there were several, I would sneak around them, open the bottom gate, and herd them out.

Still, it was disconcerting to walk out the front door and come face to face with a 1,600-pound cow in the yard. Range cattle are not as docile as the dairy cows I knew. They will just as soon turn on you, as not.

One morning, I looked out the front window and thought I saw a big black cow. I called Amelia and we headed out. As we crossed the field, it became apparent that it was a huge bull—about 2,200 pounds of half-wild creature was giving us the eye. Amelia stayed by my side and kept looking up at me like, "Are we really going to do this?" I picked up a piece of 2-foot-long PVC pipe and held it above my head, trying to look bigger than I was. Yelling as loudly as I could, I ran for the bull and Amelia ran alongside, barking excitedly. Lucky for us, the bull decided to jump back over the fence and went on his way.

Please Fence Me In

We needed to re-fence our space. Although we live on open range, we have the right to fence our property. If the freely roaming cattle or horses knock or tear down our fence, we have every lawful right to repair or replace it, but few other options. So it's best done right the first time.

We replaced the barbed-wire fence with 6-foot-high metal livestock fencing. Usually, this won't totally stop deer, but there is plenty of forage for them beyond the fence until late summer. Harvest time is when our garden is a sea of green in an ocean of brown, dry hillsides. That's when we get the deer or, as we call them, brown goats.

A Creek Runs Through It

We were able to fence our 5 acres except at the bridge and the gates. We did fence over the creek, but it had to be high enough to let the creek run under it in the winter. When the creek dries up, the gap can be access for any number of varmints, but especially deer.

Bob-O saw it as a personal challenge to stop the deer from entering our yard. When we replaced the old wooden bridge with a railroad flat-car base, we installed a solar-powered automatic gate. The combination of the noisy metal deck and the closed gate kept the deer at bay. I strung Tibetan prayer flags about 10 feet high above the lower gate. That made the area over the gate more difficult for deer to jump through.

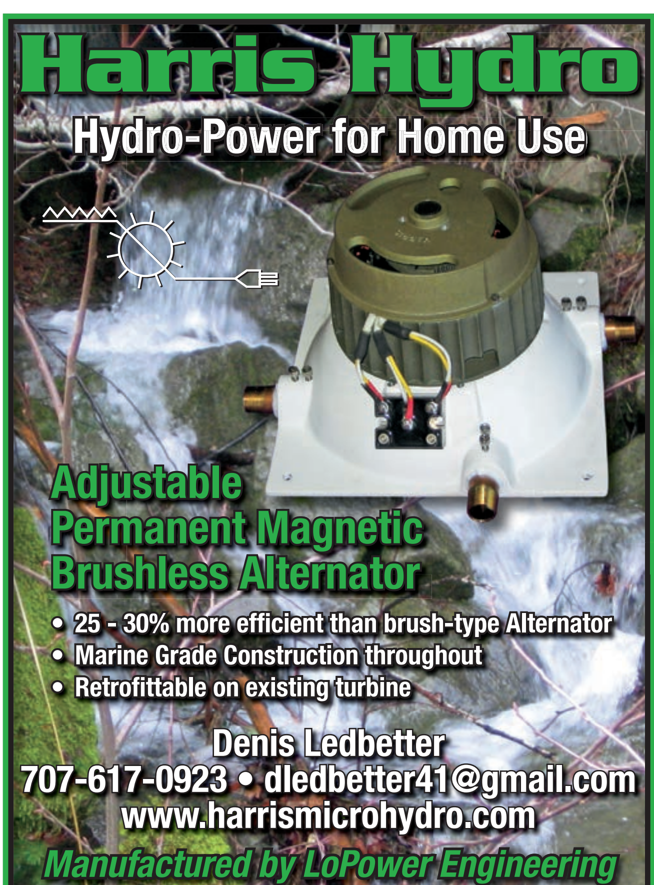
But somehow the deer still made it into our yard. At night, Amelia would run out her dog door and race up the hill to the water tanks, barking loudly, then trot home, her work done. One evening, she did happen to scare a doe and her fawn. The fawn took off in the dark. When we heard it crying, we went out to investigate.

The fawn had its head stuck in one of the wire squares of the panel fencing. The doe remained nearby as we approached with flashlights. Bob-O tried to free the stuck fawn, but it would thrash and kick, crying out. The doe was unhappy and so was Bob-O, but he was determined to free the fawn. He moved closer making soothing sounds. The fawn rested, panting heavily. But when Bob-O was a couple of feet from the fawn, it freaked out, bucking and kicking. All of a sudden the fawn pulled its head free and fled to the doe, who had moved threateningly close to us. Both the doe and the fawn took off.

Home De-Fence

Whenever a deer would breach our defenses, Bob-O would walk the fence and repair any bent or loosened fencing. We bought a used water tank from our neighbor and it sat next to the bottom gate. One day, though, as Bob-O looked out our picture window, he saw five deer—on our side of the fence—saunter toward the gate. One by one, they disappeared along the fence line behind the tank. And one by one, they reappeared not only on the other side of the tank, but also on the other side of the fence. Bob-O quickly fixed the hole in the fence behind the magic water tank.

Maintaining the fences is an ongoing job. Just like the cowboys of old, we "ride fence" to repair it, only we do it in Evie, our electric golf cart. Giddy-up!



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DIY Thermal Imaging

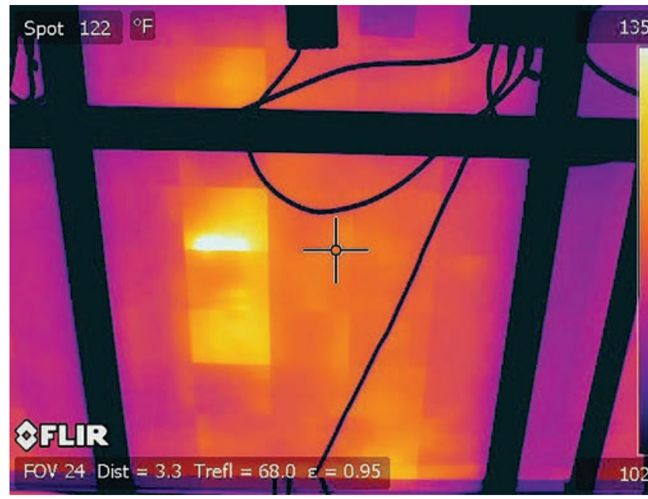
There are many uses for thermal imaging, including finding air leaks, poorly installed or gaps in insulation, and thermal bridging. You can also use the cameras to find blockage in waste plumbing, underslab leaks in hydronic heating systems, leaks in flat roofs, and electrical faults. They can also be used to spot problems in PV arrays, such as poor intercell connections, underperforming modules, and defective bypass diodes.

This technology was previously the domain of professionals, mostly because the cameras were expensive. When I first heard of thermal imaging in the 1970s, the cameras cost up to $100,000. Today, you can purchase a basic thermal imager that attaches to a smartphone for $200 (or a pro version for $400). A good stand-alone imager is about $500; a cheap "brand X" imager sells for less than $100.

While you might be able to afford an imager, just how easy is it to use it and interpret the results? Well, that depends. The companies that manufacture the cameras often include online interpretation instructions, and there are multiple online videos that can help. Flir's *Thermal Imaging Guidebook* explains imaging and how to use the cameras (bit.ly/FlirGuide).

Some images may be very simple to interpret, but knowing how to fix a leak, for example, requires another level of know-how. Should a leak that is identified on an interior image be sealed from the inside, should foam insulation be added to the wall cavity, or is it a symptom of a greater problem with the building envelope? Having a camera does not fix the problem and the images it generates may not reveal underlying issues, but it can provide a helpful start.

—Michael Welch



Justine Sanchez

This thermal image, taken during system troubleshooting and testing, reveals hot intercell connections inside a PV module.

Flir's lowest-cost handheld thermal camera provides a resolution of 60 by 80 pixels.

Courtesy Flir (2)

The Flir One Pro (Gen 3) offers 1,440 by 1,080 pixels in a unit that attaches to an iPhone or Android.