

# Integrated PV/roofing

These handsome solar-electric panels blend into and become part of standing-seam metal roofing



Photos: Stephen Heckeroth

The McMillan house uses both integrated PV/roofing and solar-heated, radiant-floor heating.

## *An interview with Stephen Heckeroth*

*By Michael Hackleman*

**A**fter pouring the foundation, framing the house, and adding a roof, how would you like it if your house was all ready to generate its own electricity? No solar modules and no roof racks to add? This is the promise of integrated PV (solar-electric)/roofing. It is cost-competitive for new home construction and retrofits to existing homes.

Stephen Heckeroth is a solar designer who has constructed innovative systems in homes and buildings to make use of passive solar energy in heating, cooling, and electricity production. I interviewed Stephen on integrated PV/roofing as demonstrated in the McMillan home.

**MH:** There have been longstanding challenges with using photovoltaic (PV) modules on rooftops to generate electricity from sunlight for homes (**Sidebar A**). A major one has been the add-on look to most of the installations. Architects, homeowners, and



Stephen Heckeroth

corporations are understandably reluctant to accept the impact of the framework and modules in an array on a building's aesthetics. You've installed Uni-Solar's integrated PV roofing in 13 projects in the past year. Will you describe how the roofing and PV material is integrated?

**Stephen:** The roof of the McMillan home was ideally oriented and pitched to use Uni-Solar solar-electric modules. Uni-Solar's technology is based around conventional standing-seam metal roofing which is available in a wide range of colors and lengths, with all the necessary trim. In this application, the flexible thin-film amorphous laminants are bonded to the 16-inch wide sheeting. There are two module sizes, reflected in two lengths: 9 feet 4 inches or 18 feet. The 9-foot, 4-inch laminants are rated

## A: Fitting crystalline solar-electric hardware to rooftops

By Michael Hackleman

Rooftops are a natural site for solar-electric generation because ground-level arrays are exposed to theft and vandalism. As well, solar-electric modules on a roof intercept the sun's rays, reducing heat gain to the building for the area covered. Still, there are at least five challenges to their effective use: module size, orientation, temperature, weatherability, and competition.

**Module size.** Standard solar modules aren't easily disguised. If the roof isn't designed to complement their look, the solar panels really stand out. The situation worsens as the size (wattage) of the array increases. There is definitely an add-on or experimental look to these installations.

**Orientation.** Solar modules need to face the sun to generate power. When fitted to existing homes, the modules generally suffer when mounted to rooftops that are not orientated to true south or at an optimum pitch for fixed modules. Finally, the output of a module is severely impacted by even partial shading of one solar cell, limiting installation to roof areas that remain unshaded through the major part of the day. The result is some odd-looking support framework to align and pitch the panels for maximum daily production and minimal shading.

**Temperature.** Rooftops generate high-temperatures in the summer sun, reducing the voltage of many types of solar modules and, often, power output. Flush-mounted solar modules compound the problem, lacking adequate cooling. Again, with smaller (shallow) roof pitches, there is insufficient convective airflow to strip heat away from the modules.

**Weatherability.** Rooftops do a good job considering the beating they get from the sun, wind, rain, snow, sleet, and hail. Fortunately, solar panels have a good history of weatherability, too. The earliest applications for solar modules were in hostile environments and extreme weather sites. Their reliability is such that most of the electronic equipment mounted on remote mountain tops or in marine installations now uses solar modules instead of fueled-generator technology. The overall weatherability and toughness of solar panels makes them ideal as a roofing substitute.

**Competition.** Roofers install roofs. Solar dealers install module arrays. This duplication has kept the cost of adding rooftop solar-electric systems prohibitively high. As well, the prospect of adding solar-generated electricity to a home has remained an unknown entity for homeowners everywhere.

at 12 volts and 64 watts. The 18-foot laminants are rated at 24 volts and 128 watts. The owner/builder or contractor installs as many Uni-Solar modules as are needed to satisfy the owner's electric needs, then uses regular standing-seam metal roofing to finish off the job.

**MH:** Tell me more about the metal roofing.

**Stephen:** Standing-seam metal roofing is a pan with edges. It comes in architectural and structural grades. Architectural grade has a 3/4-inch lip and a separate batten. Use this if it will be laid down over plywood or other decking. Structural grade has a 1.5 inch lip and has an integral batten, so it is stiffer and easier and faster to install. It will bridge a 3-foot gap in a roof's framework.

**MH:** How is the metal roofing secured to the roof?

**Stephen:** A clip slips over the lip of architectural grade roofing and is screwed into sheeting over the roof joists. The next section of roofing obscures the screws of the previous

section when its tab is folded over and a cap or batten is added. The structural grade of metal roofing also uses a clip that is slipped over the edge and screwed to the roof (sheeting or joists). However, the next section utilizes an integrated cap that slips down over the other edge and secures the joint.

By the way, standing-seam metal roofing is not new. It's a system that goes back hundreds of years. Many of the cathedrals in Europe have standing-seam roofs. They have stood the test of time.

**MH:** Is the product ready-to-go when it arrives at the building site?

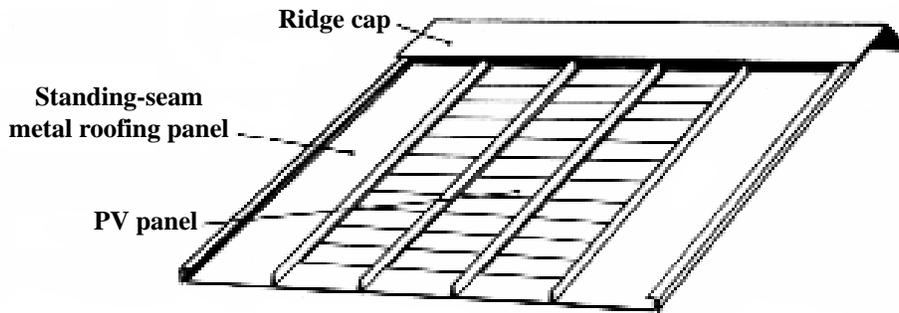
**Stephen:** To date, Uni-Solar laminants have all been factory-bonded. In the future, there will be a choice of factory-bonded or a new version of the product called peel-and-stick. Thus, you have the option of having the laminants shipped directly to the site, where they can be installed directly to standing-seam metal roofing already in place or on the ground. Overall, it's best to bond the laminant

to the metal roofing sections on the ground. You unroll the laminant along the metal roofing, align it, and use a roller to evenly press it down on the roofing as you peel off the protective layer on the back. Peel-and-stick. The roller removes air bubbles and ensures complete bonding.

Factory-bonded modules provide an owner/builder with the laminant already bonded to standing-seam metal roofing. An assembly plant in Mexico receives the pans and laminants from the USA, bonds the laminant to the roofing under controlled conditions, and ships the finished PV/roofing modules to the building site in rigid crates.

**MH:** Do you have any preferences to working with the laminants or the factory-bonded modules?

**Stephen:** It's situational. With a large order of factory-bonded laminants, you need a fork lift at the work site to pick the 2,000-pound crate off the shipping truck. It's a large truck, too. It may not be able to get to some sites. Shipping for that size of an



order from Mexico is \$1,300. Uni-Solar is re-designing its shipping crates to be lighter.

An 18-foot section of standing-seam metal roofing weighs 20 pounds. Buying it locally and applying the laminant, which is itself fairly lightweight and compact to ship, is less expensive. On the other hand, the factory-bonded material is ready to go. If the south-facing portion of the roof is the right length, it goes up fast. In either case, if you use architectural standing-seam roofing, you must take extra care not to damage the fragile pans. Structural standing-seam is easier to work with.

**MH:** Since this PV material is a product of amorphous PV technology, how does it compare or contrast with modules made of poly-crystalline or single-crystal solar cells? I once toured the Arco Solar (now Siemens) manufacturing facility in Camarillo, CA. In 1990, most of the plant was dedicated to the production of single-crystal cells, but one large room had equipment producing modules from amorphous technology. I learned that regular amorphous PV modules were made from thin coats of active material that is sprayed onto glass in a very controlled environment. I know that the efficiency of amorphous PV is only about 6-7% compared with 10-12% for single-crystal.

**Stephen:** Amorphous PV is thin-film technology. Uni-Solar uses a continuous roll-to-roll process with stainless steel foil as the primary substrate. This makes the final product flexible enough to roll tightly, compacting into an 8-inch diameter roll.

The active layer of solar material is only microns thick, compared with many thousands of an inch thick for single-crystal cells. It's also triple-junction. This means there are three different layers of material, each designed to convert overlapping portions of the frequency spectrum of sunlight that contain energy. The combined output results in more electricity than a single-junction would yield.

It is true that the efficiency of amorphous PV is 6-7%, so it is less efficient than single-crystal PV at 10-12%. However, Uni-Solar prices for amorphous PV are based on performance per purchased watt, not area. This makes them directly competitive with single-crystal PV module prices in dollars per watt. Today, that's about \$5-6 per watt, including the racks for modules. Efficiency is an issue in module-type arrays mounted to racks, where you would need

more of the amorphous PV modules to achieve the designed wattage than required with single-crystal PV modules for the same area. Collector area is less of an issue with rooftops. For example, the McMillan solar array intercepts about 406 square feet of sunshine in a space that's roughly 23 feet wide and 18 feet high, yet this represents a relatively small portion of the total roof area.

Integrated standing-seam metal PV roofing eliminates both the cost and labor of installing the structural support for PV modules. It also eliminates the cost of the roofing material itself, tile or shingles. For the section of roof the array occupies, it *is* the roof.

**MH:** What was the final system makeup for the McMillan house?

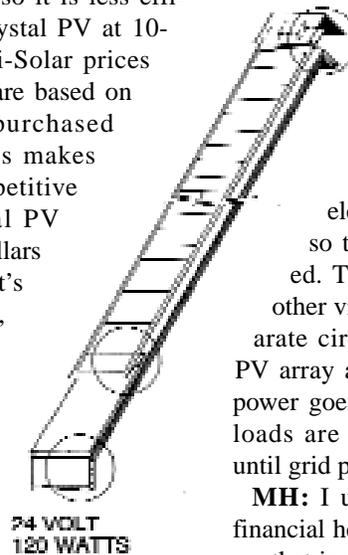
**Stephen:** We used seventeen 18-foot long laminants in the roof. At 128 watts each, this is 2,135 watts of solar-generated electricity at 24-volts DC. This is fed through a controller, a Trace C40, into a battery bank comprised of eight L-16 lead-acid, deep-cycle batteries. Each battery is rated 6 volts and 350Ah (amp-hours). These are wired to produce a 24-volt battery pack of 700 Ah capacity. The battery pack is connected to an inverter, a Trace 4024, which is rated to produce up to 4kW (4,000 watts) of electricity at 120V, 60-cycle AC.

**MH:** Anything special about the system?

**Stephen:** Utility-supplied electricity is available onsite, so the system is grid-connected. The refrigerator, lights, and other vital loads are set up on separate circuits wired to run off the PV array and battery bank. If utility power goes down, only non-essential loads are affected. These can wait until grid power is restored.

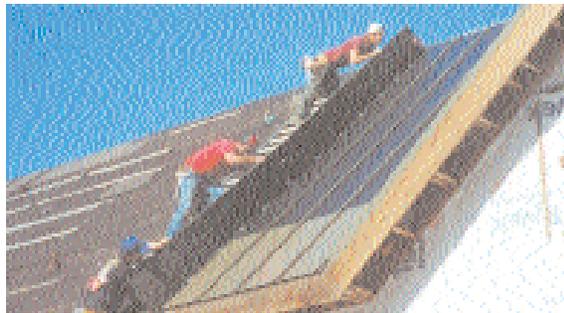
**MH:** I understand there is some financial help available for homeowners that install PV in a grid-connected home.

**Stephen:** Yes. In California, where the McMillan house is located, the state and federal programs cut the price of a PV system in half last year. The federal program is over but the California Energy Commission still offers a \$3/watt rebate or up to one-half the system cost for installations on property served by a utility. Many other states have similar programs to





Left: A Uni-Solar module is lifted to the roof and installed.



Below: Module wires are routed under the roof cap.

encourage the installation of renewable, non-polluting energy systems. Five years ago, the McMillan home was the first use of Uni-Solar PV roofing on a private residence.

**MH:** One thing I really like is the way the integrated PV roofing disappears into the roof.

**Stephen:** It's more of a chameleon than you might think. Standing-seam metal roofing comes in a variety of colors, i.e., gray, blue, green. When any of these colors are used around an array and the battens are applied between the array segments, the solar panels take on the color of the roofing. With a green roof, the array reflects dark gray-green. The array reflects gray with a gray roof and reflects blue with a blue roof. Altogether, it adds to the aesthetics of the building.

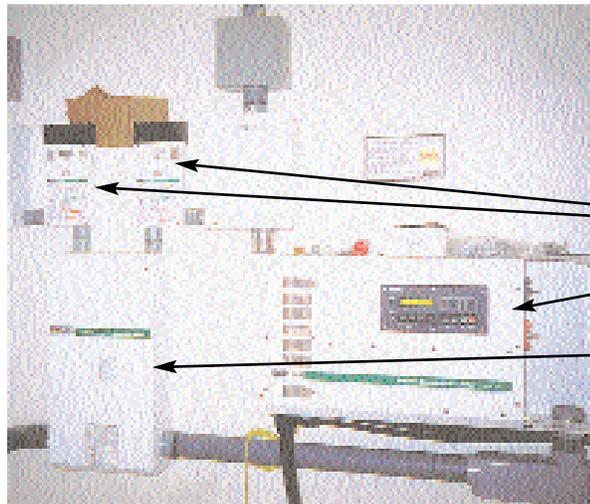
**MH:** How long does it take to install the Uni-Solar modules?

**Stephen:** It recently took about 2½ hours to install a 4kW (4,000 watt) array. This involved three people installing 30 segments of factory-bonded, structural standing-seam pans on a roof designed for the standard 128-watt modules. So, five minutes per section. I'm experienced at it, but the time usually improves with each segment installed.

**MH:** Will you approximate the cost?

**Stephen:** It figures to about \$5/watt for the site-applied, peel-and-stick laminant or \$6/watt for factory-bonded. The difference is the current shipping cost (less with peel-and-stick) and the cost of the metal roofing (not supplied with peel-and-stick). At \$5

Right: Grounding strips are soldered to the modules.



Left: A typical power center includes:  
Solar charge controllers  
Inverter/Charger  
DC disconnect

Below: Most battery packs use deep-cycle, lead-acid batteries.

per watt, the 12V, 64-watt modules are approximately \$320 each and the 24V, 128-watt modules are \$640. At \$6 per watt, the cost is \$384 and \$768, respectively.

The big difference is the cost savings of Uni-Solar modules because they don't require the roof racks to support the modules. This saves about \$2 per watt. Uni-Solar offers a 20-year replacement warranty. With any luck, the laminants and the roof will last 40-50 years. Contrast that with the roof under a crystalline-based array.



When it needs replacement, the cost of labor to remove and re-install both the PV array and roof can total to more than the original installation.

**MH:** Have you been able to verify the ratings that Uni-Solar claims for its amorphous PV? And, how long is

*Other installations  
by Stephen Heckerath  
using integrated PV/roofing.*

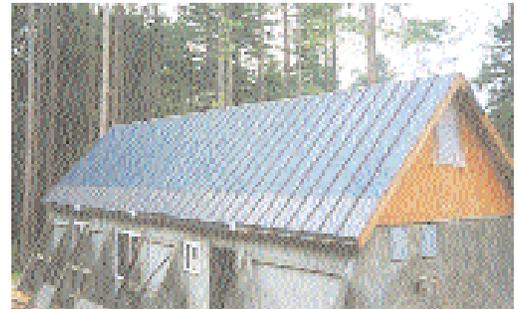


Above and left: A 5kW array on a new home outside Blain, ID.

Below: A 2kW shop roof in Mendocino, CA



Left: A 3kW garage roof in Little River, CA.



Below: A co-housing project in Oakland, CA, with a 6.5kW array.



Above: Heckerath's latest project: a 3.6kW charging station for electric vehicles.



Right: Pam Chang's Berkeley home was re-roofed with a 2.4kW array.



*All photos: Stephen Heckerath*

the payback for the energy used in manufacturing?

**Stephen:** I have verified the output of many of the arrays I've installed. Watt for watt, Uni-Solar has matched, even outperformed, single-crystal and poly-crystalline modules at a number of solar "shoot-outs" during energy events across the US and Canada recently. These are bonafide technical and performance tests with all the manufacturers represented. Each brand of module is exposed to the same sky, sun, loads, heat, dust, and clouds as every other brand.

The manufacturing process for amorphous PV consumes less energy and produces less waste byproducts than single-crystal PV production. Where it takes five years for a single-crystal PV module to pay back the energy it took to manufacture it, amorphous PV has a payback of six months.

**MH:** How does amorphous PV performance compare with that of crystalline PV in day-to-day operation? I know that amorphous PV is not as sensitive to temperature as crystalline PV. When I worked on the Solar Eagle project a few years back, our design had to allow for a big voltage drop, about 2.2 millivolts per degree centigrade per cell. With a panel made of twenty 432-cell strings of solar cells, the Solar Eagle's array output would drop more than 30 volts when it stopped and just sat in the Australian sun.

**Stephen:** Amorphous is less affected by temperature. A single-crystal solar cell is several thousands of an inch thick. It accumulates heat and drops in voltage. Amorphous PV is only several microns thick. No thermal mass. As well, there's a bypass diode across each section of an amorphous module, minimizing the drag-down effect that occurs with any partial shading. Uni-Solar modules have demonstrated good performance even when installed on east and west-facing rooftops. I know, I've done it. The

modules' non-reflective outer coating captures sunlight that is reflected off standard solar modules because of the incident angle. Amorphous PV output is generally higher in light overcast, shaded, or cloudy conditions than single-crystal PV.

**MH:** What advice can you give owner/builders who might be interested in applying this technology?

**Stephen:** Obviously, you can't have dormers, vents, or skylights coming up through the array. If added to a building under construction, the array should be sited for optimum exposure to sunlight and to avoid any plumbing, stove, and daylighting fixtures in this section. In a retrofit, site the array away from these protrusions or re-route them. The Uni-Solar modules can be arranged as one group, several small groups, or alternated with conventional metal roofing sections. The

electrical terminations can be at either end of the modules. These are fed through a watertight opening beneath the ridge cap or connections are made in the soffit behind the fascia. Wiring connections are made in the attic below the roof decking.

Altogether, Uni-Solar's modules make it easy to add a solar-electric capacity to a rooftop in a cost-efficient way.

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