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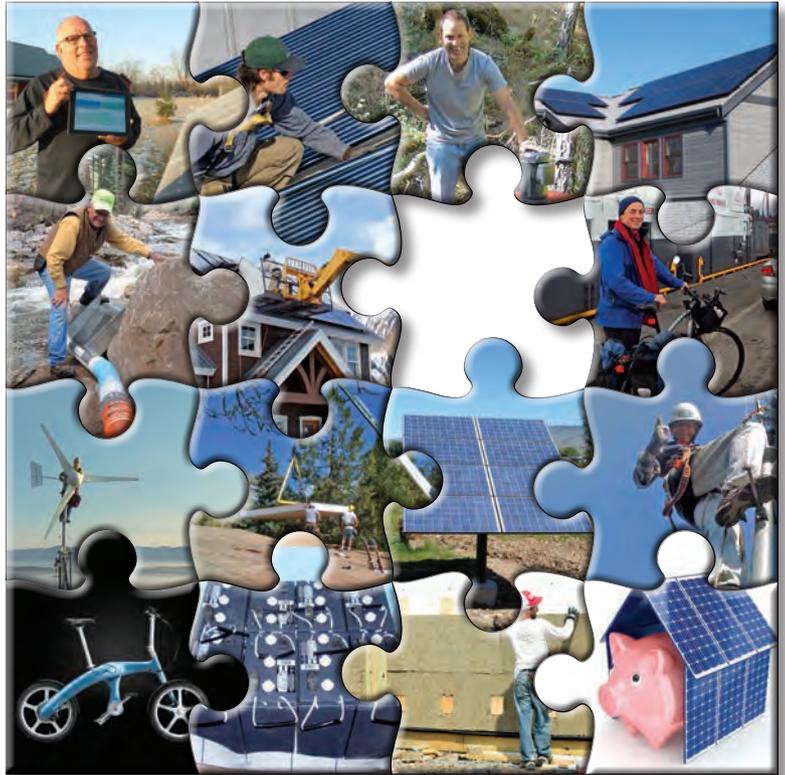


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Parts



of the Big Picture

Home Power is here to help you prepare for shifting times. For example, as we welcome news about the extension of the federal investment tax credit (FITC) for solar energy systems, warnings about volatile global financial markets and rising interest rates here in the United States are being issued. While you're still able to take advantage of the tax credit for installing a PV system, now may be the best time to finance it—before interest rates climb.

In this issue, we explore leasing versus owning a PV system. In many cases, owning a PV system makes more financial sense than leasing (page 56). But before you buy a PV system, solar installer Lena Wilensky discusses what you can do to make sure your PV system output is maximized (page 48). From choosing the right site to choosing the right equipment, there are plenty of measures you can take before ordering your modules.

Renewable energy systems play an important role in fostering overall energy, economic, and ecological resilience,

but we understand that there are other pieces of the sustainability puzzle—and we're more than a magazine about renewable energy. On page 28, Mike and Linda Gallagher detail building their high-efficiency, high-performance, modern farm house in Minnesota—including a grid-tied PV system that offsets all of their electricity consumption. We also take a look at greener transportation, this time putting the spotlight on electric bikes (page 36) and cycling as a main form of transportation (page 44). In "Home & Heart" (page 64), Kathleen Jarschke-Schultze tackles the task of reducing plastic use at her off-grid homestead.

At your home or homestead, how and when those pieces come together may be different than for your neighbors, or for other people in your community. What matters is that we keep putting those pieces together, small and large, and keep working on the puzzle.

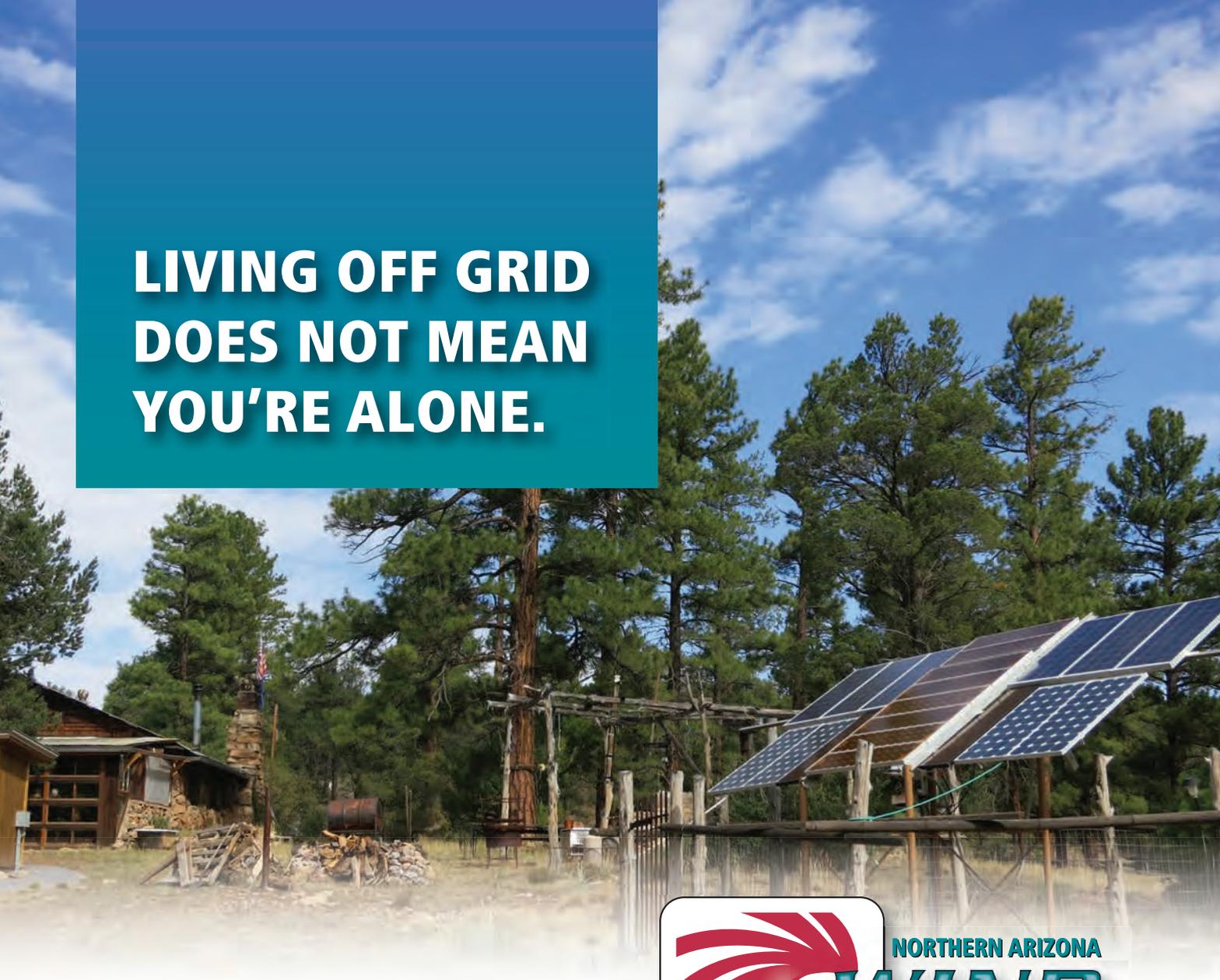
—Claire Anderson, for the Home Power crew

Think About It...

Resilience is all about being able to overcome the unexpected. Sustainability is about survival. The goal of resilience is to thrive.

—Jamais Cascio, author and futurist

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36 **powered** pedals Ted Dillard

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44 **bike** ride Ian Woofenden

Switch gears—trading in your car for pedal-powered two-wheeled transportation can provide economic, health, and environmental benefits.

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On the Cover

Renewable energy brought Mike and Linda Gallagher together to create a net-zero-energy, energy-efficient home.

Photo courtesy Mike Gallagher

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Vikram Aggarwal is the founder and CEO of EnergySage, a national online solar marketplace. Aggarwal founded the company after more than 15 years with a major global financial services

leader, specializing in private equity investing and strategy consulting. He holds a master's degree in business administration and is a CFA charter holder.



Home Power Managing Editor **Claire Anderson** lives in a passive solar, (almost) net-zero-energy home she and her husband designed. She and her family are developing their 4.6-acre

homestead to incorporate more resilience in their energy, food, and water systems.



David Butler has been a building systems engineer for three decades. During this time, he has consulted with multinational manufacturers, energy utilities, and land developers on a variety

of R&D projects related to energy efficiency. He resides in the high desert of southeast Arizona where he specializes in mechanical systems design for high-performance homes.



Ted Dillard is an evangelist for all things electric. He writes *The Electric Chronicles* (devoted to two-wheeled electric vehicles) and is the author of *...from Fossils to Flux*, a basic guide to

building an electric motorcycle. When he's not in his garden, or in his shop working on his next electric project, he can be found at www.evmc2.com.



Mike Gallagher, a retired college science teacher, has been interested in building a passive solar-powered home forever. This dream came true after he met and married like-minded **Linda**

Cullen Gallagher, a semi-retired photographer and executive director of a nonprofit supplying solar-powered lighting to people in third-world countries.



Pete Gruendeman is a machinist by training, and presently designs and builds test apparatus for a research company that is developing desiccant-based air conditioning and solar-thermal-powered

seawater desalination. He has solar thermal heating and PV (for DHW and backup power) at his home in Wisconsin.



Thirty years ago, **Kathleen Jarschke-Schultze** answered a letter from a man named Bob-O who lived in the Salmon Mountains of California. She fell in love, and has been living off-grid with

him ever since. *HP1* started a correspondence that led Kathleen and Bob-O to *Home Power* magazine in its formative years, and their histories have been intertwined ever since.



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

course in conjunction with *SolarPro* magazine and HeatSpring.



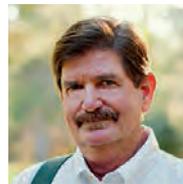
Chuck Marken is a *Home Power* contributing editor, licensed electrician, plumber/gas fitter, and HVAC contractor who has been installing, repairing, and servicing SWH and pool systems since 1979.

He has taught SWH classes and workshops throughout the United States for Sandia National Laboratories, Solar Energy International, and for many other schools and nonprofit organizations.



Justine Sanchez is *Home Power's* principal technical editor. She's held NABCEP PV installer certification and is certified by IREC as a Master Trainer in Photovoltaics. An instructor with Solar Energy

International since 1998, Justine leads PV design courses. She previously worked with the National Renewable Energy Laboratory (NREL) in the Solar Radiation Resource Assessment Division. After leaving NREL, Justine installed PV systems with EV Solar Products in Chino Valley, Arizona.



Patrick Sughrue has more than 30 years of experience in the construction industry. He has been trained in the LEED, the Oregon High Performance Home, and the Living Building

Challenge programs, and recently participated in the Passive House certification training.



Michael Welch, a *Home Power* senior editor, is a renewable energy devotee who celebrated his 25th year of involvement with the magazine in 2015. 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.



Lena Wilensky was inspired to take leave from her high school teaching career to explore the world of renewable energy. She built her experience from Solar Energy International as well, taking classes,

helping construct their PV Lab Yard, and now teaching PV Design and Installation classes around the country and online. She worked as an electrician in Crested Butte, for several solar installers, and is thrilled to now own her own business.



Vaughan Woodruff owns Insource Renewables, a solar contracting firm in Pittsfield, Maine. His firm, along with Assured Solar Energy, was selected to run the Solarize Freeport campaign.

He is a NABCEP Certified PV Technical Sales professional, NABCEP Certified Solar Heating Installer, and an instructor for Solar Energy International.



Home Power senior editor **Ian Woofenden** has lived off-grid in Washington's San Juan Islands for more than 30 years, and enjoys messing with solar, wind, wood, and people power technologies. In addition

to his work with the magazine, he spreads RE knowledge via workshops in Costa Rica, lecturing, teaching, and consulting with homeowners.

Contact Our Contributors

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

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Courtesy SMA America

SMA Sunny Boy 5.0 & 6.0-US with SPS

SMA America (sma-america.com) has relaunched the Sunny Boy 5.0-US and 6.0-US inverters. These transformerless inverters feature three independent MPPT inputs, helpful for arrays mounted on multiple rooftop planes and for different series-string configurations. A secure power supply (SPS) can now supply up to 2,000 watts to a dedicated wall outlet during a utility outage, without batteries, on a sunny day. These inverters have a 10-year warranty that can be extended to 15 or 20 years.

Sonnen Lithium-Ion Battery-Based System

Germany-based Sonnen (sonnen-batterie.com) is now manufacturing its battery storage system in San Jose, California, for the U.S. market. The maintenance-free system includes all balance-of-system components, with the inverter, controls, and metering integrated, and are intended to be AC-coupled with new or existing grid-tied RE systems. The residential “eco” model is offered in seven capacities, ranging from 4 to 16 kWh. The “pro” commercial model is available in six capacities, ranging from 24 to 240 kWh.

Both models can be used in self-consumption applications, making them useful in regions where storing and using on-site PV-generated energy on a daily basis, rather than feeding it back to the grid, makes financial sense. The eco model has a backup power mode to offer energy to household loads during power outages. Sonnen batteries use lithium-iron phosphate cells, known for their stability, and carry a warranty of 10,000 charge cycles or 10 years.

—Justine Sanchez



Courtesy Sonnen



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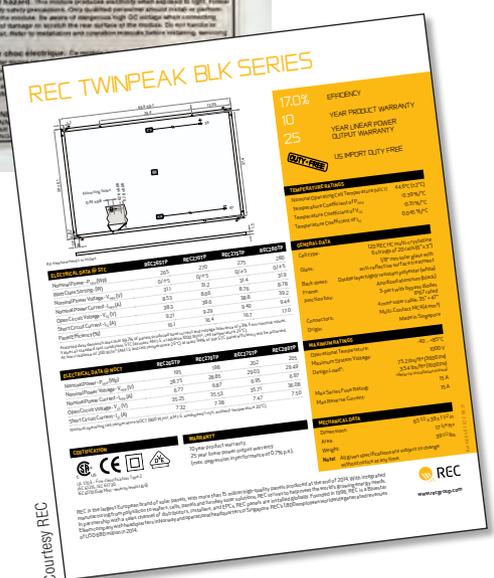
You suspect that your PV system is underperforming, but aren't sure why. Perhaps it's the weather. Maybe you added new loads to your home or had a lot of electron-guzzling guests. Either way, you need a way to verify whether or not the problem is your system's performance.

Solar professionals can perform a system performance check, but it's also something that's not too difficult to do on your own. You'll need a way to measure the modules' temperature—an infrared temperature gun (~\$90) or temperature probes on a digital multimeter. You'll also need an irradiance meter (starting at ~\$125), the modules' STC specs, your inverter's efficiency, and a way to measure inverter power output (your inverter's meter or remote monitor will work).



Cell temperature affects PV voltage, and therefore power. Operating temperature is often higher than standard test conditions (STC).

Some PV module specs can be found right on the module; others may need to come from the manufacturer's spec sheet.



It's important to take these measurements in good sunlight, to synchronize the array power output reading with the irradiance reading, and having a helper makes it easier. You'll take the power output reading from the inverter, and apply a calculation correction to the module specifications to account for the actual on-site conditions. Once you have your readings, follow the example calculations below.

Example

This example assumes modules have a positive-only manufacturing tolerance and have been installed within the past year (i.e., practically no degradation). The array is clean, and thus no soiling derates are applied. Wires are sized for minimal voltage drop of less than 1.5%, so wiring losses will not be figured in.

- **Array STC power** (from module specs):
 $250 \text{ W} \times 10 \text{ modules} = 2,500 \text{ W}$
- **Irradiance** (measured with irradiance meter): 950 W/m^2
- **Module temperature coefficient** for P_{max} (from module specs) = 0.45% per °C
- **Module temperature** (measured at array): 60°C
- **Inverter efficiency** (from CEC, bit.ly/CECinverters, or inverter specs): 97%
- **Power output** (measured at same time as irradiance and temperature): $1,988 \text{ W}$

continued on page 16

Lena Wilensky (2)

Courtesy REC

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continued from page 14



Lena Wilensky

Irradiance must be measured on the same plane as the PV array, and at the same moment as the power measurement.

Calculation steps:

1. **Correct for irradiance** (STC is at 1,000 W/m²):
 $950 \text{ W/m}^2 \div 1,000 \text{ W/m}^2 = 0.95$;
 $0.95 \times 2,500 \text{ W} = 2,375 \text{ W}$
2. **Correct for the module temperature** (STC is 25°C) using the module's temperature coefficient:
 $60^\circ\text{C} - 25^\circ\text{C} = 35^\circ\text{C}$ difference;
 $35^\circ\text{C} \times 0.45\% \text{ per } ^\circ\text{C} = -15.75\% = -0.1575$;
 $2,500 \text{ W} \times -0.1575 = -394 \text{ W}$

At 60°C, the array should produce about 394 W less than its STC rating.

Put these two derates together and we get:
 $2,375 \text{ W} - 394 \text{ W} = 1,981 \text{ W}$

3. **Account for the inverter's efficiency** to calculate what the inverter's output power should be:
 $1,981 \text{ W} \times 0.97 = 1,922 \text{ W}$

4. **Compare it to the actual power output:** 1,988 W actual versus 1,922 W expected.

Looks like this system is performing well within spec! For more information on PV system performance factors, see "Maximizing PV Performance" on page 50.

—Lena Wilensky

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Polycarbonate Window Shutters

For years, we manually covered the south-facing windows in our earth-sheltered Minnesota home with plywood shutters. We opened and closed them during the day based on the weather and sun. Hooks at the top held them closed. At the bottom, the shutters were hinged to a 2-by-4 that was bolted onto the brick window ledge. The 3/8-inch plywood was covered with 1/2-inch rigid foam, followed by a covering of aluminum foil. Strips of carpet were glued around the edges to provide a good seal.

Recently we replaced these with new shutters we made using 1-by-4s and polycarbonate sheets. We are so pleased with their performance, we thought we would share the idea.

Because the new shutters are translucent, we still get light inside when they are closed. When they are open on a cold sunny day, their smooth surface serves as a reflector, increasing heat gain. While our ducks and cats still like to sun themselves on the open shutters, there is no foil or foam to damage. Our new shutters have no hinges. They just rest on a 2-by-4 and are hooked at the top. Good or bad, we did not attempt to seal the edges when closed.

Ron Solberg • Hills, Minnesota

Homemade translucent, polycarbonate window shutters.



Courtesy Ron Solberg

Warranty Advice

After reading the letter from J. Herndon in *HP170* on PV module delamination, and the insightful comments on warranty fine points by Zeke Yewdall, I want to comment. First, anyone who finds themselves in similar shoes should contact the manufacturer. Second, I have some hard lessons learned from my investigation into numerous warranties *before* choosing modules and inverters for my system.

Given that seven out of 10 of J. Herndon's modules failed at some seven years, failures may have occurred before the five-year warranty period expired! The lesson? Arrange for module inspections before the warranty expires—whether that is five, 10, or 12 years. Some problems may be exposed that justify a warranty claim.

I would urge Mr. Herndon to write a polite and detailed letter describing the systemic failure of his modules—one or possibly two modules may be understandable, but seven is not! He also should offer the manufacturer an opportunity to examine his modules and provide the lot numbers to help them with their quality control. Responsible manufacturers will respond—often with some kind of adjustment. I would also have his installer sign the letter.

Before my solar-electric system was installed in February 2015, I examined the fine print of several module manufacturer warranties. One warranty was for 10 years but “to the original end user.” This warranty was not transferable, so capturing system value on home resale was impossible. Any warranties would be worthless to a prospective buyer.

A second manufacturer provided a five-year warranty that stated that its obligation upon failure would be to “repair the defective products, supply replacement products or provide the customer with an appropriate residual value of the products as compensation at its discretion.” This warranty is nearly worthless if the manufacturer always has the option of determining “an appropriate residual value” at its own discretion! Is that \$100, \$10, or 10 cents? The system owner would have no recourse in defending a claim.

Another warranty's provision exempts and absolves the module manufacturer from responsibility for providing any new or comparable product—with only the obligation to provide a used or repaired module. Such warranties fail to provide much protection or confidence that the purchaser is protected.

Initial warranty terms were in the five- to 12-year range, with performance warranties in 20- to 25-year range. A critical provision

on performance warranties is whether they are prorated for financial reimbursement (providing almost no value as the module ages) at the manufacturer's option, or, preferably, full replacement warranties.

Make sure the warranty you are examining applies to your location—the international warranty may be very different than the U.S. warranty. Look for any other fine-print provisions that will void the warranty claim, such as failing to have the original invoices. Will your solar provider be in business in 10 or 15 years? Make sure you have retrieved all applicable paperwork and confirm that you will be able to properly document any future warranty claims, consistent with warranty requirements.

With this homework, the modules I selected avoided all the warranty pitfalls noted above. With due diligence and understanding the provisions and rights that you have, your risks can be substantially reduced.

Chris Corbett • Albany, New York

Real Cost of Storage

Most discussions of renewable energy systems with storage, when addressing the storage part, include initial and replacement costs, life, capacity, temperature effects, ease of maintenance, and such. All reasonable. But I have yet to see a discussion on the real cost of using stored energy. Here's my take on the issue.

Say Uncle Henry gives you some PV modules—free. Is the energy you get from them free? If you use it immediately, yes. But, if like most of us, you find you need to store it for later use, then no. So, what's it going to cost you?

To determine the cost of the otherwise-free energy that was stored in and removed from your battery bank, just determine the cost of the replacement battery. Divide that by the total of all of the energy that went through it in its lifetime. Part of that is figuring out how much energy that is. It's all expressed as the formula:

$$\text{Cost per kWh} = \frac{\text{battery purchase price}}{(\text{energy capacity} \times \text{the typical depth of discharge} \times \text{cycles of life at that DoD})}$$

Most manufacturers will provide cycle life versus DoD information. The deeper the discharge, the fewer cycles one will get out of any battery.

I recently designed a 5 kW grid-tied PV system with about 35 kWh of lead-acid battery storage. I looked at three different battery types, using the manufacturer's specifications. I assumed 100% round-trip efficiency (what goes in comes back out) and no losses, just for calculation purposes. I concluded that:

continued on page 20

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continued from page 18

Comparing Battery Cost Per kWh Stored

Brand & Model	Deka 8G31	Deka 8A27	Deka GC15DT
Battery type	Gel	AGM	Flooded
Cost	\$266	\$221	\$180
Capacity at C20 rate (Ah)	97.6	92.0	230.0
Nominal voltage	12	12	6
Capacity (kWh)	1.1712	1.1040	1.3800

% DoD	Total Cycles		
10%	5,800	3,100	1,300
25%	2,010	1,100	1,100
5%	1,000	500	813

Total kWh			
10%	679.3	342.2	179.4
25%	588.5	303.6	379.5
50%	585.6	276.0	561.0

Cost per kWh			
10%	\$0.392	\$0.646	\$1.003
25%	0.452	0.728	0.474
50%	0.454	0.801	0.321

- Storage is not cheap, so change your usage habits where possible.
- AGMs do not appear to be competitive with gel cells. Neither is competitive with flooded at DoDs greater than 25%.
- Flooded units under light usage (low DoDs) are particularly expensive.
- If cost per kWh is important, then flooded cells are the answer

At \$0.32 per kWh, flooded cells are competitive with grid energy in some parts of the United States. In my case, with utility energy about \$0.16 per kWh, I will buy flooded units and only use them when the grid is down. This methodology can be applied to any battery type and manufacturer's product that you are interested in.

John Schaefer • Datil, New Mexico

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Solar Hot Water Pump Module

I have a non-functional PV module that powers the pump of a 17-year-old still-functioning solar water heating system (manufactured by a company that is no longer in business). I'd like to replace the module, but how do I determine its wattage so I can buy a suitable replacement? The ink on the module's label has faded, though the name looks like Solarex, which is also no longer in business. The module has a black plastic base and 13 5/8-inch square frame.

David W. Potter • Orange Grove, Texas

The module is probably 10 watts, which, back in the day, is in the range of power you could get out of a square foot of PV. You can count the number of cells to determine the voltage, but it's likely a 36-cell module, which is for 12 V nominal applications. Any full-service retailer should be able to supply you with a new module.

But are you sure it's bad, and that it's not something else? After that much time, loose connections are likely, possibly anywhere between the module and where it hooks up (direct to pump or controller).

Michael Welch • *Home Power* senior editor

I concur with Michael's advice, but my primary suspect would be the pump in the 17-year-old system you describe. If it is a pump motor with brushes, that is what I would check first, but wiring and connections could also be the problem. The PV module would be last on my list to check.

A 12 VDC pump can easily be checked with a 12 V battery. Connect it after ensuring the polarity is correct—red wire to positive; black to negative. Many pumps will just run backward with reverse polarity, but a few high-efficiency models made for solar water heating can be damaged if the wires are reversed. If the pump runs when connected to the battery, that eliminates the pump as the problem.

March and Hartel DC circulation pumps, suitable for use with a PV-powered SWH system (pictured: a thin-film PV module).



Chuck Marken

Most small SWH pumps are not economically repairable, with the exception of brush replacement on those types. Be cautious of replacing a failed pump with a product from the marine or RV industries. In a batteryless system, in which the module is connected directly to the pump, most of these pumps will have a limited life. Marine RV pumps are designed to be powered by an electrical system with a battery. Connected directly, PV voltages can often exceed the pump's maximum voltage rating, causing damage.

Any replacement pump should be accompanied with a module recommendation. March, Milton Roy (Hartell), and El Sid have been making small DC pumps for the solar industry for decades. El Sid is a reliable pump also, but double the recommended PV module size if you'll be pumping an antifreeze-based system. The bottom line is to buy a pump from a manufacturer that makes pumps for PV-direct systems.

Module testing is straightforward. You need a multimeter and a sunny day for the best results. Connect the two PV module's wires to a multimeter that's set for DC voltage to measure VOC (voltage, open-circuit). An old 12-volt crystalline module may read as little as 18 volts. An older thin-film module could read as little as 13 to 14 V.

In rare cases, a module can have a good VOC measurement but still not produce any power under a load. A much better test is to connect the module to a known, operational load (a small motor or light, tested with a battery) under good sunlight conditions.

Chuck Marken • *Home Power* solar thermal editor

Hydronic Heating

I'm trying to design a long-term cost-effective heating method for my 32-by-48-foot uninsulated shop. I'm considering a stand-alone solar water heating (SWH) system that uses aluminum wall plates and tubing or radiators and fans.

Spray foam should take care of insulation and make the building more rigid, but I'm wondering if an SWH system, along with a 1,000-gallon storage tank, would make the effort worthwhile. I could go natural gas heat since the house is connected to a gas line, but trenching to the line would be needed.

Wayne Gale • via homepower.com

When considering a solar heating system in a cold climate, two major factors contribute to its effectiveness—a high-performing building envelope and a heating distribution system that matches up well with solar. Radiant distribution is the best match for a SWH system since it is typically designed to maintain a building's comfort with much lower temperatures (90°F to 100°F). Other types of hydronic distribution, such as baseboard elements, need 180°F to 190°F water.

Radiant distribution is typically embedded tubing in a concrete slab, but there are other options. John Siegenthaler provided a comprehensive view of many of these options in "Renewable Hydronic Heating" (*HP152*), including a thorough explanation of the details that make radiant systems an excellent match for solar.

Trying to retrofit insulation under a slab or embed tubing in an existing floor is a lot like trying to put toothpaste back in the tube. You'll need to do the best you can to maximize the floor's efficiency and find another way to distribute heat than a radiant slab. Since a majority of a slab's heat loss occurs along its perimeter where it is most exposed to the

coldest air temperatures, you should make sure that the edge of the slab (or the perimeter frost wall) is insulated. For heating distribution, you could consider a radiant wall or a radiant ceiling using PEX tubing and the aluminum distribution plates you mention.

The system depends upon what is driving your decision-making process. If it is solely cost and your conventional alternative is natural gas, it will be difficult to make the numbers pencil out for a traditional solar system. The combined cost of the solar equipment and the retrofit of the heating distribution system will be substantial when compared to natural gas.

There may be some solar solutions that could work for your application. If you use the space occasionally, a solar air heating system could be an excellent solution. Gary Reysa's article, "Low Thermal Mass Sunspaces" (HP158), and his website, builddsolar.com, are excellent resources. These systems are simple, very DIY-friendly, and can be installed on a shoestring budget. There are also off-the-shelf solar air-heating systems available.

Another solution is to use solar-electric arrays combined with minisplit heat pumps. By accruing net-metering credits with your utility in the summer and using electricity to power an air-source heat pump in the winter, you can offset much of the heating demands in the space with solar energy. Since the performance of heat pumps diminishes as outdoor temperatures drop, you might need some other type of heat to maintain comfort.

Vaughan Woodruff • Insource Renewables, Pittsfield, Maine

Microhydro to Control Flooding & Erosion

I am interested in a microhydro power system for a local golf course that has issues with erosion and flooding from an on-site stream. Would microhydro power be an effective way to remove energy from the stream, thereby reducing erosion and potential flooding?

Christian Heymsfield • via homepower.com

Microhydro systems with penstocks (pipelines) can reduce the risk of erosion and flooding in a stream because they route some of the water through a pipe instead of having it run down the streambed, and because they reduce the speed of the water. The whole job of a hydro system is to take the energy (pressure times flow) out of the water, to be used at the other end of the system where the water is dropped. But there are caveats:

- Any reduction in erosion or flooding will only be for the length of the pipeline, since the water will be put back into the stream after it goes through the turbine. The water's head (vertical drop) will be "starting over," so it will need to flow downhill again before it builds up its original erosive potential.
- Streams with significant variations in flow can be a challenge for hydro design. Capturing most or all of the energy of high flows requires a large intake, penstock, and turbine (as well as large balance-of-system components, etc.). This means the system will be overdesigned for moderate flows, and may reduce the system's efficiency. In typical hydro systems, a compromise is frequently made in which higher flows are not completely captured.

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- All of the electrical energy generated needs to be used, “diverted” to a dump load, or sent to the utility grid. The complete system—including the electrical side—needs to be able to handle the peak output of the turbine. Most home systems are designed around an average flow, and don’t bother with capturing the peaks, so the system can be smaller.
- Capturing a wider range of flows requires equipment that can adjust the system’s capacity to the flow. This can be as simple as using valves to change the number of turbine nozzles in use, or changing nozzle sizes. In larger systems, it could mean automated turbine control.

Begin with detailed measurement of the stream—both head (vertical drop) and flow (measured seasonally). Also, examine the on-site energy load (in kWh). Consider how much energy the stream could make, and what you’ll do with it. It may be that you’ll find a solution to the erosion and flooding problem that will also provide significant energy to the facility. The answer is in the results of a comprehensive resource and load analysis.

Ian Woofenden • *Home Power* senior editor

Roofing on SIPs

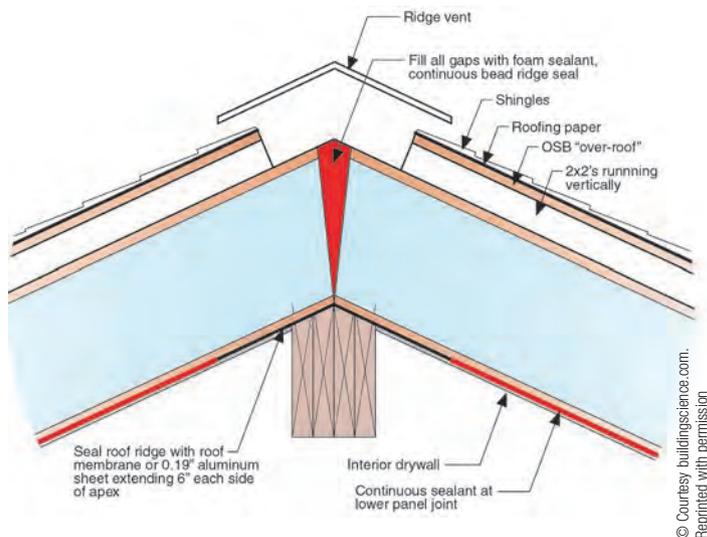
I’m in the early stages of building a structural insulated panel (SIP) home in the deep south and want to install a PV system on its roof. However, I’ve encountered the issue of potential incompatibility (and voiding the warranty) of shingles on a SIP roof.

I’m thinking that establishing a “cold” roof using 2-by-4s attached to the SIP’s top, but secured from the under/inside of an unvented roof with lag bolts (16 inches on center) would serve to secure a mounting base for a roof-mounted PV array. The cold roof would keep heat from building up inside the roof SIPs via simple convection through a ridge vent system, and if there is an unexpected cold snap, there would be no ice dams. The 2-by-4 spacers also would serve as a strong base for attaching the roof-mounted PV array. Of course the lag bolts would need to be applied with suitably sized washers to reduce any potential of pull-through. If there is a need to finish the inside of the attic, simple carpentry would allow this with minimum expense. Can you give me some feedback and expert advice?

Rick Sabb • Detroit, Michigan

Let’s start with the shingle warranty. Although some manufacturers do not offer a warranty for a “hot roof,” I do know that ELK brand does allow this type of installation on SIP roofs. The reason that others might not cover this type of installation is because of a perceived increase in shingle temperature. However, research conducted by Building Science Corporation (buildingscience.com) showed that although asphalt shingle temperatures increase slightly (2° to 3°F) in an unvented roof assembly, the color of the shingles and the roof orientation have a much more profound impact on their durability. If you are going to install a PV system over the roof, I would recommend a light-colored roofing material to keep your PV modules’ temperatures lower.

According to the “Builder’s Guide to Structural Insulated Panels (SIPs)” published by Building Science Corp., the typical reduction of shingle life over an unvented SIP roof assembly is between one and two years. As with any construction, there are different options. In all cases, the seams of all panel joints should be taped on top and bottom with a vapor-impervious material to inhibit air and moisture movement through the joints. A good way to go is to apply asphalt shingles on a SIP roof with a synthetic underlayment. A better way might be to install a layer of plywood or OSB over the SIPs. And, in my opinion, the best application would be to add a 3/4 to 1 1/2-inch sleeper and then the layer of plywood or OSB.



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These recommendations are also dependent on the climate you are building in. Even in the deep south, it would take more than a cold snap to create a problem with ice dams, since it’s highly unlikely snow and ice would sit on the roof for any length of time.

Lastly, considering the cost of the materials and labor to add a cold roof system, it might be more cost-effective to install a standing-seam metal roof, which doesn’t need a cold roof system, and should last twice as long as asphalt shingle. Plus, a standing-seam roof is easy to mount PV arrays on—no penetrations are necessary.

As to fastening the PVs to your roof, I refer you to an article in *HP156*: “Solar on SIPs.” If you do go to a cold-roof system, I would recommend GRK Fasteners (grkfasteners.com) as a better choice than lag screws. Enjoy your new home and PV system!

Patrick Sughrue • *ArtisanTinyHouse.com*

Tax Credit for Community Solar

On page 2 of *HP170*, Claire Anderson’s piece refers to a “recent ruling by the IRS” allowing an owner in a community shared solar array to claim the 30% tax credit.

I’d like to know more about this ruling, so I can determine if I could claim it. Does the ruling have identifying information, a date, number, office, or anything associated with it. Who could I ask other than a tax accountant? How did you find out about it?

My electric utility, a rural electric cooperative, installed a community PV array last year and sold shares in it. I bought a share and would be pleased to buy more— especially if I could claim the tax credit.

Thanks for your help and for your great magazine.

Glenn Heins • *via homepower.com*

The ruling was for an individual case, so may not widely apply, but could set an important precedent for other rulings to follow. See: ly/SharedSolarIRS for further info.

You should still consult with a tax expert. However, perhaps the Clean Energy States Alliance (CESA), as well as other community solar advocacy groups could also provide you with information and leads.

Claire Anderson • *Home Power* Managing Editor

Heat Pump Thermostat Management

I recently hired a heating repairman to inspect my older air-source heat pump system to make sure the freon was charged sufficiently and the system was operating properly—and ask if upgrading to newer equipment would be worth the money. During the inspection, he mentioned something about efficiency and cost that I'd never thought of, and I wanted to double-check the concept with the efficiency experts at *Home Power*.

Our standard mode of operation is to turn the heating system off at night. (Basically, the programmable thermostat is set so low that it almost never comes on during the night.) In the morning, it kicks on to heat the house to 67°F for the day. I work from home, so that temperature is maintained all day. This works fine on all but the coldest winter nights—our house has mediocre insulation, so if it's really cold out, we need some nighttime heating.

Understanding a little about heat-transfer theory, I assumed that letting the house get cold at night means a lower temperature differential with the outside, and thus less heat loss for those hours. More efficient overall, right? Bringing the house back up to temperature in the morning would require less "heat" than keeping the house warmer all night. Correct?

But the furnace technician told me that is an "expensive" way to run the system. Letting the house get colder at night means that when the system comes on in the morning, the auxiliary electric heater (as well as the heat pump) comes on to bring the house up to temperature quickly. He says that because the auxiliary heating elements are so much less efficient than the heat pump, a lot more energy is required to make that heat. So, while it may require less heat overall, the way I'm generating that heat requires more electrical energy.

Instead, he suggested that the nighttime setting be no lower than 60°F so that the heat pump can bring the house up to temperature by itself (or at least, the auxiliary electric elements only run for a short time).

I even asked him about disarming/disconnecting the auxiliary electric elements and running only the heat pump. He replied that the heat pump running by itself would take forever to catch up after a cold night. Keeping the house warmer at night was his solution to saving energy!

I'm sure that there is complicated math to find the actual balance point in this equation, including outdoor temperatures, the efficiency of my house's envelope, and the coefficient of power of my heat pump. But, in general, is this guy's theory correct? Have I been doing it wrong all along?

Todd Renard • Southern Oregon

Your heating technician's advice is sound for the most part. Electric heat strips cost several times more per Btu of heat produced than a heat pump, so you want to avoid using the auxiliary heat as much as possible. The question is how to do that without sacrificing comfort.

Today's heat-pump thermostats are much better at managing auxiliary heat staging during steady-state operation. However, even the smartest thermostats will energize the auxiliary heat when recovering from deep setback—even when the heat pump is perfectly capable of a quick recovery. That doesn't mean you can't save energy by reducing the set-point at night, or when the house will be unoccupied for more than a few hours. The trick is to insert yourself into the control strategy.

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First, have your tech install a manual override switch on the low-voltage wire that controls the auxiliary heat strips. Such a switch is required by code in some states. Depending on your skills and knowledge of thermostat wiring, this can be an easy DIY project. I typically mount an inexpensive toggle switch (SPST) on a blank trim plate next to the thermostat or directly on the air handler cabinet. The main thing is that it must be convenient. Also, you do not want to disable the strips by interrupting their power supply. Without supplemental heat, the system would blow cold air during defrost cycles. And finally, you'll need an outdoor temperature monitor, preferably one with a high/low memory.

With the auxiliary heat temporarily disabled, through observation you can estimate your home's thermal balance point (the outside temperature below which the heat pump can no longer keep up with the heat loss). The balance point will typically be between 25°F and 35°F, depending on the size of the heat pump relative to the design heat load. Wind and solar gain are also factors. You'll also discover how long it takes your heat pump to recover from setback when outside temperatures are above the balance point. I think you'll find that 7°F (67°F to 60°F) is too aggressive unless outside temperatures are at least that many degrees above the balance point during recovery.

Longer term, it's more convenient to install an outdoor thermostat on the heat pump that locks out the strips above an adjustable set-point. When using setback, you'll want to set the lockout a few degrees above the balance point to provide some headroom for recovery. However, you won't be able to tell from the system thermostat display whether the auxiliary heat is actually on. A better solution would be to replace your thermostat with one that supports aux lockout (requires a compatible outdoor temperature sensor).

The more difficult question is whether it makes sense to use setback when you know auxiliary heat will be needed for recovery. Heat-pump efficiency drops as it gets colder outside, but even at 0°F, it's still a lot more efficient than the strips. Depending on setback hours, how cold it gets, and how fast the house loses heat, it may sometimes cost less to maintain a warmer, stable temperature overnight than to rely on highly inefficient strip heat to reheat the house. The problem is that with so many dynamic variables at play, there's no way to work this out deterministically. But it's possible to make comparative estimates based on observation if you have your heat pump's expanded performance data and a circuit-level energy monitor. Fun stuff!

As for upgrading your heat pump, I strongly recommend that you first consider professional air sealing and insulation upgrades. Also, since electric supplemental heat is expensive, leaky ducts can have an outsized impact on energy bills for homes with heat pumps. If your ducts are routed through the attic or crawl space, you should have them tested for leakage. Anything over about 5% of system airflow is too much.

David Butler • Optimal Building Systems

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Pairing Up for a Net-Zero Solar Home

Story & photos by Mike & Linda Gallagher

In 2011, Mike Gallagher retired from a 31-year career at Century College in White Bear Lake, Minnesota, where he taught environmental science and helped organize its solar technician training program. A few years before retirement, he instituted a training partnership between the college and the Minnesota Renewable Energy Society (MRES).

At about the same time that partnership was started, Linda Cullen, executive director of Fifty Lanterns International, a solar lighting nonprofit, was asked by a MRES member to fill in for a speaker at the annual Midwest

Renewable Energy Association event in Custer, Wisconsin. Shortly thereafter they met again at an MRES solar class, and their shared love for solar energy turned into love for each other.

After long discussions, they decided they wanted to share their passion for solar energy by building an affordable house that would use a fraction of the energy most other new houses use. They sold their two houses in St. Paul and, with the proceeds from those sales, started planning their green dream home on Mike's 32 acres outside of Stanchfield, Minnesota.

South overhangs are designed for seasonal shading.

A covered porch wraps around the house on the other three sides, providing summer shade and rainy-day shelter.



The Process

From the beginning, they knew they did not want to burn any fossil fuel to heat, cool, or power the house. With more than 7,800 heating degree-days in their area (Stanchfield, Minnesota), but some winter sunshine, that meant designing a well-insulated passive solar home.

While they had some solar experience, they didn't have house design or building experience, so they knew they needed to hire an architect and energy planner. Even though they shared the same basic goals, Mike was primarily interested in the functional aspects of the house and Linda was motivated in researching design aspects. Design came first. They pored through books and Internet sources for designs.

To fit with the vernacular, the design took notes from local farmhouses, but, as Linda says, it's a "farmhouse with a twist"—an open floor plan. Ample natural lighting was a must. Also, with 360 degrees of amazing views, she wanted the house to feel like looking through every window was like looking at a landscape painting. She and Mike were also inspired by a passive solar home they'd toured on a wintry day. With floor-to-ceiling windows on the south side, Mike says, "it was as close to experiencing the weather outside as you could get—and still be toasty warm." With a wide open solar window on a relatively flat area atop a hill, siting wasn't an issue.

They worked with architect Rolf Jacobsen, who had previous experience designing passive solar homes in the Midwest, and hired engineer Philipp Gross to work with Jacobsen to make sure they had appropriate heating and cooling systems and that the design incorporated the principles of super-insulation, airtightness, and passive solar gain. The calculated heating load of the house is 5.2 kW (17.7 kBtu/hr.) In a conventionally built home, heating loads for homes in cold



Above: An open floor plan modernizes the interior of the farmhouse style.

Right: Ample solar gain keeps the living space bright and warm in winter.





Above: Stacks of EPS foam for insulating the foundation and concrete slab floor.

Top right: Foundation insulation in place, ready for waterproofing and backfill.

Right: The house was framed with 2-by-8 studs to provide ample space for insulation, then sheathed on both sides with OSB.



climates are usually estimated at 50 or 60 Btu/hr. per square foot—that calculates to 90 kBtu/hr. for an 1,800-square-foot home (the size of Mike and Linda's home). Their home is about 80% more efficient than a standard home.

Decreasing the home's embodied energy was also important to the couple, who wanted to use lower-toxicity, recycled, or biodegradable materials in the home's construction. "While we did use EPS foam around the footings and foundation walls," says Mike, "we wanted to limit its use due to its high embodied energy. That's why we chose the cellulose-infill wall system rather than SIPs [structural insulated panels]."

After about a year of planning, a design was settled on, a construction crew was hired and they broke ground in August 2014. Mike and Linda learned very quickly the importance of hiring people with experience building high-performance homes. There were many delays along the way because they had trouble finding professionals who not only shared their vision, but had the skills to turn the vision into reality.

Mike, being a former teacher, was eager to give a chance to a general contractor (GC) who was educated in sustainable building and design but had limited hands-on experience.

"Halfway through the build, however" says Linda, "we took back the reins. In hindsight, things would have been smoother had we been the GCs, using a consultant to guide us. Just because an architect can design it doesn't mean a carpenter can build it within our budget. The carpenters, energy designer, and contractors all had to work together for the common goal."

Construction

The approximately 5-foot-deep footings were wrapped in EPS rigid foam board, as were the poured concrete walls, then all was backfilled. The above-ground walls used 2-by-8 studs on 24-inch centers, with OSB (oriented strand board) on either side of the studs. Eighteen thousand pounds of dense-packed cellulose was blown into wall and ceiling cavities. Interior walls were then built out with 2-by-2s or 2-by-4s, creating cavities for wiring and plumbing.

They eliminated as many penetrations—water pipes, a dryer vent, cooking stove vents—as possible through the OSB. Prosoco joint and seam filler was used where OSB sheets met each other to eliminate as much air leakage as



Left: Nine tons of cellulose insulation was blown into the wall cavity.



Right: An additional 3 inches of mineral wool insulation was added to the exterior, bringing the total to R-40.

possible. Three inches of Roxul rigid mineral wool insulation was installed on the outside layer of OSB, giving a total wall thickness of about 14 inches. The insulation value in the walls is R-40; the roof is R-70.

Argon-filled, triple-pane tilt-and-turn windows were supplied by Wasco Windows, a Milwaukee-based manufacturer, as were the all-glass triple-pane doors. Following passive solar guidelines, most of the windows are on the south side of the house, and the 22-inch-deep south side roof overhang minimizes summer solar gain and maximizes it in the winter. The south side of the house is approximately 529 square feet; south-facing windows are approximately 136 square feet, resulting in a glazing percentage of 25%. The windows are also NFRC-certified, with a U-factor of 0.15.

There is no central furnace system—two Mitsubishi minisplit heat pumps, two electric Steffes heaters that use ceramic “bricks” to radiate heat (used only during “off-peak” hours), and a Tulikivi masonry wood stove provide supplemental heat. Wood will continue to be harvested off the property for the foreseeable future. “But,” says Mike, “when the sun shines, the dark concrete floors absorb the sun’s heat and keep the house comfortable.”

When constructing a house as tight as this one, it is important to have a ventilation system. The blower-door test showed 250 cfm at 50 Pa, giving 0.76 ACH (air changes per hour). An air-to-air heat exchanger—a Zehnder Comfo-air 350—that is 90%+ efficient conditions incoming fresh air and exhausts humid stale air.



Left: The tight house required an HRV for efficient fresh air circulation, which was hidden behind the upstairs knee-wall.

Right: Smoke testing for air leakage. The final pressure test resulted in only 0.76 ACH.





Left: Efficient Energy Star appliances make a good match in achieving net-zero annual energy use.



Right: A masonry stove and two electric mass heaters (one behind the rocker) provide backup heat.

Surviving the Building Process

The first half of the build, Mike and Linda lived in St. Paul and commuted every day to Stanchfield, a two-hour round trip. For the last six months, they lived on site in a pop-up camper inside the pole barn. They had no running water, no bathroom, and no privacy.

“It was an amazing experience to be there every day to play such a big part in building our house,” says Linda. “Often, some of our crew also camped on-site with us.”

To shower, Linda heated water on a small gas stove attached to the outside of the camper. “I carried my hot water, shampoo, and glass of wine to a spot behind the woodpile and took my bucket-baths there. Bundling up in the cold to maneuver through building materials, power tools, and a mud obstacle course at midnight to the portable potty is an experience I hope never to repeat.”

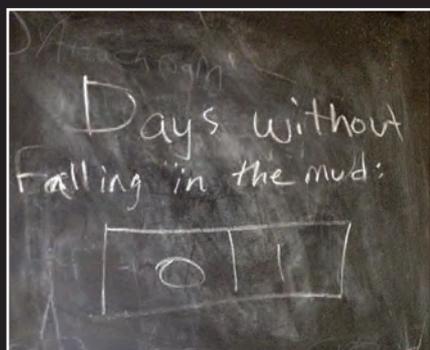
At times, things went painstakingly slow. It was hard to leave the site even for a day—there were always decisions to be made. They were also the ones who made the 15-mile round trip to the nearest home improvement store for supplies and materials, sometimes several times a day.

“We were in the trenches and often up to our knees in boot-sucking mud,” says Linda. “We hauled, pounded, lifted, sawed, and gathered. We tried to maintain a clean, happy, and pleasant

worksite, and always praised the efforts and energy of our crew as they bonded together with a common goal. We sang songs, played practical jokes, shared meals, and danced in the moonlight. Every day, we thanked the crew for building our house.”

Early on, says Linda, a good friend told her that building a home was like giving birth—“a long process, seemingly close to unbearable at times, and very emotional—but in the end all worth it.”

“At times, it seemed our project had the gestation period of an elephant,” says Linda. “But building sustainably really is worth it in the end. Living here is a dream come true for both of us. We will look back on this special time fondly, known as ‘the year we built our very special house.’ We not only lived through it; we loved through it.”



Active Solar

Active solar energy was one design imperative. Originally, they planned to use the south-facing roof (pitched at 45°) for a solar water heating system. However, Mike had installed a solar thermal system at a previous house that resulted in too much summer hot water and not enough in the winter. Realizing that they'd receive no financial benefit for having surplus hot water, they decided to increase the PV capacity to 10 kW to offset their water heating with a Marathon off-peak electric water heater, and get paid by the utility for excess electricity when not heating water.

Under their utility program with East Central Energy, Mike and Linda's PV system production is credited at the same rate paid for peak electricity—about \$0.12 per kilowatt-hour. They budgeted about \$40,000 for their PV system, and estimated the size based on a list of loads used in their previous homes. The array consists of 32 SolarWorld 315-watt modules connected to a 10 kW Fronius string inverter on a stationary ground-mount rack.

The vertical supports were helical screws, rotated 5 feet into the ground. The system was designed and installed by Powerfully Green of Champlin, Minnesota. In addition to installing the system, they also furnished Linda and Mike with an eGauge, with which they monitor not only solar production, but their energy use in real time. The software allows Mike and Linda to summarize the data in various formats, so they can instantly see how their system is performing and adjust their usage patterns, as well.



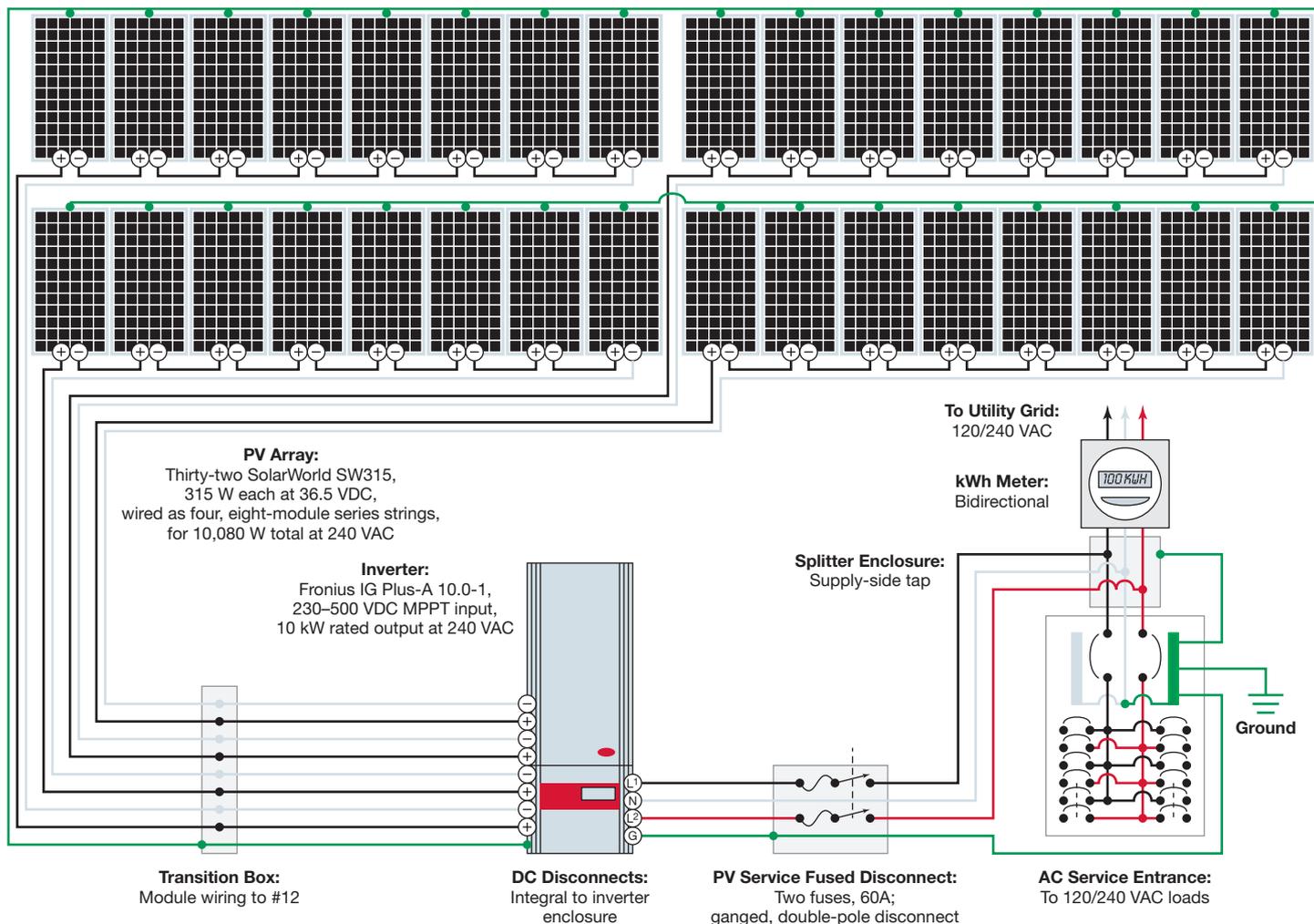
Top: Posts for the ground-mounted array were placed 5 feet deep.

Above: Mike helps the solar crew assemble the Zilla ground-mount rack system.

Below: Thirty-two SolarWorld 315-watt modules provide more than 10 kW of rated power—and an estimated 13.1 megawatt-hours of energy annually.



Gallagher Batteryless Grid-Tied PV System



Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.

Tech Specs

Overview

Project name: Gallagher residence

System type: Batteryless, grid-tied solar-electric

Installer: Powerfully Green

Date commissioned: June 2015

Location: Stanchfield, Minnesota

Latitude: 45.6°

Solar resource: 4.4 average daily peak sun-hours

ASHRAE lowest expected ambient temperature:

-23.8 °F

Average high summer temperature: 89.6°F

Average monthly production: 1,092 AC kWh
(PVWatts estimate)

Utility electricity offset annually: 100% (estimated)

Photovoltaic System Components

Modules: 32 SolarWorld SW315, 315 W STC, 36.5 Vmp, 8.71 Imp, 45.6 Voc, 9.35 Isc

Array: Four eight-module series strings, 10,080 W STC total; each string: 292 Vmp, 8.71 Imp, 364.8 Voc, 9.35 Isc

Array combiner box: Integrated into inverter

Array installation: Zilla mounts installed on south-facing ground mount, 30° tilt

Inverter: Fronius IG Plus-A 10.0-1, 10 kW rated output, 600 VDC maximum input, 230 – 500 VDC MPPT operating range, 240 VAC output

System performance metering: eGauge EG3010

System Costs

Initial Cost: \$40,000

Less 30% Federal Tax Credit: -\$12,000

Final installed cost: \$28,000



Left: Checking the 10 kW Fronius IG-Plus inverter.

Right: Reading system output (through the frost) on the eGauge.



Results

The PV system went live at the end of June 2015. They receive a check from the utility at the end of each month for the excess energy the system has generated. As of November 24, 2015, their system had generated 6,140 kWh, and they had used 1,890 kWh. That leaves 4,250 kWh, for which they have been paid approximately \$510.

The home achieved a Home Energy Rating System (HERS) rating of -7, meaning that the home is a net energy producer. A HERS score is a way to estimate, in relative terms, how well a house will perform, and accounts for the house's construction, insulation, windows, appliances, PV system (if any), climate, and a few other factors. A normal house built to today's code usually has a HERS score of about 100. A 20-year-old house that has been well-maintained might have a HERS of 150.

As of early November, they have had only one fire in the masonry heater, and turned on the brick heater once—just to test systems before they are really needed, when temperatures outside plummet. Inside temperatures remained in the mid- to upper 60s (and in the 70s when the sun was out), even though there have been plenty of frosts and even light snowfall.

Early in 2015, the construction crew assured the couple the house would be complete by the end of July, so they planned a housewarming event for August 22. Unknown to anyone, they planned to be married that day, and were—a couple brought together by the power of the sun!

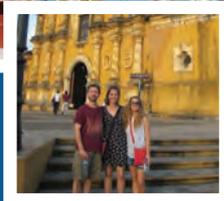


"GRID Alternatives set up an incredible week for us: humanitarian purpose; a terrific cultural education; and the chance to meet new friends. I'd absolutely do it again."

- Polly Shaw, Volunteer



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PEDAL & POWER

Electric Bicycles

by Ted Dillard

Courtesy Bosch

Few would argue against the many benefits of pedal power, whether the health, commuting, economy, or simply the fun that bicycles provide. However, many would-be enthusiasts find themselves in need of or preferring a little assistance.

In most cases, this comes in the form of 250 to 750 W motors powered by lithium batteries. Electric motors can give you just enough help to avoid arriving at your destination sweaty and tired. Electric motors can boost top speed, usually to just under 30 mph. And if you have more enthusiasm than energy, an electric bike allows you to keep up with more exuberant riders without risking exhaustion or injury.

Bicycles with electric motors have been around for many years, but in the last few years, we've seen several developments that are making them more usable, more practical, and more enjoyable.

While "What do I get for my money?" may seem a simple question to ask, the answer is not at all straightforward. With most personal electric vehicles, you can compare power ratings, battery capacity, range estimates, top speed, and other specs. But e-bikes are far more difficult to compare by price. Motor ratings, because of gearing options and adjustable assist rates, don't always tell the tale of final output. Range figures are almost impossible to estimate, since every rider will vary their "output," and one day will be different from

web extras

"Electrify Your Ride" by Ted Dillard in *HP146* • homepower.com/146.84

"Personal Electric Vehicles Get More Personal" by Ted Dillard in *HP144* • homepower.com/144.58

Hi-Power Cycles conversion kit uses a Crystalyte hub motor.



Courtesy Hi-Power Cycles

another. Beyond that, simple build quality includes not only the bicycle and normal components, but now extends to the drive systems, batteries, enclosures, charging, and battery management. A road test and personal comparison goes a long way to settle cost questions.

Since many of these products aren't handled by large distributors, you're also comparing shipping, dealer support, and service/warranty issues. A manufacturer that sells through normal bike channels can afford to offer support, but for many of the small companies, offering sales and support is an expensive proposition. More than most PEVs, electric bicycles tend to be a "you get what you pay for" product.

Motor Types

Hub motors. The most common design mounts a hub motor on the rear wheel of a conventional bicycle. More complex applications can use dual motors—one front and rear—for more power, better weight distribution, and better handling. These motors are controlled by an electronic speed controller, and often feature regenerative braking.

Mid-drive systems. Several iterations of pedal-assist have been released in the past few years, among them, the Bosch e-Bike systems, featuring four product lines with sophisticated electronics and control. The drive system can be tailored to the rider's whim, including smartphone linking and feedback, gear shifting, and a computer system that is a systems manager, navigator, and personal workout trainer all in one (bit.ly/BoschEbike).

"Mid-drive" means the pedals, motor, and transmission housing are enclosed in one assembly, and installed at the

A hub motor assembly on a BionX factory e-bike.



Courtesy BionX

Courtesy Bosch



Whether kit or factory bike, controls and gauges are cleanly designed.

bottom bracket on a conventional bike. There are a few notable advantages of a mid-drive over in-wheel hub motors, mostly more normal weight distribution (hub motors are rear-wheel heavy). Their drawbacks are that they are noisier, and far more expensive. In spite of these drawbacks, mid-drives seem to be the choice of almost every major electric bike manufacturer. While many hub motors have normal gearing for the human drive—the pedals—hub motors typically don't allow front derailleur gearing. A mid-drive can incorporate gears that benefit both the pedal-drive and the electric drive, whether in the housing of the drive itself, or as a standard rear-derailleur set.

Series-hybrid drives. While conventional e-bikes hang on to the traditional pedal-chain configuration, Mando's Footloose has a "series hybrid" drive system that uses a small generator powered by the pedals to charge the battery pack, which powers the motor through a conventional throttle. This folding bike gives the advantage of a small battery pack mounted within the carbon frame, yielding a lighter-weight bike (bit.ly/MandoFoot).

DISTINCTIONS

"Electric assist" is a general term that means any bicycle with an electric motor that helps propel the bike.

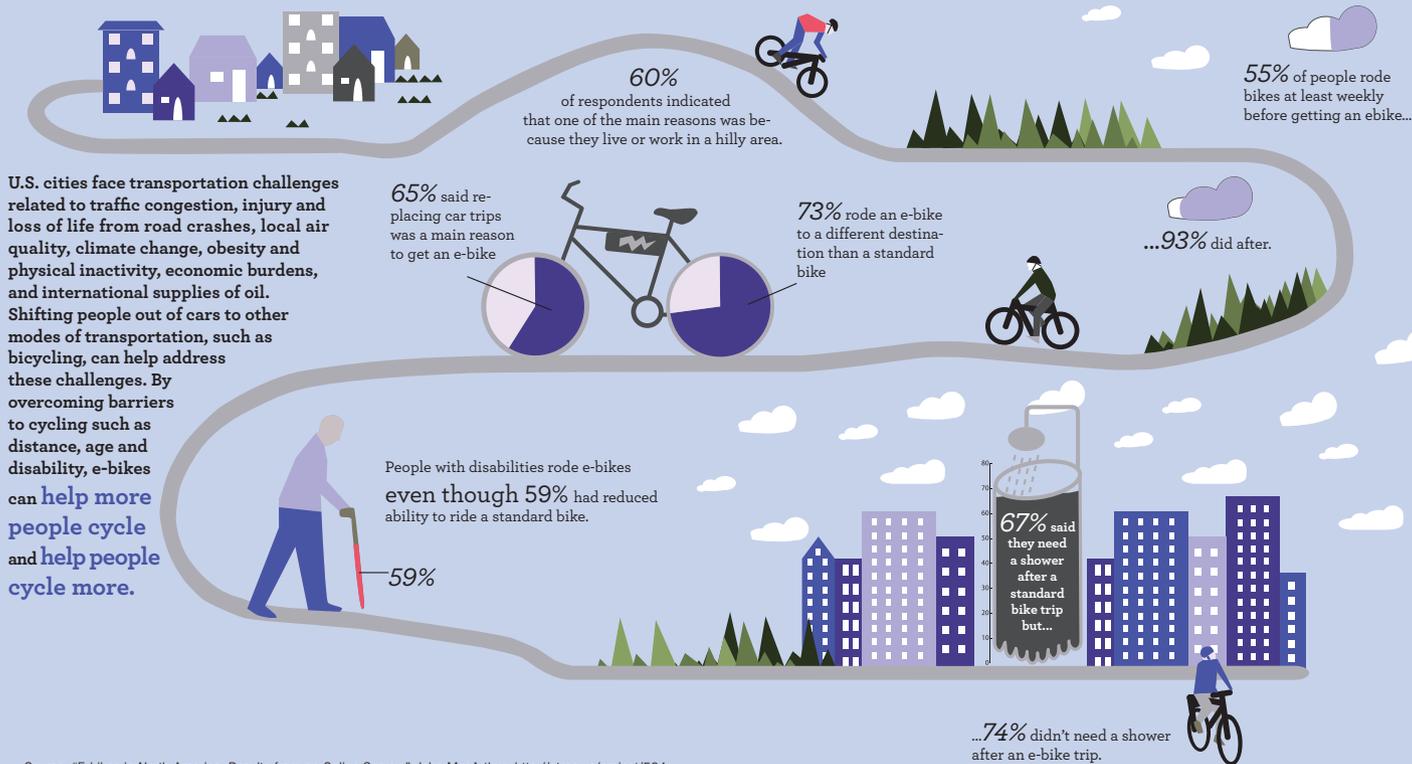
"Electric drive" can refer to a bike that is part moped—it has an electric motor that can drive the bike to near motorcycle speeds without pedaling.

"Proportional drive" is the term that several manufacturers use to denote an electric drive system that responds to the rider's speed and force of pedaling, increasing power as the rider increases effort.

"Pedal assist" generally refers to a system that is closely related to proportional assist, and provides power when the rider pedals.

WHY DO PEOPLE USE E-BIKES?

Portland State Transportation Research and Education Center



Source: "E-bikes in North America: Results from an Online Survey," John MacArthur, <http://otrec.us/project/564>

web extras

For more details on finding the right e-bike to suit your situation, check out electricbikereview.com

For more information about DIY, building and maintaining e-bikes, don't miss Endless Sphere • endless-sphere.com

Using the term "series-hybrid" to describe a bicycle drive system can be confusing, but makes sense in the context of automotive hybrid drive designations. Think of the human pedal-power as performing the same function as your auxiliary gas engine—turning a generator rather than directly driving the wheels.

Conversion Kits

Among the earliest options available were electric motor conversion kits, and these are usually found as basic hub-drive systems. Almost any standard bicycle can be converted to electric by bike-shop techs or the enterprising DIYer. The kits and systems are fairly basic in their design and control systems, and are controlled with a handgrip or thumb throttle. Companies like Crystalyte (crystalyte.com) offer complete kits, readily available through several retailers.

BionX (ridebionx.com) is a veteran electric bike company with its "Proportional Assist" system, and offers complete kits using this system. The system provides four levels of assist that engage as the rider exerts more energy. You push a little harder on the pedals, and get a little more assist—great for hills.



Courtesy Bosch

A Bosch mid-drive system mounted on a frame specifically made for it.

Featherweights & Heavyweights

Weighing between 35 and 50 pounds (or even more), most e-bikes are undeniably heavy and, most often, a little bulky due to the motor mounts and battery packs. Enter the Maxwell EP0 by a team of alumni hailing from Rochester Institute of Technology.

An e-bike designed with the bike-messenger track bike as a starting point, the Maxwell EP0 is lighter, nimble, and yet still provides a respectable amount of assist and decent range (15 miles, with moderate pedal input). At a leaner 27 pounds, the bike comes pretty close to the mark—the battery pack is located inside the tube chromoly-steel frame, and its unique controller is smaller and lighter than conventional designs. The EP0 is still in startup pre-production,

Courtesy Mando



The Mando Footloose is a series-hybrid e-bike, where pedaling charges the battery, so it's only electrically coupled to the drivetrain.

TRUNK BIKES & OTHER PERSONAL ELECTRIC VEHICLES

While e-bikes evolve and enjoy new popularity, and electric motorcycles come into their own, electric stand-up scooters, folding e-bikes, and two-wheeled self-balancing boards push the boundaries of imagination—and fun.

Small, foldable, electric-powered, limited-range folding bikes are being promoted almost entirely as “concept” vehicles, to fill a gap in an urban commuter’s daily journey. You drive your (presumably electric) car and park it in a convenient lot a mile or two from your destination, then reach into your trunk, pull out your e-bike, unfold it, and make the rest of the trip on two wheels—not quite the size of a moped or bike, but bigger than your kid’s toy scooter. Probably the most mainstream example of the car commuter’s folding electric bike is Ford’s concept Smart Mobility MoDe:Me and MoDe:Pro, but several other companies have similar concept products. None of these products are in production, with no real specifications or prices, and seem to be exploring the market rather than offering real products.

In contrast, available folding electric scooters are only a few hundred dollars, fold into something that you can tuck under your arm, and

weigh about as much as a few books and a briefcase. We’re very familiar with products like the Razor electric scooters seen at almost any “big box” retailer, but in recent years there are several intriguing new products in the vein of Segways. Out of China, there’s the SoloWheel (solowheel.com) and the Ninebot One (ninebot.com). Both offering lightweight, single-wheeled self-balancing electrics with two footpads and controlled by shifting body weight. Although they appear to be more of a toy than a commuter solution, in an urban environment they have their place—in the cities of China, you’ll see them in daily use. Segway, the U.S. company that pioneered this tech, was recently bought by NineBot, resulting in a few new models that appear to be far more similar to the original Segway, though lighter and less expensive.

While the Hoverboard that took the 2015 holiday season by storm made appearance in music videos and the celebrity media, they’ve also been sighted in U.S. cities—young, suited executives making their way through traffic to the subways and busses.

As a small, lightweight, urban, short-range transportation solution, though they may be toy-like, these products take personal electric vehicles into a new, practical, and exciting (dare we say “fun”?) era.



Left: A SoloWheel Orbit single-wheel personal EV.

Courtesy SoloWheel



Right: A Hoverboard, two-wheeled, gyroscopically stabilized, stand-on personal EV.

Courtesy Hoverboard



Courtesy Maxwell

The Maxwell EP0 is a lightweight, nimble e-bike.

but the team has delivered several production “beta” models and is accepting orders (maxwellmotorbikes.com).

On the other end of the weight spectrum are the electrified cargo bikes like the Yuba eMundo, a workhorse version of its Mundo model, with a BionX supplied drive system. These heavyweight bikes (the eMundo weighs 65 pounds) can carry loads ranging from groceries to passengers, without gasoline or registration, with ranges of up to 35 miles, at pennies a trip. (yubabikes.com). While the Yuba is a premium product, a more affordable option is the RadWagon by RadPowerBikes (radpowerbikes.com). It’s got a far more powerful in-hub motor, it’s only slightly heavier (75 pounds) and it’s just under half the price, at \$1,699.

The Velomobiles or “Bike Cars”

Few of the subgroups of bicycle enthusiasts are as emphatically committed as recumbent riders, and counted among these designs are an even smaller group—the velomobiles.

Velomobiles are almost always trikes—three-wheeled, recumbent, and often enclosed, both to protect the rider against the elements and to decrease aerodynamic drag. A recent development on this design is the addition of electric drive, generally in the 500 to 750 W range.

Of the two I’ve tested, there’s a wide range of both performance and quality—the Organic Transit ELF, a fully enclosed Kickstarter-funded startup, and Outrider’s Alpha—a fairing-less, proportional-assist rig placing the rider

The Yuba eMundo utility bike is specifically for hauling loads, with a frame that’s designed accordingly.



Courtesy Yuba

in a far more horizontal position, and more sport- and speed-oriented. The ELF weighs about 160 pounds and is powered by a 750 W motor, controlled by a simple throttle (organictransit.com). The Alpha can be equipped with several power ranges, up to 4,300 W, and lists a top speed of 50 mph. While the ELF has a 100 W PV module on the roof, and claims a full charge in seven days from this, the Outrider depends on a plug-in charger.

The riding experience for these two machines couldn't be more different. While, due to the steering and

Courtesy Outrider



The Outrider Alpha is a recumbent trike, with up to a 4.3 kW motor and a top speed of 50 mph.

ELECTRIC MOTORCYCLES

Last year brought some fairly remarkable developments in production electric motorcycles. One U.S. brand—Zero Motorcycles—firmly established itself as a legitimate manufacturer, while its main competitor Brammo was acquired by Polaris and rebranded under its Victory brand.

After several faltering steps in 2014, Mission Motorcycles, once tested and touted as the 21st century generation of super-bike, filed for bankruptcy in a dispute between the founders. Lightning Motorcycles has yet to sell more than a handful of electric motorcycles, and a few more manufacturers have announced production runs, product releases, company reorganizations, and investor backing, but have yet to have a retail product launch. A few major companies, notably Harley-Davidson and Yamaha, continue to field electric concept bikes at shows, yet remain quiet about production plans.

The Italian company Energica is the one standout of 2015. Backed by CRP, an Italian manufacturing company, it has developed the EGO and EVA models of electric super-bike. With speeds that can top 150

Courtesy Zero



Zero offers several bikes including dirt, dual-sport, and street models.

mph and 0-to-60 acceleration in the sub-4-second neighborhood, these models are well able to hold their own in the 600 cc sport-bike market. In 2014, Energica had its own world tour, getting riders in seats and hitting U.S. shores in the summer of 2015.

While Zero offers a fairly complete line of electric dirt, dual-sport, and sport-street bikes, Energica tops the charts with two bikes that fill the gap that Mission Motorcycles and Lightning Motors left open—true electric “superbikes.”

A lot of company problems may be attributed to underestimating the astronomical cost of bringing a vehicle to market. The end result is what appears to be a few solidly developed and backed products with a sober view of their future goals—not a mature market, but a promising one.

Energica’s bikes are targeted squarely at the “superbike” market.



Courtesy Energica

suspension geometry of the ELF, not to mention the noise of the body panels over anything but a silky-smooth road surface, our test riders were unable (and unwilling) to try to ride it at speeds greater than 15 mph. So while it's a terrific concept, riding the 4-foot-wide ELF on a busy, narrow New England road is hazardous at best, though the chances of you being visible in the ELF are much higher than in the Alpha.

Lacking an enclosure, the Alpha, low and muscular (but still heavy by bike standards at 100 pounds), feels like it was built specifically for speed. At just over 32 inches wide, it's a little more road and bike path-friendly, but still no match for its two-wheeled counterparts (outriderusa.com). As with most

recumbent rides, for road safety, it absolutely requires the "illuminated LED visibility whip" that is supplied standard.

While these are two products at polar extremes of the market, our best advice is "caveat emptor"—let the buyer beware, as well as research, read, and, if at all possible, ride, before deciding which velomobile, if any, is right for you. (For more information on velomobiles, see *Low Tech Magazine's* article at bit.ly.LowtechVelo.)

Whether for easier commuting, grocery-getting, extended travel, or keeping up with the kids or grandkids, with all of the options available, it should be easy to find green wheels to suit your needs.



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Bicycling as Transportation

Home Power senior editor Ian Woofenden has bicycled more than 20,000 miles in the last five years. Here, he shares his advice on how to get out from behind the steering wheel and behind the handlebars!

Story & photos by Ian Woofenden

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homepower.com/172.44

I read two things in my youth that had a lasting impression on me. One was that a bicycle is the most energy-efficient way for a person to travel. The other was that if you count up all the time we take to buy, finance, license, insure, maintain, repair, and drive a car, we're really only going about 10 miles per hour. I haven't done the research to confirm or deny either statement, but the general drift made complete sense to me as a young person, and started a love of bicycles that has lasted for decades.

But like most Americans, I got caught up in the car culture while raising a family and leading my busy life. My kids are now grown, and I've lived without a car for the last five years (I do own a dump truck, and borrow and rent cars as needed). I enjoy the benefits of exercise, lower cost, closer connection to community and nature, as well as what comedian Robin Williams called "the closest you can get to flying."

Use the Bike You Have

Most of us learned to ride bikes when we were young, and the old adage is correct—you don't forget how to ride, even if you haven't done it for years. The biggest stumbling block to using your bicycle more is *you*. Many people find ways to work bicycles into their transportation scheme, ranging from it having a minor part to being a key player.

I encourage you to get on the bike you have, but if you need to buy one, try different bikes first. Borrow friends' bikes. Rent bikes. Try cheap yard-sale bikes. Talk with local bike nerds and bike shop owners. You'll gradually find a bike that is suited to your needs. Real-world experience combined with input from others is the best route to improving your rolling stock. Meanwhile, you'll get all the benefits of getting onto your bike.

Why Bike?

- Decrease your carbon footprint. Cars are a significant portion of the typical American’s environmental footprint, and depending on your situation, needs, and determination, you can take a big bite out of that by using bikes.
- Save money. For a few hundred dollars, it’s easy to find a quality used bike that will handle most of your transportation needs. After my bike’s initial purchase, my annual bike-maintenance budget is just a few hundred dollars. Compare that to the cost of fueling and maintaining even an “economical” car, not to mention its purchase cost.
- Improve your health. My body gets a boost from regular exercise, my mind gets stimulated, and my emotions are calmed by a regular ride.
- Engage with your community. I often see birds, mammals, reptiles, plants, and even rocks that I never would have seen if I’d been whizzing by at 60 miles per hour. And unless I’m very focused on my schedule and destination, I have time to make eye contact with other humans, wave and smile, and sometimes even stop to visit.
- Lighten up. Traveling by bike affects how much stuff I use, own, and travel with, and forces me to prioritize what I really need. I can easily travel for a weekend or a week with only two panniers to carry my clothes and office (plus my travel guitar strapped on top).



One of the author’s trusty steeds, loaded for a typical weekend or week-long trip. Even the guitar comes along for the ride.

farther-flung errands, visiting friends, or just enjoying a new area of the gorgeous part of the world I live in. And I’m capable of doing 90 to 100 miles in a day when I have the time and interest, and occasionally do trips of a few hundred miles or more to see family, friends, clients, or countryside.

While I love riding from my island home to Seattle, it takes a day (and a day of recuperation doesn’t hurt either), so I more typically combine 20 to 50 miles of biking with car, bus, or train. The train is comfy and direct, and major commuter routes around the country allow bikes in the baggage cars without boxing. But it’s a bit on the costly side for short runs, so I more often use buses. Almost all city and regional buses have racks on the front that can carry two to three bikes, and some will also allow bikes inside.

Hybrid Travel

My travel routine includes a trip to town once or twice a week, which typically ends up being 12 to 20 miles round trip, depending on what’s on the errand list. A few times or more a month, I may go farther by bike alone, commonly doing a 35- to 40-mile day when I’m seeing a client, doing

A typical trip to town—the author and his newest bike on a ferry.



Local and regional buses offer bike racks, helping extend your travel range.



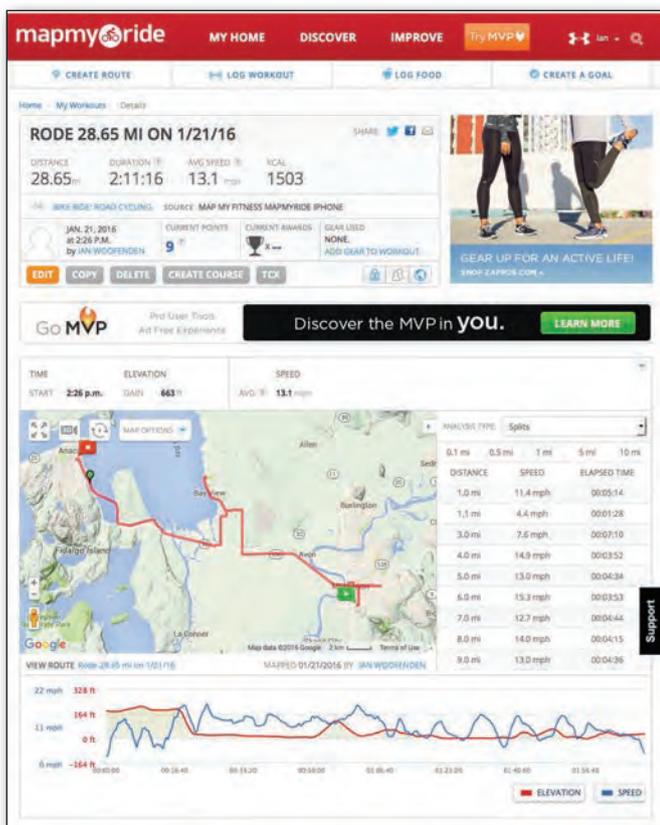
One of the author’s bikes and others loaded in an Amtrak train’s baggage car.



Where to Ride

It turns out that railroad engineers and traveling bicyclists have similar goals—to make the route as flat as possible. Termed “rail trails,” many abandoned railroad right-of-ways are being turned into walking, bicycling, and equestrian trails. They are a lovely way to get around town or across the country, without worrying about the primary danger to bicyclists—cars. Check out your area, and places you hope to travel, and see what you find for rail trails and other dedicated bike paths, both paved and not.

Some people confine their biking to dedicated bike trails, but this limits bicycling’s usefulness as transportation. I bicycle on all kinds of paths and roadways—from mountain bike trails to highways. And while dedicated bike trails are definitely the most pleasant, once you get used to riding intelligently and safely, other options open up the world.



Above: Smartphone apps can suggest bike-friendly routes and track your rides, including distance, speed, elevation changes, and even your heart rate.

The author regularly uses this old rail line, converted to a bike path, to cut across a bay near his home. The alternate route is longer, with dangerous high-speed automobile traffic.



Biking Tips & Tricks

- **Adjust the seat.** At the proper seat height, you should be able to fully extend your flat foot to the pedal (yet maintain a slight knee bend when the ball of your foot is on the pedal). Having this longer stroke gives you more power and also reduces stress on your knees.
- **Consider your pedaling cadence.** Selecting a gear that lets you pedal a bit faster and not as hard is actually easier on your body *and* more efficient in getting you down the road.
- **Check the forecast.** Choose your riding times and routes to benefit from or avoid the wind (or other inclement weather), and choose your clothing accordingly.
- **Carry water.** For longer trips, also bring food—it is your fuel.
- **Learn the rules of the road.** Riding on the wrong side of the road, turning and stopping unpredictably without signaling, and not paying attention to others can be problematic in a car—on a bike, they can be deadly. Stop at stop signs, though some communities allow rolling stops for bikes. Thinking of yourself as a vehicle and acting accordingly is a good start to sensible riding.
- **Be visible.** Wear bright clothing. Use flashing lights on the front and rear (even during the daytime) of the bike. And, when appropriate, take up the entire lane (see bicyclesafe.com for more safety tips).
- **Use mirrors.** I never travel without a mirror on my own bike, or a Velcro-attached mirror on the handlebars of a borrowed or rented bike. My primary bike has two mirrors (it’s surprising how much that right hand mirror helps my awareness of what’s going on behind me).
- **Take breaks.** Stop for a rest: a visit, a phone call with a friend, or a nap can give you a second wind, lifting your spirits and your body.

Resources

railstotrails.org • trailink.com • bicyclesafe.com • warmshowers.org • mapmyride.com



Bike routes help separate you from dangerous car traffic. Then, however, you become the “high-speed” danger—ride with respect to pedestrians and equestrians.



You don’t have to figure out how to “tow your own,” as the author does here with a wheelbarrow—bike trailers connect safely to your bike and can expand your load-carrying capacity.

It might seem logical to seek routes with the least traffic, but this isn’t always the best plan. More important is the road space and surface, and the route’s grades. Seeking routes with less climbing will often get you to your destination more quickly and with less sweat. I frequently ride longer miles to avoid hills. Topographical maps and apps can help avoid the grinding hills (unless you’re looking for that), and local bike maps and experienced local bikers can help find the roads with more space and smoother road surfaces.

Go For It

You can choose to go “all the way” or to bike some of the time, for whatever reasons—transportation, sport, relaxation, exercise, or commuting. To get started, find a bike near you, a quiet path or road, and then expand from there. There’s a world of clean, quiet, low-stress, low-cost, high-benefit transportation awaiting you when you leave the steering wheel and get behind some handlebars!



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Simply the Best

Maximizing Performance of Grid-Tied PV Systems

by Lena Wilensky

A PV system is a substantial investment that needs to perform well to earn its worth. Here are some ways to protect that investment by maximizing system output.

A PV system's job is to produce as much energy as possible. Maximizing system performance means getting the best return on investment, as utility bills are reduced or even eliminated. More energy (kWh) produced means a quicker payback time and a greater return on investment. With an off-grid system, an optimally performing system will save on generator run-time and thus fuel and longevity expense, as well fulfill its most important function: providing enough power when you need it. If you are comparing PV system bids, it's wise to look at the cost per kWh (\$/kWh) of different proposals. PV system initial cost is often talked about in dollars per watt. The problem with this metric is that, depending on siting and shading factors, the same size PV system could perform very differently depending upon variables—for example, a 5 kW system facing true south is likely to produce more energy over its lifetime than if it was on an east-facing roof.

Consider two 5 kW systems that each cost \$20,000. One is installed on a south-facing roof and produces 7,000 kWh annually; the other is on an east-facing roof that experiences some shade and produces 3,500 kWh annually. While the cost per watt is the same—\$4 per watt—the cost per kWh is quite different. The first system makes twice as much energy for the same cost, doubling the return on investment compared to the second system.

Site Specifics

Finding a good solar site on a property will go a long way toward maximizing PV performance. If you are lucky enough to be starting from scratch—building a home or adding on to one—there are some basics to consider. Potential clients often approach us to install a PV array on their new home after the home's design and engineering are complete. Usually, it's too late to make simple changes that would have increased a system's annual output and thus lowered the system's dollar-per-kWh cost.

The best site for your array might not be your roof. Though system costs may be higher, ground-mounted arrays may offer better solar exposure—and better payback.



Lena Wilensky (2)

Array orientation & tilt. In the northern hemisphere, the sun is strongest in the middle of the day at an azimuth of 180° (i.e., south) and at solar noon. To get the most energy production from a PV array, it's important to orient modules correctly. With that said, varying about 20° from the ideal orientation doesn't affect overall annual production substantially.

In addition to the array's compass direction, we also have to look at its tilt angle to ensure it is capturing as much sun as possible. Tilting a fixed south-facing array so that the tilt angle is equal to the site's latitude position will often (but not always) be the best angle for annual output. For example, the latitude at my Colorado home is 40°N, so a 40° tilt or 10:12 roof pitch works well.

Tracking mounts can increase energy that a pole- or ground-mounted array produces by moving the PV array (changing its orientation and/or tilt angle) to follow the path of the sun throughout the day. This ensures more direct sun hitting the modules in the mornings and afternoons, rather than simply maximizing harvest in the middle of the day. To determine if a tracking mount could maximize your PV investment, you will need to compare the \$ per kWh of a tracking mount and a comparable fixed mount. While a tracking array will probably produce more kWh in the same amount of space as a similar sized fixed pole mount, the increased production may come at a higher cost per kWh. In some cases, it makes more sense to add a second fixed mount or a larger fixed mount to increase kWh production rather than spending more money on a tracking mount.

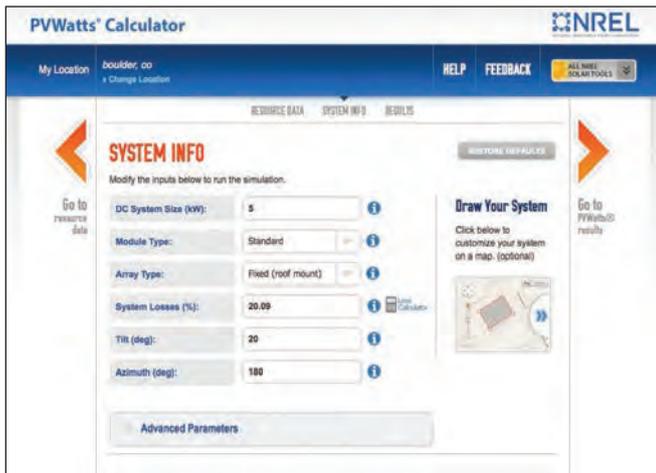
Nonoptimal Roof Layouts

If PV array layout options are limited, there are ways to improve performance at less-than-ideal solar sites. For example, if you need to install on multiple roof faces at different tilts and orientations, you can minimize production losses by using module or string-level control devices such as microinverters, DC optimizers, or string inverters with multiple maximum power-point tracker (MPPT) inputs. These devices ensure each module or series string is producing its maximum power at all times of the day—something a single MPPT string inverter cannot do unless all modules are at the same tilt and orientation.



Courtesy Warren Tessler

Multipitched or partially shaded subarrays require a solution for variable output between individual modules. In this case, microinverters were used.



The National Renewable Energy Laboratory's PVWatts (pvwatts.nrel.gov) online tool can estimate PV system production based on orientation and tilt. You input the PV array's orientation and tilt, as well as some other variables, such as locale, module nameplate rating variations, shading, snow losses, wiring losses, etc., and it will output the PV array's expected production (see the yearly production table from PVWatts data).

PVWatts is a great calculator for answering many solar siting questions, such as: Is it worth putting modules on my east-facing roof, or should we use a south-facing ground-mount? Should we mount modules at the roof pitch or tilt them? How much energy will be produced if the array is not facing true south? If you know the system cost for each layout, you can compare which has the best dollar-per-kWh yield.

Above and right: The PVWatts online calculator is a great way to quantify the many variables of system performance for your location.

Typical Annual PV Production (kWh)

Tilt	Azimuth, Degrees from Facing North									
	270° = W		225° = SW		180° = S		135° = SE		90° = E	
	kWh	% of Max	kWh	% of Max	kWh	% of Max	kWh	% of Max	kWh	% of Max
20°	6,152	78.4%	7,064	90.0%	7,548	96.2%	7,360	93.8%	6,569	83.7%
30°	5,898	75.2%	7,133	90.9%	7,794	99.3%	7,542	96.1%	6,464	82.4%
40°	5,606	71.5%	7,064	90.0%	7,846	100.0%	7,560	96.4%	6,278	80.0%
50°	5,281	67.3%	6,852	87.3%	7,708	98.2%	7,414	94.5%	6,016	76.7%

Note: For a 5 kW fixed array in Boulder, Colorado; Latitude = 40°N

Data courtesy PVWatts



Ben Root (2)

This array receives a lot of shading from evergreen trees—even past midday.

In the late afternoon, the same array receives partial shading from the stovepipe.

Array shading. For best performance, the array should be free of shading, such as from vents or chimneys. Shading on just one corner of a PV cell can cause significant power loss in the entire module. If an entire row of cells is shaded (say the bottom fifth of a module), the entire module may shut down. And just one underperforming module can cause that entire series string's performance to drop significantly, or potentially not produce at all. Good solar access would be shade-free from 9 a.m. to 3 p.m. (the bulk of the solar day) year-round—and a longer shade-free window is even better (such as 8 a.m. to 4 p.m.)

Mitigating shading can be difficult. One option is to remove the shade-causing object: For example, moving a vent fan to the north side of the roof. However, removing the offending object is not always possible or desirable. For example, cutting down a tree that provides shade (which decreases the air-conditioning load) to reduce array shading can be counterproductive, and moving a neighbor's home that shades your perfect ground-mount location is simply not possible.

A Solar Pathfinder will show year-round shading at a particular site.

Investigate several possible array locations. If the roof isn't ideal, and the yard is too small or shaded, consider a solar awning, pergola, or even a vertical mount on a wall. Perhaps a combination of several locations will add up to the production you desire.

Let's say there's an otherwise-viable location, but the neighbor's tree shades one or two modules for two hours during the middle of the day. Those shaded modules are not going to produce much (if any) energy no matter what we do, but we can decrease their effect on the rest of the PV array by using microinverters, DC optimizers, or by grouping the shaded modules on one MPPT inverter input. These methods isolate modules (or strings) so one or two shaded modules don't jeopardize the rest of the array's production. Note that this minimizes the effects of shading, but does not erase them altogether. So when estimating production numbers for a new PV system, shading losses should still be figured in. (Shade factor can be determined with a solar site analysis tool like the Solar Pathfinder, solarpathfinder.com.)

In cases of partial shading, microinverters and DC optimizers can limit the shading effects to individual modules, not the entire string or array.



Lena Wilensky (2)



Equipment Choices

PV modules. After finding the best solar site, you can often improve system output and efficiency through equipment selection. All PV modules are rated in watts at standard test conditions (STC). The specifications also include a power rating tolerance, such as +5%/-5% or similar. In this case, it means that a 280 W module might produce between 266 W and 294 W at STC. This variation is due to manufacturing tolerances, but it's important to realize that a 280 W module might really be a 266 W module. Some module manufacturers offer modules with only positive power tolerances, such as +3%/-0%, so that you know what you are getting and can avoid factoring in those manufacturing inconsistencies.

If you have a limited mounting area, you may want to choose premium high-efficiency modules to increase your system's capacity. While this can reduce the per-watt mounting expense, high-efficiency modules often cost more per watt. A careful analysis comparing the options should be done to see which module options meet system needs, but still pencils out (see "Ask the Experts" in *HP168*).

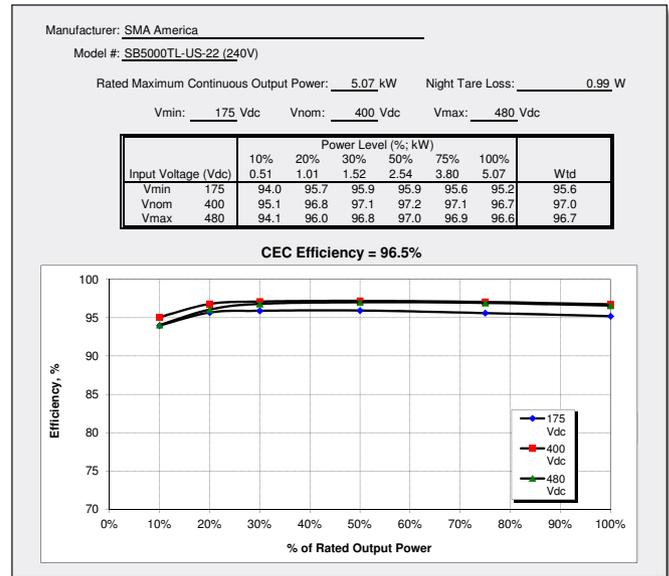
Array mounting. Module power ratings are higher than most modules will produce in the field because high PV cell temperatures reduce the module's voltage, and because less-than-ideal solar irradiance reduces module current. We cannot increase solar irradiance, but we can make sure there is sufficient (3 inches or more) air gap between the roof and the array to facilitate airflow, which helps to keep modules cooler. (Ground- and pole-mounts offer unrestricted airflow around the modules, keeping modules even cooler.)

Inverters. Most inverter manufacturers list peak efficiency ratings for their products, but this number is more for marketing purposes than a reflection of what normal operation will yield. The California Energy Commission (CEC) publishes a list of inverters' "Weighted Efficiency," where their efficiencies were established under conditions, temperatures, and power levels that better reflect real-world usage (see bit.ly/CECinverters). Some inverter manufacturers include the CEC weighted efficiency on their spec sheets.

A higher CEC efficiency reflects better equipment power conversion losses and higher system output. In hot climates, inverter efficiency can be decreased or the inverters could even shut down if their internal temperature gets too high. Placing inverters out of direct sun and where air can circulate around the inverter housing helps keep them cool and more efficient.

Designing module series strings. When specifying PV modules and inverters, it is important to account for the effects of temperature and age on array voltage to make sure it always stays within the inverter's DC input voltage window. Inverter manufacturers generally provide online string-sizing tools that allow you to input a specific module, inverter, and your site's high and low temperatures to help determine the number of modules allowed in each series string.

Example CEC Inverter Performance Data



Modules degrade over time. For crystalline silicon modules, the average power degradation rate is about 0.5% per year. Depending on how a module is aging, this power loss may be due to current loss, voltage loss, or a combination of the two. Less current output results in proportionally less energy production, but, over time, voltage loss can cause your array to sink below the lower limits of the inverter's voltage window, shutting down power production during the hottest part of the day—just when you want to be harvesting all that solar energy. So again while designing your system and sizing module series strings to a particular inverter, it's good practice to make sure your array is well within that lower voltage threshold.

System Monitoring

Once a PV system is installed, it's helpful to verify production. Many people just check their electric bills and assume all is well if their bills are low. But this isn't an accurate way to assess PV system performance. Your electric usage changes month by month and most utilities only show the net result on your bill, so you won't know if your system is producing the energy that it should be.

Installing a production meter on your inverter's output is a great way to keep track of total energy produced, but it does require that you log the usage at regular intervals to see if your system is meeting energy specifications. Your inverter also displays cumulative totals, but, again, these need to be checked regularly. Many inverter companies and other third parties also offer more in-depth data monitoring and data logging that records and displays daily, weekly, monthly, and annual production. Some products even send an email alert if production looks out of spec, or if they detect equipment problems. If you think your system is underperforming, you can also compare instantaneous power output against estimates—see "Methods" in this issue.



Battery backup adds expense and inefficiency to a system. Is the emergency power worth the energy and dollar cost?

Batteries. A battery-based grid-tied PV system will supply backup power during a utility outage, but also has lower overall system efficiency than a batteryless system. Different battery technologies (lead-acid, lithium-ion, nickel-cadmium, etc.) have different characteristics, but all batteries lose some energy in converting electricity to chemical energy and back again, and just from being on standby. That energy has to come from either the PV array or the grid, and thus lowers the overall efficiency of the PV system (see “Adding Battery Backup to Your PV System” in *HP168*). One option for a limited amount of batteryless backup power during a sunny day is an SMA America TL inverter with secure power supply (SPS). Assuming enough available PV energy, the inverter can supply up to 1,500 watts (and some models supply up to 2,000 W) to a dedicated outlet (see “Backup Power Without Batteries” in *HP159* and “Gear” in this issue).

Energy Loss from Snow

Common sense tells us that in snowy areas, some PV production loss will occur due to snowfall. The question of how much is a more difficult one, but PVWatts can help. Click on the little calculator icon next to the input box and a number of different variables, including one for “snow %,” appear. Here, you can estimate what percentage of production loss might be due to snow effects. In my experience with installing PV systems in the Colorado mountains, annual losses in the 5% to 10% range are common. Areas with less snowfall and warmer weather might experience losses between 1% and 5%.

Here are some considerations for installing a PV array in snow country:

Higher tilts (and roof pitches) are better. A bare south-facing roof that holds snow for a couple of days after a storm will also hold snow with a PV array on it. In Rocky Mountain locations, this applies to roof slopes less than about 30°.

This shallow-pitched porch roof is preventing snow from shedding off the slightly steeper-pitched PV array above it.



Lena Wilensky (2)

Provide adequate ground clearance. An array that has a bottom edge only a few feet above grade will likely get shaded and potentially damaged from snow that accumulates at its bottom edge.

Watch out below. Snow shed from an array placed on a steeper pitched roof above a lower pitch has a tendency to build up, potentially covering the lower part of the array and damaging modules, racks, and the roof.

Beware of roof valleys. Valleys tend to hold snow longer than planar roofs, as do dormers and pipe flashings.

Mind the orientation. East- and west-facing arrays will have a harder time shedding snow since they won't receive the same amount of direct sun as south-facing arrays.

Keep arrays close the ridge. This helps ensure no snow can build up above the array. Otherwise, snow trapped above an array could create an ice dam, damaging the array and roof.

If you do get snow buildup on your PV array, it may make sense to clear it off to keep production humming along, but only if you can safely do it. If there is any doubt about being able to stay out of harm's way while clearing your array, let the snow clear on its own. In snow country, a few days of snow cover aren't going to significantly reduce your PV system's annual production, anyway—the bulk of its energy harvest happens during the summer months.

Here are some strategies to consider, making sure to stay well clear of snow sliding off, whether you are on the roof or below it. People die every year from snow sliding off roofs.

- Use a roof rake to knock down snow below the array
- Use a roof rake with a soft attachment, such as a push broom head, to gently brush snow off the modules
- Get on the roof (safely, with appropriate fall protection) and gently clear snow from the array with a plastic snow shovel or push broom, being careful not to scratch the panels or disturb the module frames. A thin layer of snow will melt pretty quickly in the sun.



A steep roof on a tall structure adds complexity and cost to the installation.

Wiring. Energy can be lost from voltage drop in long wire runs or wire that's too small. This is the case not only in the PV array circuitry, but if the AC output circuit voltage drop is large enough it can cause the inverter to shut down when the PV system is producing the most power. With full current flowing, the voltage drop can push the AC voltage out of the inverter's output voltage range, shutting it down.

On the DC side, if there's voltage drop due to wire loss, power will be lost. If the voltage drop is severe enough, especially if wiring losses are combined with hot PV cells and module degradation, the entire array may fall below the inverter's input voltage window, causing power production to stop. To minimize voltage drop in wire runs, consider ways to reduce wiring run lengths and/or install the correct wire gauge to keep input and output voltage within the inverter's limits. (See "Ask the Experts: Voltage Drop" in *HP153*. There are also online voltage drop calculators available.)

Over time, even a little dirt or pollen buildup on your modules can cause a drop in overall performance.



Lena Wilensky (2)

Installation Factors

Installation factors can affect performance and system expense. If your system costs go up, then your cost per kWh goes up. To keep installation costs lower:

- The array location should be convenient to access for installation and maintenance (but not to children, animals, or other unauthorized visitors).
- Wire runs from the array to the inverter and grid interconnection should be as short as possible and easily installed. The more wire and conduit that needs to be run, the higher the installation cost. If your installer has to trench underneath a walkway or patch a driveway, cost will go up.
- Consider your mounting options. For example, steep metal roofs that are three stories up can take twice as long to install as an array on a single-story garage roof at a shallow pitch. Ground- and pole-mounts can be more expensive than rooftop mounts and require substantial digging and concrete work for the footers, which will also drive up costs.
- Adding batteries to your grid-tied system for backup will drive up prices significantly, depending on what loads you want to back up and for how long.

Reducing Operating Losses

We can wring a little more performance out of our PV array with cleanliness. Dust, leaves, pine needles, and even bird poop can build up on PV arrays over time and reduce performance. Regular inspection and cleaning can help, especially in areas without much rain. Snowstorms can also cover arrays and reduce production, especially on low-sloped roofs and where shedding snow may accumulate at the bottom edge and cause shading. Good design and maintenance can help alleviate losses from snow.

Making the Most of What You Have

It can be difficult to find the perfect PV system scenario in the real world, but that's no reason to pass on PV. The decreasing cost of PV modules; increasing cost of utility electricity; new power conversion technology; and installer know-how have combined to make it financially viable to put up arrays that are not facing true south and tilted optimally.

If you know the cost of the system and how much energy it will produce, you can make an informed decision about whether it is worth the investment, and at what level you want to optimize output. And once it's up and running, you can monitor the system to make sure it is performing as expected.



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Leasing vs. Owning a PV System



What's Best for Homeowners

by Vikram Aggarwal

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For homeowners who want to transition to solar electricity, there is no better time than the present. 2015 was the biggest year ever for PV installations in the United States, and the residential sector in particular continues to grow at unprecedented rates. Falling PV module costs, rising electricity prices, and increased awareness of PV's financial benefits are making solar electricity an increasingly attractive option.

Growing Financial Benefits

In the past, high costs kept the majority of homeowners from installing PV systems. Many early adopters chose to go solar because of environmental concerns, or a desire to reduce their reliance on the electric power grid. In recent years, however, the solar market has opened up to an entirely new class of consumer. Today's potential PV system owners are also motivated by the prospect of saving money on their electricity bills and making a responsible investment in their home.

Beneficial market conditions and significant financial incentives are bringing new solar customers into the market in greater volumes than ever before. The top three economic factors include:

Reduced system costs. Declining equipment prices and installation costs are directly reducing the out-of-pocket costs required of homeowners who want to install a PV system. Since 2010, the costs of going solar have fallen by 45% in the residential sector, according to the Solar Energy Industries Association (SEIA).

Increasing utility electricity costs. Climbing electricity rates add another reason to explore renewable options. Since 2005, residential electricity costs in the United States have increased by an average of 3% every year, according to the U.S. Energy Information Administration.

Federal and state incentives. Public sector financial incentives further reduce the cost of solar for consumers: the most significant being the federal investment tax credit (ITC). Property owners who own their systems outright can use the ITC to reduce their tax burden by 30% of the cost of their solar energy system. For example, if a homeowner installs a \$20,000 PV system on their property, the ITC allows them to claim a \$6,000 credit on their tax bill, effectively reducing the cost of the system to \$14,000. State and municipal incentives can further reduce the net cost of going solar for homeowners.

Solar Bargain Hunters

These factors are expanding solar demand and garnering more potential system owners who are financially focused and likely to compare options before purchasing. These individuals want to find the best solution for their particular household, and are not necessarily interested in the simplest buying process or least expensive system.

Market research shows that there are between 4 and 6 million active solar shoppers in the United States at any given point. Interestingly, the majority of these people are not motivated by environmental reasons, but by the pure economics of switching to solar power. As such, these individuals want to understand the financial merits of each option before making a purchase. During their research process, they're discovering that system ownership enables them to achieve a higher return on solar investment as compared to leasing.

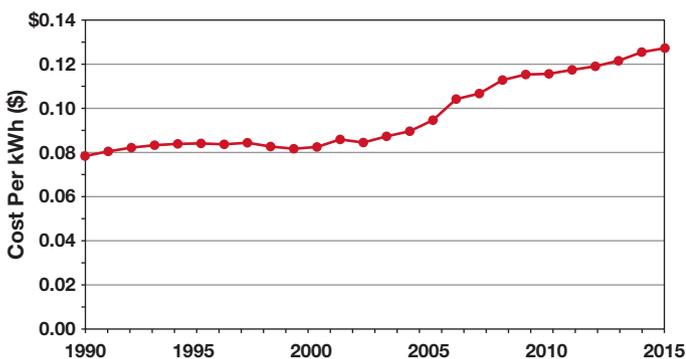
Financial Benefits of Loans

Large solar installation companies rely almost entirely on third-party ownership, which includes solar leases and power purchase agreements (PPAs). Under this model, the solar company installs a PV system and the property owner pays the company a fixed price to "rent" the system for the duration of the agreement.

The companies' aggressive advertising of solar leases and PPAs created an artificial upsurge in demand for leases and PPAs, as many homeowners were led to believe that system ownership was cost-prohibitive. Traditional loan options for homeowners were limited, and the options that did exist suffered from a lack of advertising dollars and brand awareness.

But as consumer awareness increases, so does the demand for PV system ownership, and the supply of new financial products increases to match it. PV system loans allow homeowners to buy their PV system outright and capture more of its value. Homeowners can access PV loans through a variety of institutions—many traditional banks and credit unions fund PV installations with home equity loans and home equity lines of credit, and specialty lending institutions focused on energy efficiency and renewable energy projects also offer loan products tailored to residential PV projects. In many cases, PV loans require no money down, thereby increasing the range of potential applicants.

Average Residential Electricity Prices in the United States



ITC Extended

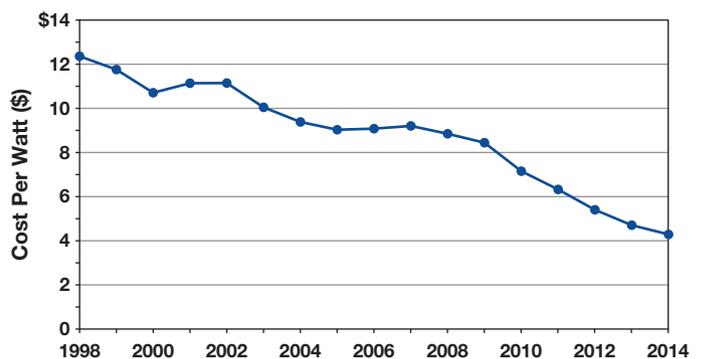
The federal investment tax credit (ITC) was set to expire at the end of 2016, but legislation was passed to extend it for another five years. The bill extends the 30% solar ITCs for both residential and commercial projects through the end of 2019. In 2020, the credit drops to 26%; in 2021, it drops to 22% before dropping permanently to 10% for commercial projects and 0% for residential projects in 2022. The bill also included language that allows owners who start construction of their PV system before the end of 2021 to claim the larger credit provided that project is commissioned before the end of 2023.

—Justine Sanchez

Potential system owners are not restricted to traditional loan products. In some areas, public-private partnerships provide low-interest financing for PV systems. For example, the Connecticut Green Bank provides low-interest loans supported, in part, by public funds.

With property assessed clean energy (PACE) financing, homeowners can take out a loan based on their home's equity and repay the loan, along with their property taxes, through a yearly assessment, rather than the monthly payments required by traditional loans. In most cases, the annual savings that result from installing a PV system are higher than the cost of the yearly assessment, and homeowners typically enjoy financial gains as soon as their PV system is operational. PACE is a particularly attractive option for homeowners who don't have good enough credit to access favorable loan options, because while funding amounts and interest rates for traditional loans are determined by credit score, PACE loan amounts are determined by the property's value. Currently, residential PACE financing programs are available in California, Connecticut, Florida, Missouri, and New York. According to PACENation, PACE financing has already supported the installation of renewable energy systems on 19,500 homes in the United States.

Median Installed Cost for Grid-Tied PV Systems in the United States



web extras

For more information on PACE financing, see bit.ly/PACEinfo



The Value of Ownership

When you compare multiple financing options, the benefits of system ownership are usually clear. The examples from Massachusetts and New York illustrate the relative value of a cash purchase, \$0-down solar loan, and \$0-down lease/PPA. These examples were developed using real-time market pricing data from the EnergySage Solar Marketplace, remote sensing technology to assess roof suitability and system size, state and federal financial incentives, and localized electricity rates. Total financial returns will vary depending on electricity cost and incentives available to homeowners. However, even in areas without state-level incentives, such as California, 20-year savings are still significantly higher for homeowners who own, rather than lease, their systems.

The first example analyzes a property in Massachusetts with a \$150 monthly electricity bill. The key figure, 20-year net savings, is highlighted at the top.

The second example features a property in New York with a \$200 monthly electricity bill. The differences from

the Massachusetts property are due to differing incentive structures, as well as a higher electricity bill.

The \$0-down solar loan (the middle column) makes it possible for homeowners to capture more of their solar energy system's value, and provides a route to system ownership for those that cannot afford a cash purchase. Homeowners with access to solar loan products can save significantly more over their system's lifetime than if they entered into a solar lease agreement or PPA.

Ownership = Higher Home Value

Multiple academic studies back up the assertion that ownership means better value. The National Renewable Energy Laboratory found that the levelized cost of energy (LCOE) was 19% to 29% lower for homeowners who bought their systems compared to third-party-owned systems. LCOE is an estimate of the average per kilowatt-hour cost of the electricity produced by an energy system, and can be a good way to quantify the system's long-term value. In addition to greater savings, academic studies have also found that installing a PV system on a home increases property values—but only if the system is owned, rather than leased.

Considering that PV arrays can generate electricity for 25 to 35 years (or more), the difference between a 20-year monthly lease agreement and outright system ownership becomes significant.

Example Massachusetts Financials

	Buy System Outright	Zero-Down Loan	Zero-Down Lease
20-yr. net savings	\$21,000	\$16,000	\$7,100
Net cost	\$9,000	\$0	\$0
Payback (yrs.)	4.6	0.0	0.0
Property value increase	3+%	3+%	0

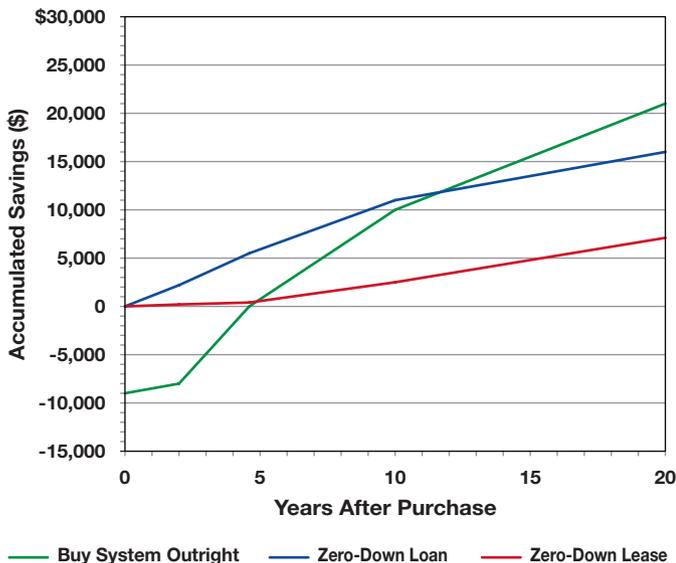
Note: Assumes \$150 per month utility bill

Example New York Financials

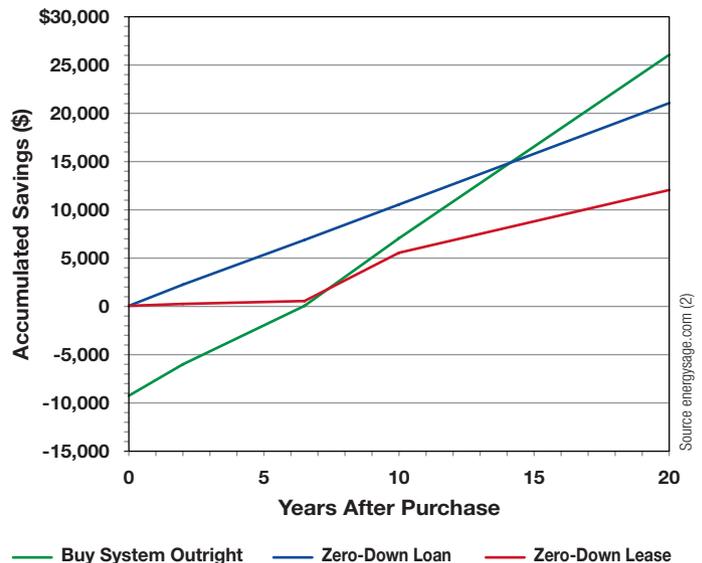
	Buy System Outright	Zero-Down Loan	Zero-Down Lease
20-yr. net savings	\$26,000	\$21,000	\$12,000
Net cost	\$9,100	\$0	\$0
Payback (yrs.)	6.5	0.0	0.0
Property value increase	3+%	3+%	0

Note: Assumes \$200 per month utility bill

Accumulated Savings



Accumulated Savings



Source: energysage.com (2)

Lease & PPA Options

While financially motivated shoppers tend to opt for system ownership, saving money is only one reason that homeowners choose to go solar. Many solar shoppers will choose a lease or PPA, especially if they:

- Don't want the responsibility of system maintenance or repairs
- Are ineligible for solar investment tax credits

Leases and PPAs are also very beneficial to the large solar installer corporations that offer them. Whoever owns the solar energy system (the installer corporation, in the case of most leases and PPAs) also receives the benefit of the federal ITC and any state or municipal incentives for solar energy. While some of that value is passed down to the consumer in the form of lower rates, the remainder goes straight to the bottom line of the system's third-party owner. These are all benefits that the system owners give up by not owning it themselves.

As for the rest of the value, third-party owners generate revenue both from the tax benefits associated with the systems as well as from their customers' fixed monthly payments. While

this structure leads to a healthy profit margin for the installer corporation, it also splits the financial benefits of solar between the end consumer and the third-party owner.

Because the market for residential solar has only taken off in the past five to eight years, many of the long-term effects of homeowners' solar financing decisions are only now being recognized. In addition to giving up financial benefits, homeowners are also finding that solar leases can make it more difficult to sell their property.

While purchasing a solar energy system and installing it on a home increases the home's value, potential homebuyers are often hesitant to enter into a solar lease, even when they understand and appreciate the value that a PV system adds to the property. Some homeowners are finding that they have to buy out their lease contracts to sell their property: a 2015 study by Lawrence Berkeley National Laboratory found that, in 23% of solar lease home sales, either the buyer or the seller had to buy out the lease to close the sale.



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Labels & Markings

by Ryan Mayfield

The number of labels required for PV systems can seem disproportionately excessive when compared to other electrical systems. In fact, one of the running jokes in the PV community is that installers would be better off if they would stop installing modules and get into the labeling business.

This article discusses critical labels needed for grid-tied PV systems. Labels called out in the *Code* that are typically pre-installed on equipment—such as modules and inverters—aren't covered.

In the 2014 *NEC*, modifications were made to the label requirement, as outlined in Articles 690 and 705. Article 690 does include Part VI, "Marking," but that is not an all-inclusive list of the required labels. One change that appears in nearly every section calling out labels in the 2014 *NEC* is the added requirement that "warning sign(s) or label(s) shall comply with 110.21(B)."

Section 110.21(B), "Field-Applied Hazard Markings," is an addition that lines out the minimum requirements for labels. The main points for this section include that:

- The marking shall utilize effective words and/or colors and/or symbols
- Labels shall be permanently affixed to the equipment and not handwritten
- Labels shall be able to withstand the environment in which they are installed

This section uses informational notes to direct us to the ANSI standard for acceptable guidelines on words, symbols, and colors of product safety signs and labels (ANSI Z535.4-2011—see resources).

Prior to the 2014 *NEC*, there were no instructions for color-coding. Based on the ANSI standards, red labels with white lettering are appropriate in conjunction with the word "danger"; "warning" should be used in conjunction with black letters on an orange background; "caution" used with black letters on a yellow background; "notice" used with italicized white letters on a blue background; and "safety instructions" printed in white letters on a green background.

Articles 690 and 705 detail labels that require the word "warning." In some cases, other guidelines include specific language and color schemes. I suggest following the ANSI guidelines. If you choose to ignore the ANSI recommendations, installing only red labels with white lettering, you'll risk individual labels becoming indistinguishable—lost in a sea of red—and losing the attention of the individuals who need to see that information the most.

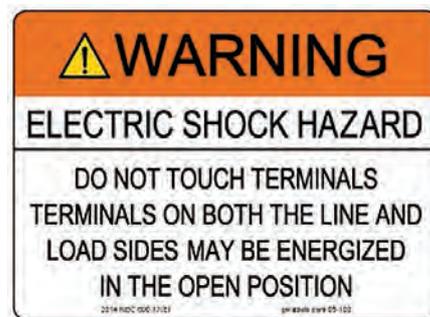
DC Side Labels

Article 690.17(E), 690.35(F), and 690.53, discuss the locations for the DC disconnect labels. You can install three separate labels or combine them into one or two labels. Many times, the available space on the DC disconnect will dictate the preferred approach. The first two sections mentioned include generic language for the DC disconnects, but both begin with "Warning Electric Shock Hazard."

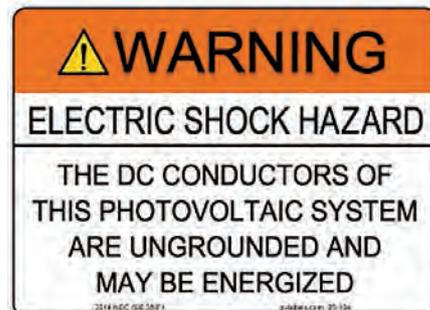
Based on the ANSI guidelines, these labels should be orange with black lettering. The label warning of voltage on both line and load terminals should only be placed on the DC disconnect. As with the overuse of red labels, the inclusion of this label on all disconnects in PV systems is prevalent. This will typically not be an appropriate label for the AC disconnects. Note that the 690.35(F) requirement is only for ungrounded PV systems, so the language included with that section may not apply to all systems.

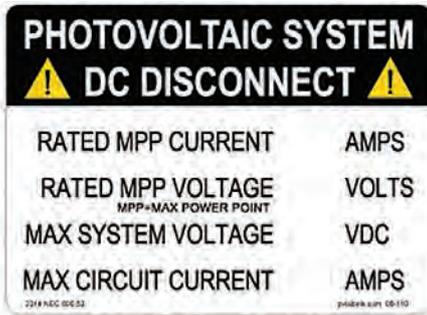
The 690.53 language that needs to be included on the label acts to inform future technicians as to the available voltage and current levels within the disconnect. Because this label does not require any cautionary language, it can be any color—for example, black lettering on white background. This label needs to include voltage and current values for the specific installation (see "Code Corner" in *HP154* and *HP163*,

690.17(E)



690.35(F)





690.53

and “Determining PV Array Maximum System Voltage” in *HP146* for additional information on those calculation methods).

Another label specific to the DC side of the installation is the one called out in 690.31(G)(3) for all exposed raceways, cable trays, and other wiring methods; enclosure covers; and conduit bodies where openings are unused.

This label must be visible after installation, reflective, and printed in capital white letters with a minimum height of 3/8 inches on a red background. In this case, the color requirements are not in agreement with the ANSI guidelines—*NEC* 690 language supersedes other requirements. In addition, there are spacing limitations for these labels—they must be placed no farther than 10 feet apart. The labels must appear on every

section of raceway that’s separated by walls or partitions. As with the DC disconnect labels, this requirement appears only in the section specific to DC wiring methods and should not be required on the AC side of the system.

The final label mainly pertaining to the DC side of the system is the one called out in 690.56(C), “Facilities with Rapid Shutdown.” As more jurisdictions are implementing 2014 *NEC* and the rapid shutdown section, this label will be necessary. This label also has specific color and text-height requirements, with specific verbiage.



690.31(G)(3)

AC Side

Several labels are necessary for the AC side, including some new ones in 2014, based on the equipment selection and location. Sections 690.54, 690.56(B), 705.10 and 705.12(D)(2)(3) (b) all have label requirements that can seem redundant. In short, the intention is to indicate the electrical characteristics of the PV system, along with all the requisite disconnect locations.

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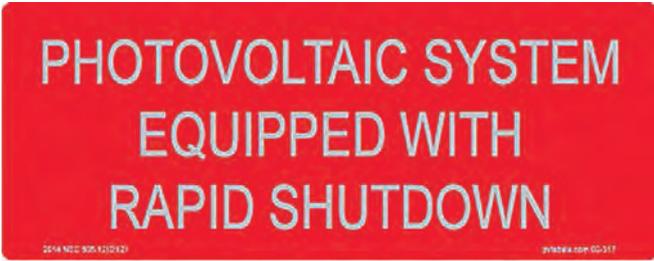
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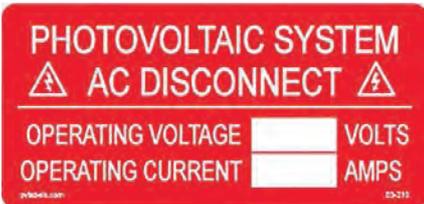
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This label meets Section 690.56(C).

The 690.54 label is to identify an interactive system's output current and voltage on the AC disconnecting means. For a residential installation, this could be as simple as labeling the breaker where the inverter terminates in an AC load center. For larger commercial systems, this may be an AC disconnect used at the point of interconnection.

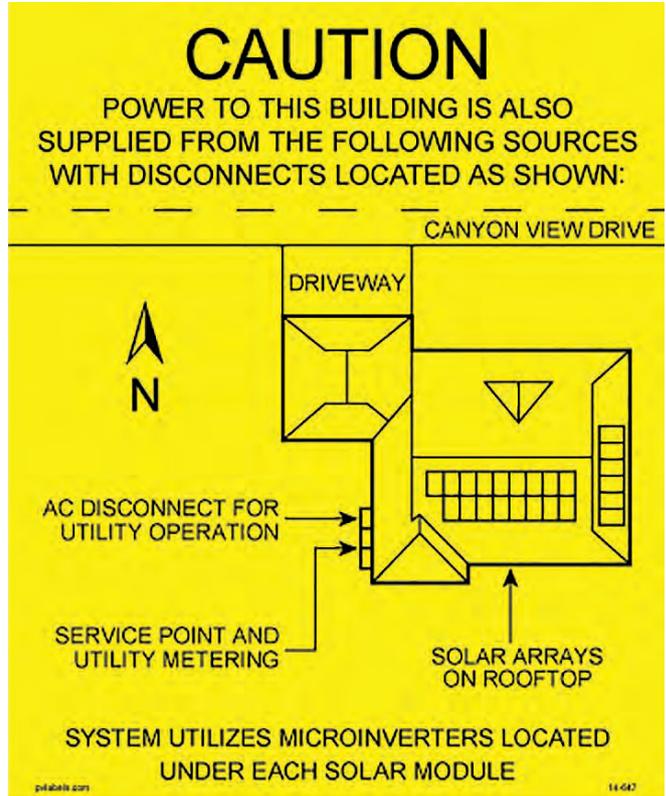
The 690.56(B) label takes this one step further, instructing us to label the service disconnecting means and PV disconnection means if they are not at the same location. Generally, a plan view line drawing of the facility with the locations of the disconnects clearly called out is the best way to meet this requirement.



690.54

Article 705.10 simply requires a label at the service equipment stating the presence of multiple power sources. If the inverter point of interconnection is at a remote location from that main service equipment (in a subpanel, for example), then a similar label would be required at the subpanel. And finally, 705.12(D)(2)(3)(b) requires a warning label for PV systems that are interconnected on the load side of the main breaker and when 125% of the inverter output plus the main breaker rating exceed the rating of the bus bar—this is commonly referred to as the 120% rule (see “Code Corner” in *HP151* and *HP160*).

For example, on a residential system in which the inverter's output is connected directly to the main service panel, two labels should suffice—one on the cover of the main panel indicating the presence of multiple sources (705.10) and a label adjacent to the inverter breaker indicating current, voltage, and the warning to not move the breaker (690.54 and 705.12(D)(2)(3)(b)). Note that 690.56(B) wouldn't apply since the main disconnect and PV disconnect are in the same location. If the utility requires a visible lockable disconnect at the meter location, this should also be labeled as the PV AC disconnect even though that disconnect isn't an explicit *NEC* requirement.



690.56(B)

For a complex PV installation that includes interconnection at a remote location from the main service gear, the labeling may involve more labels at multiple locations, but the same principles apply. Identify all the power sources present, and you can fairly easily follow the *NEC* to install the proper labels.

This “Code Corner” covers the most common applications and labels. There are additional requirements for battery-based systems and systems using multiple inverters that are aggregated in AC panels. Fortunately, as the industry matures and entrepreneurs identify opportunities, resources for meeting these needs are created.



Resources

PV Labels • pvlabels.com

Hellermann Tyton • hellermanntyton.us

Specialty Solar Supply • specialtysolarsupply.com

ANSI Z535.4-2011 • bit.ly/ANSIlabels

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What's Your Bag?

by Kathleen
Jarschke-Schultze

Every year, approximately 500 billion plastic bags are used worldwide. More than 1 million are used every minute. The Great Pacific Garbage Patch, located a few hundred miles off the coast of Baja, California, in the North Pacific Gyre, is the largest ocean garbage site in the world. This floating mass of plastic is twice the size of Texas, with plastic pieces outnumbering sea life six to one. Plastic constitutes approximately 90% of all trash floating on the ocean's surface, with 46,000 pieces of plastic per square mile.

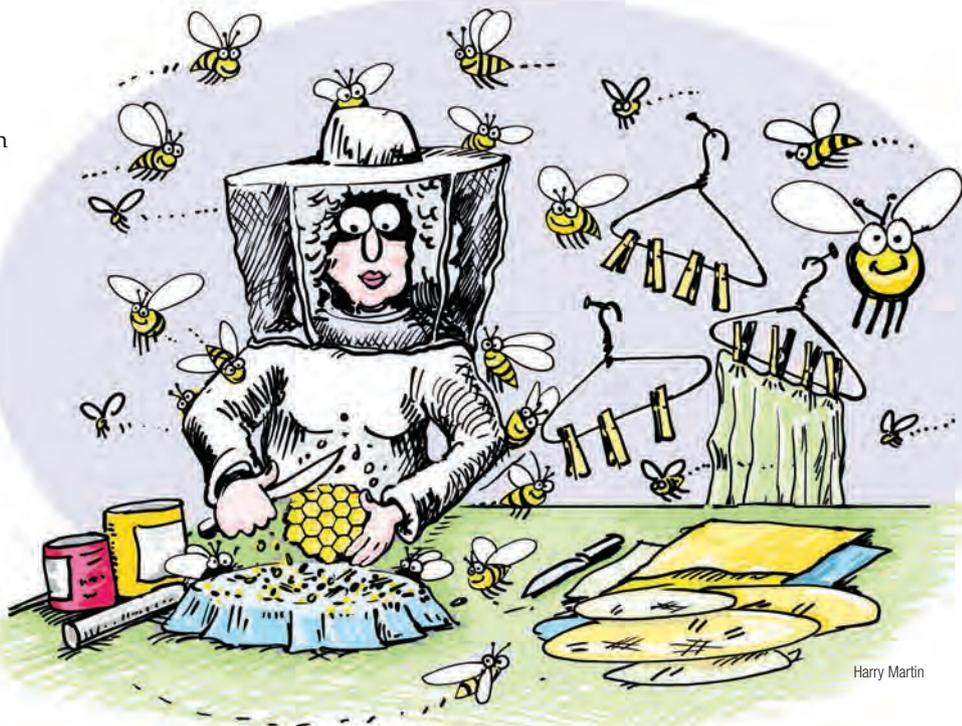
This is just plain scary. The average American throws away approximately 185 pounds of plastic per year. I plan to not be average. The production of plastic uses around 8% of the world's oil production. Any way we can reduce our use of petroleum while reducing plastic trash is a win-win.

There's the lack of recyclability for soft plastics, plus health concerns about BPA and phthalates getting into foodstuffs from soft plastics. Not to mention the toxicity during manufacture. Also, all plastic recycling involves tens of thousands of miles of transport, and is often done in countries with few environmental regulations. For these reasons and others, reducing my homestead's use of plastics has been a continuing concern.

I recycle containers according to their material type. For example: PETE or PET 1, HDPE 2 (plastic bag manufacturers use PE-HD 02), PVC 3, etc. For years, I have been carrying my own shopping bags to avoid adding to our plastic load. So, what about alternatives to plastic wrap and one-use produce bags?

Move On, Creepy Cling Film

Instead of buying plastic wrap to cover bowls or pies, I use shower caps from motels we've stayed at. I just throw the packages into my kitchen drawer. Then when I need a clean, form-fitting cover on a dish they are at hand. They can be gently washed, hung up to dry, and reused. But shower caps are still virgin plastic and eventually reach the end of their nonrecyclable life, so I continued to look for a solution.



Harry Martin

Pyrex glass dishes with snap-on lids or Ball glass jars are good options for storing leftovers, but sometimes I just want to leave food in the dish or bowl in which it was prepared. For that, a friend suggested a unique alternative to cling wrap—100% cotton cloths, impregnated with beeswax—which appealed to me since it was something I could easily make. Being a beekeeper, I was able to quickly lay my hands on a couple of pounds of beeswax from my hives. I had large cookie sheets, which I covered in parchment paper to better contain the melted wax. I found a new 2-inch paintbrush in our painting supplies and claimed it as my own.

Next, I needed some cotton cloth. On my next trip to town, I stopped by a fabric store. I don't sew and I felt a little lost. I stumbled on a whole section of printed cotton cloth specifically for quilters. Because quilters don't always use a lot of one pattern, there was a large array of what is known as a "fat quarters," 18-by-22-inch pieces—a friendly quilt-piecing size. It was my lucky day. The fat quarters were on sale for one-third of their regular price. I got 10 or so different patterns. I cut each fat quarter into a variety of sizes, maximizing use of the cloth. I was able to get one 12-by-12, two 6-by-6s, and two 9-by-10 cloths from each piece of fabric.

continued on page 66

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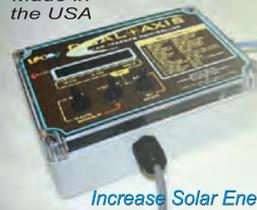
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continued from page 64

I preheated my oven to 185°F and made sure the parchment paper covered my pans. I hung a coat hanger from a cupboard handle and put a handful of clothespins on it—to hang the cloths for cooling when I removed them from the oven.

The most trouble I had with this project was grating the beeswax. My hand grater did not grate—it just smeared the beeswax. Next, I tried my salad shooter, using the grating cone, but the wax just sat on top of the cone and bounced, and I was afraid to force it. I ended up getting an old pocketknife and whittled the beeswax shreds onto a plate.

When I had enough beeswax shreds, I spread some of the cloths on the parchment paper-covered pans and sprinkled the beeswax as evenly as I could in a sparse layer over the cloths. Then I placed the pans in the preheated oven. I was anxious about the first batch and kept peeking, so it took a little longer than 6 minutes to melt; subsequent batches were done in less than 5.

After removing the hot pan from the oven, I used the paintbrush to quickly even out the soft wax. I hung them by one corner to cool, which did not take long. By the time I got the next pan prepped and in the oven, the previous cloths were cooled.

I started using my “bee cloths” right away. I found that I could press the cloth down over the edge of a bowl and the warmth of my hands would mold the cloth to the bowl. A short time in the refrigerator and the cloth would be stiffly snug. I folded small bits of cheese like a little gift and, by molding my warm hands around it, formed it to the cheese.

The bee cloths can be washed in cold water with a mild detergent and hung to dry. The beeswax is a natural antibacterial. They will last a few months. When they start to lose their wax coating, they can be “re-energized” the same way they were first made. I gifted my sisters and all the women in my dinner club with sets of assorted bee cloths, because, really, what cook does not want a set of these?

Veggie Bags

For folks who want to reduce their overall plastic consumption, sewing or buying washable organic cotton cloth produce bags is the best bet. They can even be used in the bulk aisle, for everything from grains to granola, so long as you have a handy tie to secure them.

If you forget your cloth storage bags and find yourself pondering plastic, make sure to get as much life as possible from them. My idea for getting more lives from plastic produce bags is pretty simple, but involves some sewing (or not—the sewing-averse can buy these online). It involves two plastic-bag socks—cloth tubes with elastic at both ends, with a cloth loop for hanging them. As you acquire and wash and dry plastic bags, you shove them in the top of the tube. When you want to reuse one, you pull it from the bottom.

The veggie bag holders you can make are just smaller versions of the plastic-bag socks. Make two smaller cloth “socks” with a large carabiner attached to each. Hang one in your kitchen, where you deposit the plastic bags when returning from shopping. When that bag holder is full, put it with your cloth shopping bags in the car.

As you are shopping, clip the carabiner onto the shopping cart in a convenient place, and simply pull the bags you need from the bottom of the sock. At home, the bags go back into the bag sock in your kitchen, as you unpack your groceries.

Reduce, Reuse, Recycle

Sometimes what we do to reduce our personal use of plastics, oil, antibiotics, pesticides, herbicides, etc., seems like a very small drop in a very large bucket. But there is a song that rolls around in my head: “Drops of water turn the wheel, every wound shall be healed...”



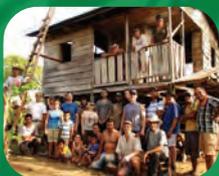
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What's a Pyranometer?

A pyranometer measures the brightness of sunshine, or light in general. When a pyranometer is pointed directly at the noontime sun on a clear summer day, the reading will be about 1,000 watts per square meter, depending on the altitude and moisture or dust in the atmosphere.

“Standard” sunshine, which is used for rating solar thermal and PV products, is defined as 1,000 W/m², measured perpendicular to the surface the sunlight is shining on. The surface being tested is typically a photovoltaic or solar thermal panel but can also be the windows of a home, for quantifying the maximum solar gain. In this case, one would put the pyranometer on the occupied side of the window, with the face of the pyranometer parallel to the glass.

As-built, a pyranometer measures total sunshine, which includes beam radiation and diffuse radiation. Beam, or specular, radiation is the parallel rays of light that come from a point source that is capable of casting a shadow or being focused by a parabolic reflector. Light from the sun on a clear day is the best example of beam radiation. What we call “bright blue skies” are actually dark blue skies and typically scatter only a small fraction of sunlight.

Next to this evacuated-tube solar thermal array are two Li-Cor model PY pyranometers, the left one equipped with a shadow band. The pyranometer on the right measures the total incoming sunshine—diffuse plus beam radiation. Which measurement you need depends on the nature of your project. For PV and solar thermal projects, measuring total radiation makes sense.

For passive solar applications in which radiation might advantageously be blocked by an awning or overhang, measuring beam radiation—total radiation minus diffuse radiation—is helpful.



Lena Wilensky

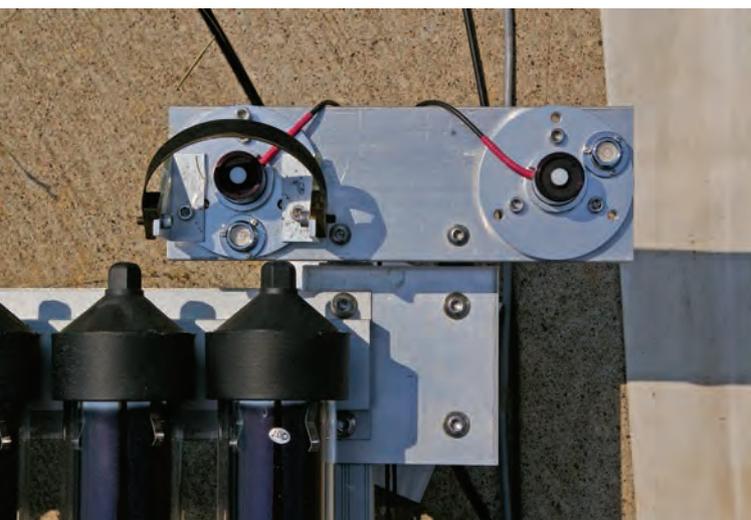
A handheld pyranometer is good for instantaneous measurements, such as verifying PV array output.

Window overhangs on passive architecture block beam radiation because they are parallel rays, all traveling in the same direction.

Diffuse radiation comes from all directions at once and casts no shadows, even when there is plenty of light outside. During a bright, overcast day, with no obvious bright spot in the sky, the light is 100% diffuse. You can still generate some energy with diffuse light with PV modules, but this light cannot be concentrated with a curved mirror. Diffuse radiation is not blocked by window overhangs because the light comes from all directions.

Pyranometers are like solar cells in that they generate a small current that is proportional to the intensity of the light shining upon it. The two Li-Cors were being read by a data logger, with a value being recorded every minute. A single pyranometer reading is not useful, nor are hundreds of readings, unless maybe one wants actual readings as part of their solar experiment. To predict the future solar resource before installing a PV array or building a passive solar home takes millions of readings, taken throughout the daylight hours, 365 days a year, for several years. This is what is behind NREL's PVWatts website (pvwatts.nrel.gov/).

—Pete Gruendeman

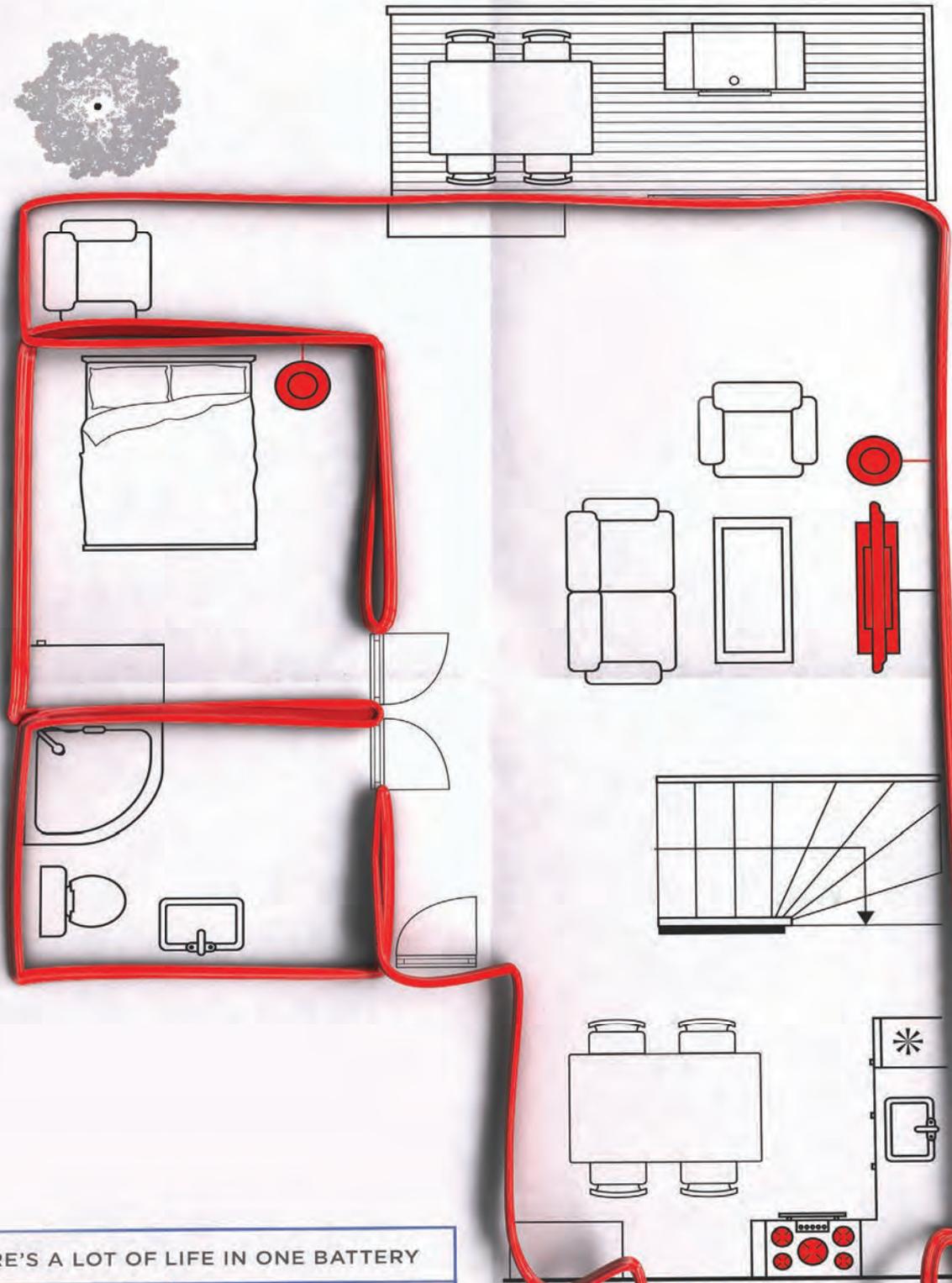


Pete Gruendeman



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